

Natural Antioxidant and Antimicrobial and its Relation to Quality and Safety of Smoked Mullet Fish

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ABSTRACT: Fresh mullet (*Mugil cephalus*) fish of economic importance was subjected to different liquid smoked treatments; Liquid smoked (LS), LS combined with Pomegranate extract 100 mg /kg (LS+P1), LS combined with paprika powder 5g /kg fish (LS+P2) and LS+P1+P2. to study the effect of these treatments on liquid smoked fish quality and safety during storage at 4 °C. Results revealed that the treatment of fresh fish with 2% lactic acid buffered will exert antimicrobial, reduce pH and enhance safety and quality.

The mean moisture content values were 72.38%, 57.96%, 58.57%, 57.65% and 58.25% for fresh fish, liquid smoked (LS), LS combined with pomegranate extract mg/K (LS+P1), LS combined with 0.5% paprika powder (LS+P2) and LS combined with pomegranate extract 100mg/kg and 0.5% paprika powder (LS+P1+P2) at respectively. All the liquid smoked process resulted in a significant decrease ($p < 0.05$) in moisture content of mullet *Mugil cephalus* samples as compared with fresh fish. The highest total volatile basic nitrogen (TVB-N) values were recorded in fresh fish while the lowest were shown according to the flowing order Powder (LS+P1+P2) flowed by LS combined with 100 mg/kg LS+P1 flowed by LS+P2 and flowed by liquid smoked (LS). Results revealed that salt content in all liquid smoked treatments were much lower than WHO recommended limit. smoked fish with low salt content will encourage consumers, improve the public health and enhance safety. The data indicate the effectiveness of pomegranate peel extract and paprika powder as natural antimicrobial and antioxidants due to the reduction in TVB-N values. Samples treated with LS, LS+P1, LS+P2, LS+P1+P2 have a shelf life at 4 °C of 65,70, 70 and 75 days respectively. This signifies a prolongation of shelf life at 4 °C of 59,64,64 and 69 days, respectively as compared with untreated fish.

Key Words: Fish, Liquid smoked, quality, Pomegranate peel extract, Paprika Powder.

INTRODUCTION

Food quality and safety have become a major concern to consumers, producers, food industries, and regulatory agencies worldwide (Hassoun and Coban, 2017; Zanin *et al.*, 2017). Fish are highly perishable food products due to microbiological activity and oxidation of lipid, which are known to be the principal causes of quality deterioration of such products (Ghaly *et al.*, 2010; Chaillou *et al.*, 2015; Secci and Parisi, 2016; Sun *et al.*, 2019). Therefore, offering high quality Fish and safe combined with consumers demand for natural preservatives create challenging problems (Karoui and Hassoun, 2017; Mendonca *et al.*, 2018). Recently, there has been expanded focus on natural antimicrobial and antioxidant as alternatives to synthetic preservatives to enhance food safety and quality and extend the shelf life (Çoban and Kelestemur, 2016; Secci and Parisi, 2016; Kharchoufi *et al.*, 2018; Mendonca *et al.*, 2018; Pisoschi *et al.*, 2018; Hanania *et al.*, 2019; Ribeiro *et al.*, 2019).

Smoking is the oldest fish preservation since it delays microbiological and oxidative changes (Goulas and Kontominas, 2005; Varlet *et al.*, 2009). Over the past three decades, liquid smoke flavours have been increasingly used as an alternative to traditional smoking (Alcicek *et al.*, 2010; Ledesma *et al.*, 2017; Ceylan *et al.*, 2018)

Liquid smoke flavours have some advantages over traditional smoking methods, such as easy application, lower cost, environmental friendliness and provides a higher diversity of smoked food and antimicrobial and antioxidant activity can be evaluated. It is also easier to control smoke contaminants like polycyclic aromatic hydrocarbons (PAHs), which are considered carcinogenic, and mutagenic molecules produced during pyrolysis of wood (Theobald *et al.*,2012; Mahugija and Njale,2018; Rascon *et al.*,2019).

Nowadays,75% of smoked foods produced in the United States are treated with liquid smoke (Varlet *et al.*, 2009). Fish that smoked using liquid smoking method are often done to produce a high quality smoked fish (Ledesma *et al.*,2017; Ceylan *et al.*,2018). Mullet (*Mugil cephalus L*) is one of the most widely distributed seafood fish all over the world (Waltham *et al.*,2013; Bouzgarrou *et al.*,2016; Ao *et al.*,2017) and play important economically and nutritionally roles in Egypt. The overall aim of the present study is to evaluate the effects of liquid smoking with pomegranate peel extract, Paprika Powder and lactic acid buffered system on the quality and safety of smoked mullet (*Mugil cephalus_L*) fish. Number of chemical parameters, total psychrotrophic aerobic bacteria, *Enterobacteriaceae*, Yeast and Moulds, and sensory analysis were measured.

MATERIALS AND METHODS

Materials

Fresh mullet fish (*Mugil cephalus L*) weight 25 kg were purchased from the fish market ,Bahry, Alexandria and transported in ice boxes to Food science laboratory, Fac. of Agriculture, Saba Basha, Alexandria University. Sensory evaluation of raw fish freshness was carried out included Appearance, Eye, Gill, Odour, Texture and Viscera. Concentrated liquid smoke composition was 83 % water ,6% Acetic acid, 4% Phenol, 3% syringol, 2% Guaiacol, 1% Benzaldehyde and1% ethan (acetaldehyde). All chemicals used were of analytical grade.

Methods

Preparation of fish samples

Fish samples were washed with tap water, removed scales, beheaded, eviscerated, cut to two pieces, washed again with tap water and allowed to drain at 4 °C for 30 min.

Preparation of pomegranate peel extract

Pomegranate fruit having no visible external cuts or spoilage was purchased from the local market in Alexandria. The fruit was washed, and peel was separated and cut into small pieces. The pomegranate peel was dried at 50 °C for 4 days, powdered by grinding and sieving using a 40-mesh sieve (420 µm). The extraction was obtained by mixing 20 gram of dried pomegranate peel with 500 ml of distilled water with shaking at 100 rpm in dark at an ambient temperature for overnight. The obtained extracts were centrifuged at 2147× g for 30 min followed by filtration using Whatman filter papers number 1 and concentrated in vacuum rotary evaporator. The extracts were then lyophilized to

form powder at -50 °C (Telstar Model 50, Spain). Pomegranate extract powder were used at 100 mg /kg fish.

Preparation of Paprika

Pepper pods of *Capsicum annuum* L. were purchased from local market in Alexandria. The pepper pods were washed, dried at 50 °C for 3 days, grinding and sieving using a 40-mesh sieve (420 µm). Paprika Powder were used at 5g /kg fish.

Treatment with 2% lactic acid

Cleaned Fish were decontaminated by sprayed with 2% lactic acid. spraying was performed uniformly using a spray gun over the surface on both side of the fish. After treatment the fish were allowed to drain at 4 °C for 30min.

Dry salting

Decontaminated fish were dry salted at 4 °C for 24 h using fine refined NaCl (Almaks Company, Alexandria). The temperature of the dry salt was kept low (4 °C), to control microbial growth (Siskos *et al.*, 2005; Dimitriadou *et al.*, 2008). The ratio between salt and fish weight was 0.20, when dry salting was completed, excess salt was removed by careful rinsing of the fish with water (approximately 20 sec). Before smoking, the fish were allowed to drain at 4 °C for 30min.

Liquid smoking of fish samples

The decontaminated fish were soaked for 5 h at 4 °C in 1000ml diluted liquid smoking solution (40 ml concentrated liquid smoke /L water).

Four different treatments were tested

- (1) Liquid smoking and allowed to drain at 4 °C for 30min (LS).
- (2) Liquid smoking and treated with 100mg/kg pomegranate peel extract allowed to drain at 4 °C for 30min (LS+P1)
- (3) Liquid smoking and treated with Paprika Powder 5 g/kg (LS+P2)
- (4) Liquid smoking and treated with pomegranate peel extract (LS+P1+P2) 100 mg /kg and treated with Paprika Powder 5 g/kg.

Fish Samples were dried at 70 °C for 3 hours, cooled, packed separately in polyethylene bags and stored at 4 °C for 75 days. Samples were analyzed chemical, Microbiological and Sensory after 0, 6, 15, 30, 45, 60,65, 70 and 75 days of storage.

Chemical analysis

Proximate composition analyses

Moisture, Protein, fat and ash of the fish samples were determined according to the standard methods of AOAC (1984).

Determination of pH

The pH value was determined according to the method of Wang *et al.* (2014). Ten gram of fish sample was homogenized with 90 ml distilled water in a blender for 1 min. The pH value was measured using a pH meter (Mettler Toledo Co., Zurich, Switzerland) at ambient temperature.

Determination of salt

The Salt percentage was determined according to the procedure of Pearson (1973). One gram of fish fillet homogenate was mixed with 50 ml of distilled water and titrated with 0.1 N silver nitrate using 0.5 ml of 5% potassium chromate to the first appearance of a slight orange color against the yellow color of the indicator. The NaCl percentage in fish samples were calculated as 1 ml of 0.1 AgNO₃ = 0.005845 g of NaCl.

Determination of total volatile basic nitrogen (TVB-N)

The determination of TVBN was conducted according to the procedure of Miller (1998). 10 g of sample was blended with 50 ml of distilled water; the blender was washed with 250 ml of distilled water into the distillation flask and 1 g of magnesium oxide was added to the mixture. The TVB-N was released by boiling the mixture with magnesium oxide, which prevented volatile acids from distilling over into the boric acid. The distillate of volatile nitrogen was received in 25 ml of boric acid 2.0% then titrated by 0.1 N sulfuric acid and methyl red was used as indicator.

TVB-N (mg N/100 g of fish) = Titration (ml of 0.1 N sulfuric acid) X 14.

Microbiological analyses

Three samples of 10 g fish were sampled aseptically and homogenized with 100 ml sterile saline solution (0.85% NaCl, w/v) for 2 min. From this homogenate decimal dilutions were made in sterile physiological saline containing 0.1% peptone. Psychrotrophic aerobic bacteria colony forming units were determined in plate count agar (PCA) (Oxoid CM 325), incubated for up to 5 days at 20 °C. Yeast and mould colony forming units were determined on Rose Bengal Chloramphenicol agar (Oxoid CM 549) with supplement (chloramphenicol antibiotic supplement (Oxoid SR 78), incubated up to 5 days at 30 °C. *Enterobacteriaceae* were determined as colony forming units on violet Red Bile Glucose agar (VRBG) (Oxoid CM 485) with an overlay of the same agar incubated for 18h at 37 °C (Zeitoun *et al.*, 1994).

The microbial population of each plate was counted and reported as log₁₀ CFU/g.

Statistical analyses

All experiments were carried out in triplicate and average values with standard errors were reported. Analysis of variance (ANOVA) was conducted and differences between variables were tested for significance by one-way ANOVA with Tukey's post test using graphpad instat version 3.05 for Windows 95 (GraphPad Software, San Diego CA, USA). A statistical difference at P < 0.05 was considered to be significant.

RESULTS AND DISCUSSION

Freshness is a major contribution to quality of fish and fishery products. For all kinds of products, freshness is essential for the quality of the final product. A series of changes take place in fish immediately under ispostharvest condition (Olafsdottir *et al.* 1997; Diop, *et al.*, 2016.; Lazo *et al.*, 2017)Therefore, sensory evaluation assessment of raw fish quality is the primary way to evaluate freshness. Appearance, eye, gill, odour, texture and viscera of fresh Mullet (*Mugil cephalus*) fish were examined by five panelists with 9 for highest score (Table 1).

Table (1). Sensory evaluation of Raw Mullet (*Mugil cephalus*) fish

Appearance	Gill	Eye	Odor	Texture	Viscera
8.45 (±0.14)	8.72 (±0.12)	8.50 (±0.18)	8.11 (±0.23)	8.26 (±0.13)	8.41 (±0.15)

The values stated refer to three samples, with SD in brackets.

The results presented in Table (1) showed the initial values for appearance, Gill, Eye, odor, texture and viscera, were 8.45, 8.72, 8.50, 8.11, 8.26 and 8.41 at respectively. The fresh Mullet fish exhibited high sensory quality. Lactic acid is the most widely utilized organic acid in the food pharmaceutical, cosmetics and chemical industries. Its production is currently attracting a great deal of research and development (Wang et al., 2013; Noori et al., 2018) and it has been generally recognized as safe (GRAS) by the U.S. Food and Drug Administration (Wang et al., 2013). The effect of the treatment with lactic acid buffered system on pH and microbiological quality of fresh fish is shown in Table (2), the results revealed the decontaminating effect of lactic acid. The use of 2% lactic acid buffered system resulted in a reduction of 1.77 and 0.54 log CFU/g for psychrotrophic aerobic bacteria and yeast respectively as compared with blank samples. The assessment of *Enterobacteriaceae* commonly forms part of the microbiological quality monitoring of foods safety (Zeitoun et al., 1994). A reduction of *Enterobacteriaceae* CFU/g from $\log_{10}=3.16$ to $\log_{10}=1.62$ was obtained. Likewise, a reduction of 1.12 pH units is obtained by treatment with 2% lactic acid. According to Shirazinejad et al., (2010) and Metin et al., (2001), the treatment with 1–3% lactic acid resulted antimicrobial effect without adverse effects on sensory properties in seafood. The treatment of fish with 2% lactic acid buffered will exert antimicrobial, reduce pH and enhance safety and quality.

Table (2). Effect of the treatment with 2% lactic acid buffered system on the microbiological quality of fresh fish

Treatment	pH	Log CFU/g		
		Psychrotrophic aerobic bacteria	<i>Enterobacteriaceae</i>	Yeast
Fresh Fish	6.42 ^a (0.053)	4.62 ^a (0.108)	3.16 ^a (0.210)	2.64 ^a (0.140)
Treated with 2% lactic acid buffered system pH3	5.30 ^b (0.044)	2.85 ^b (0.144)	1.62 ^b (0.103)	2.10 ^b (0.100)

Values in the same column with the same superscripts are not significantly different ($P \geq 0.05$)

The values stated refer to three samples with SD in brackets.

The approximate composition of fresh and liquid smoked fish treated with pomegranate peel extract and paprika powder was evaluated as shown in Table (3).

Table (3). Chemical composition percentage of fresh and liquid smoked mullet *Mugil cephalus* fish treated with pomegranate peel extract and paprika powder

Treatment	Moisture Percent	Protein Percent	Fat Percent	Ash Percent
Fresh fish	72.38 ^a (±0.82)	17.19 ^b (±0.71)	5.84 ^c (±0.55)	4.59 ^c (±0.28)
Liquid smoked (LS)	57.96 ^b (±0.36)	27.20 ^a (±0.52)	8.89 ^a (±0.41)	5.95 ^b (±0.17)
Liquid smoked combined with pomegranate extract 100 mg/kg (LS+P1)	58.57 ^c (±0.42)	27.31 ^a (±0.40)	8.40 ^b (±0.38)	5.72 ^b (±0.19)
Liquid smoked combined with 0.5% Paprika Powder (LS+P2)	57.65 ^b (±0.35)	27.51 ^a (±0.47)	8.58 ^b (±0.35)	6.26 ^a (±0.21)
Liquid smoked combined with pomegranate extract 100 mg/kg and 0.5% Paprika Powder (LS+P1+P2)	58.25 ^c (±0.37)	27.47 ^a (±0.59)	8.38 ^b (±0.37)	5.90 ^b (±0.23)

Values in the same column with the same superscripts are not significantly different ($P \geq 0.05$). The values stated refer to three samples, with \pm SD.

The data revealed the moisture, protein, lipid and ash content of raw and liquid-smoked mullet (*Mugil cephalus*) fish. The mean moisture content values were 72.38%, 57.96%, 58.57%, 57.65% and 58.25% for fresh fish, liquid smoked (LS), LS combined with pomegranate extract 100mg/kg (LS+P1), LS combined with 0.5%paprika powder (LS+P2)and LS combined with pomegranate extract 100mg/kg and 0.5%paprika powder (LS+P1+P2), respectively. All the liquid smoked process resulted in a significant decrease ($p < 0.05$) in moisture content of mullet *Mugil cephalus* samples as compared with fresh fish. This decrease in moisture content values might be due to salting and drying during smoking (Cardinal *et al.*, 2001; Alcicek,2011). Industrial specifications for “smoked finished products” generally recommend a water content in the fish flesh of less than 65% (Kharchoufi *et al.*, 1998; Cardinal *et al.*, 2001; Alcicek,2011). These values are higher than our values for all liquid smoked treatments.

The percentages of total lipid, protein, and ash, of liquid-smoked mullet (*Mugil cephalus*) fish were significantly increased ($p < 0.05$) due to moisture loss during processing similar findings were reported by other researchers (Goulas and Kontominas,2005; Alcicek,2011; Al-Reza.,2015). The fat content of LS+P1, LS+P2 and LS+P1+P2 samples were significantly decreased ($p < 0.05$) compared with LS. Protein content of LS+P1 (27.31), LS+P2 (27.51) and LS+P1+P2 (27.47) were slightly increased compared with LS. These results are in agreement with those obtained by Alcicek (2011) and Iheagwara (2013) who found treatment with thyme oil or ginger extract combined with liquid smoked caused an increase of protein and decrease of fat contents. Ash contents increased significantly ($p < 0.05$) in all liquid smoked treatment compared with fresh fish. Chemical quality changes of Liquid smoked mullet (*Mugil cephalus*) fish during storage at 4 °C are given in Tables (4).

Table (4). Chemical quality changes of Liquid smoked mullet (*Mugil cephalus*) fish during storage at 4 °C.

Parameters	Fish group	Days of storage at 4 °C								
		0	6	15	30	45	60	65	70	75
TVB-N mg N/100 g of fish	Fresh fish	10.28 ^a	29.18 ^a	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	LS	8.35 ^b	9.82 ^b	11.94 ^a	16.82 ^a	20.75 ^a	25.18 ^a	28.96 ^a	n.d.	n.d.
	LS+ P1	7.02 ^d	7.86 ^c	9.08 ^b	12.08 ^b	16.04 ^b	22.85 ^b	24.77 ^b	28.85 ^a	n.d.
	LS+P2	7.57 ^c	8.02 ^c	9.24 ^b	12.25 ^b	15.85 ^b	22.72 ^b	24.89 ^b	28.94 ^a	n.d.
	LS+P1+P	6.65 ^e	7.11 ^d	8.17 ^c	10.02 ^c	13.56 ^c	18.12 ^c	20.15 ^c	23.87 ^b	28.75 ^a
Salt content g/100g fish	Fresh fish	0.18 ^b	0.20 ^b	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	LS	1.79 ^a	1.77 ^a	1.78 ^a	1.84 ^a	1.88 ^a	1.94 ^a	1.98 ^a	n.d.	n.d.
	LS+ P1	1.66 ^a	1.68 ^a	1.74 ^a	1.75	1.77 ^a	1.79 ^a	1.82 ^a	1.84 ^a	n.d.
	LS+P2	1.77 ^a	1.78 ^a	1.75 ^a	1.74 ^a	1.76 ^a	1.78 ^a	1.83 ^a	1.83 ^a	n.d.
	LS+P1+P	1.74 ^a	1.74 ^a	1.75 ^a	1.75 ^a	1.76 ^a	1.79 ^a	1.80 ^a	1.81 ^a	1.82 ^a
pH	Fresh fish	6.56 ^a	6.96 ^a	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	LS	5.28 ^b	5.32 ^b	5.58 ^a	5.77 ^a	6.08 ^a	6.42 ^a	6.76 ^a	n.d.	n.d.
	LS+ P1	5.30 ^b	5.38 ^b	5.53 ^a	5.67 ^a	5.77 ^b	6.07 ^b	6.44 ^b	6.78 ^a	n.d.
	LS+P2	5.32 ^b	5.45 ^b	5.49 ^a	5.53 ^{ab}	5.73 ^b	6.01 ^b	6.38 ^b	6.72 ^a	n.d.
	LS+P1+P	5.29 ^b	5.28 ^b	5.37 ^a	5.42 ^b	5.45 ^c	5.65 ^c	6.02 ^c	6.34 ^b	6.75 ^a

Values in the same column with the same superscripts are not significantly different ($P \geq 0.05$).

The values stated refer to three samples.

n.d.= not determined because of spoilage.

The total volatile basic nitrogen (TVB-N) present in the flesh of fish is recognized as indicator of freshness by A European Union (Wells *et al.*,2019). The total volatile basic nitrogen consisting of volatile amines, such as ammonia (NH₃), dimethyl amine (DMA) and trimethyl amine (TMA), that are responsible for the fishy odor associated with fish spoilage (Pezeshk *et al.*,2011; Sampels, 2015; Wells *et al.*,2019).

The analysis of total volatile basic nitrogen (TVB-N) is widely used to determine the quality and shelf life of fish; its increase is related to the activity of microbial spoilage and endogenous enzymes (Guan *et al.*,2019; Wells *et al.*,2019). The initial level of TVB-N concentration in fresh marine *M. cephalus* muscle samples (control) was 10.28 mg N/100 g, is indicative of freshness of the raw fish, the value is in agreement with values reported in other studies for marine *M. cephalus* (Jnr *et al.*, 2006; Orak, and Kayisoglu,2008; Mostafa and Salem, 2015).

The highest TVB-N values were recorded in fresh fish while the lowest were shown according to the flowing order liquid smoked combined with 100 mg/kg and 0.5% Paprika Powder (LS+P1+P2) flowed by LS combined with 100 mg/kg (LS+P1) flowed by LS treated with 0.5% Paprika Powder(LS+P1) and flowed by liquid smoked (LS). The TVB-N for fresh samples (untreated) increased rapidly and rich to 29.10 mg N/100 g after 6 days of storage at 4 °C.

The increase in the TVB-N value is mainly due to the activity of endogenous enzymes and the degrading bacteria (Ozogul *et al.*, 2004). Significant decrease of TVB-N values ($P < 0.05$) were found after liquid smoked fish treatments comparing to the fresh fish. possibly due to a treatment with lactic acid, salting; the antimicrobial and the antioxidant activity of liquid smoked, pomegranate peel extract and paprika Powder. and finally, due to drying at 70 °C for 3 hours. Previous study showed that liquid smoking reduces the accumulation of TVB-N in the muscle (Goulas and Kontominas 2005; Alcicek, 2014; Lingbeck *et al.*,2014; Bouzgarrou *et al.*,2016).

According to Alcicek (2011) the limits of safety consumption fisheries products namely by TVBN value 30 mg while a level of 35–40 mg TVB-N/100 g of fish muscle is generally identified as the fishy food decomposition (Fan & Zhang, 2008; Ghaly *et al.*,2010).

Interestingly, the detected TVB-N values in this work were obviously lower than the criterion of decomposition and criterion of spoilage in all liquid smoked samples during 65 days of storage at 4 °C.

According to highest acceptable TVB-N value of 30 mg /100 g, all samples at the end of storage periods were below the critical marginal quality, followed by off odour next day. According to that limit, samples treated with LS, LS+P1, LS+P2, LS+P1+P2 have a shelf life at 4 °C of 65,70;70 and 75days respectively. This signifies a prolongation of shelf life at 4 °C of 59,64,64 and 69 days respectively as compared with untreated fish. This could be explained by synergistic effect between LS and P1, LS and P2, LS and P1+P2. In this study during storage period at 4 °C TVB-N values were affected significantly ($P <$

0.05) by the treatment with Liquid smoke, pomegranate peel extract, paprika powder and the storage time. The results revealed the effectiveness of pomegranate peel extract and paprika powder as natural antimicrobial and antioxidants due to the reduction in TVB-N values.

There is increasing public health concern regarding high sodium intake. The World Health Organization (WHO) recently reviewed the guideline for sodium intake (WHO,2012) and confirmed their earlier conclusions regarding the adverse effects of high sodium intakes on blood pressure, and consequently on the risk of cardiovascular disease throughout the world.

Nowadays, International health authorities recommend salt reduction content in food products to improve the public health (WHO,2012; Dotsch -Klerk *et al.*, 2015; Kurtz *et al.*,2018; Mork *et al.*,2019; Pedro and Nunes,2019). Sodium chloride is the main sodium source added for food preparation and processes.

Many people on sodium restricted or health-oriented diet avoid smoked fish consumption because of its high sodium content. As shown in Table (4) the salt content in fresh muscle fish (control sample) was 0.18 g/100g and increased after liquid smoking treatments to 1.79, 1.66,1.77 and 1.74 g/100g in LS, LS+p1, LS+P2 and LS+P1+P samples respectively. This increase in salt content values might be due to salting and drying during smoking (Cardinal *et al.*, 2001; Alcicek,2011). Results revealed a slight increase in salt content to be 1.98 after 65 days in LS, 1.84 after 70 days in LS+P1, 1.83 after 70 days in LS+P2 and 1.81 after 75 days in LS+P1+P. This increase in salt content might be due to Partial dehydration (Martinez *et al.*,2011). According to WHO (2012) current salt intake recommends of 5 g/d. Interestingly, the detected salt content in all liquid smoked treatments were much lower than recommended limit. smoked fish with low salt content will encourage consumers, improve the public health and enhance safety.

Effect of liquid smoked on pH of mullet (*Mugil cephalus*) fish during storage at 4 °C is shown in Table (4). The initial pH value for fresh fish used in this study was 6.56. Significant decreases ($P < 0.05$) were obtained with all liquid smoked samples compared to fresh fish sample. This decrease may be due to the presence of acid in liquid smoke which deposited on the fish during liquid smoking process (Alcicek, 2011; Bouzgarrou *et al.*,2016). After 6 days of storage at 4 °C the pH values of samples treated with LS, LS+P1, LS+P2 and LS+P1+P2 were significantly decreased ($P < 0.05$) as compared with fresh fish. The pH value of fresh fish increased rapidly due to formation of volatile nitrogen amines resulting from microbial fish spoilage (Alcicek, 2011; Bouzgarrou *et al.*,2016).

Treatment of fish with 2% lactic acid buffered will exert antimicrobial, reduce pH and enhance safety and quality. The most marked result was noted in the treatment with LS+P1+P2, which prolongs shelf life to 75 days at 4 °C and improve safety and quality, while ensuring low salt content was much lower than WHO recommended limit. Synergistic effect was observed between LS and P1, LS and P2, LS and P1+P2. In this study during storage period at 4 °C

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الملخص العربي

مضادات الأكسدة ومضادات الميكروبات الطبيعية وعلاقتها بجودة وسلامة أسماك البوري المدخنة

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تم اجراء معاملات مختلفه باستخدام سائل التدخين علي سمك البوري الطازج (*Mugi cephalus*) حيث تمت المعامله بسائل التدخين ثم سائل التدخين مع مستخلص قشر الرمان بتركيز ١٠٠ مجم لكل كيلو جرام من السمك وايضا استخدام سائل التدخين مع بودرة الفلفل بابريكا ٥ جرام لكل كيلو جرام سمك ثم باستخدام سائل التدخين مع قشر الرمان مع البابريكا بنفس التركيز السابق وذلك لدراسة تأثير هذه المعاملات علي جودة وسلامة السمك المعامل بسائل التدخين اثناء التخزين علي درجة حرارة ٤ م .

اوضحت النتائج ان معاملة السمك الطازج بحامض اللاكتيك في وسط منظم ادي الي خفض رقم الـ pH وعمل كمضاد للميكروبات ودعم الجوده والسلامه .

اتضح ان متوسط المحتوى الرطوبي ٧٢,٣٨ % ، ٥٧,٩٦ % ، ٥٨,٥٧ % ، ٥٧,٦٥ % ، ٥٨,٢٥ % لكل من السمك الطازج والمعامل بسائل التدخين والمعامل بسائل التدخين مع قشر الرمان والمعامل بسائل التدخين مع البابريكا واخيرا والمعامل بسائل التدخين مع قشر الرمان والبابريكا علي التوالي .

اظهرت كل معاملات بسائل التدخين انخفاض معنوي في المحتوى الرطوبي للعينات المعامله من السمك مقارنة بالسمك الطازج . اوضحت النتائج ايضا قيم عاليه من اجمالي النيتروجين الاساسي المتطاير الـ TVB-N في السمك الطازج بينم أدت المعاملات الي انخفاض في تلك القيم تبعا لترتيب التالي السمك المدخن بالسائل مع مستخلص الرمان مع البابريكا يليه المدخن بالسائل مع مستخلص الرمان ثم المدخن بالسائل مع البابريكا واخيرا المدخن بالسائل . اكدت النتائج ايضا ان محتوى الملح في كل العينات المعامله اقل كثيرا عن المستوي الموصي به من قبل WHO حيث يؤدي المستوي المنخفض من الملح الي تشجيع الاستهلاك ويدعم سلامة المنتج ويحسن الصحة العامه .

اكنت النتائج ايضا ان العينات المعامله بسائل التدخين والمعامله بسائل التدخين مع مستخلص الرمان و المعامله بسائل التدخين مع البابريكا و المعامله بسائل التدخين مع الرمان مع البابريكا ادي الي فترة صلاحية ٦٥ و٧٠ و ٧٥ و٧٠ يوم علي التوالي. وبذلك تتأكد امتداد فترة الصلاحيه علي ٤ م ° الي ٦٤ و٦٤ و٦٩ و٦٩ يوم علي التوالي عند المقارنه بالسلك الغير معامل .

