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EFFECT OF SMOKING METHODS ON THE QUALITY CHARACTERISTICS AND POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) CONTENT OF MULLET FISH (*Mugil cephalus*)

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ABSTRACT

This work aims to study the effect of smoking methods (traditional and liquid flavouring) on the quality of whole and gutted mullet products and polycyclic aromatic hydrocarbons (PAHs) contents, which may represent carcinogenicity agent for consumer. Also, physico-chemical, bacteriological and sensorial characteristics were determined. Results showed that there was loss in both water and protein content of smoked fish while the content of lipid, salt and ash were increased. In addition, the values of total volatile basic nitrogen (TVB-N), Trimethylamine nitrogen (TMAN) and thiobarbituric acid (TBA) were increased clearly in the samples smoked by traditional method comparing with those smoked by liquid method. Concerning PAHs, it was found 5 components in raw fish flesh and its concentration was bout 0.78 µg/kg, and then increased to 9 components after smoking to record 13.37 and 1.72 µg/kg flesh of whole fish smoked by traditional and liquid methods, respectively. The corresponding concentrations of gutted samples smoked by the same previous methods were about 16.36 and 1.80 µg/kg flesh, respectively. Besides, total viable count and halophilic bacteria were decreased in all smoked samples in particularly in gutted samples smoked by traditional method. Moreover, although the traditionally-smoked samples gave high scores for colour, taste and overall acceptability but it contained high level of harmful PAHs as compared with those smoked by liquid method. In conclusion, the authors recommended that smoking of whole and gutted mullet fish by using the liquid method, since, it gave satisfied product characterized with good physico-chemical, bacteriological and sensory attributes with minimum content of PAHs especially with smoked gutted fish as compared with the traditional method.

INTRODUCTION

Smoking methods have been used for centuries as a method for preserving meat and fish. Smoking impregnates the high protein food with aromatic components which lend flavour and colour to the food, and also play a bacteriostatic and antioxidant role (Hattula *et al*., 2001). Smoking is one of the oldest methods of food preservation and is still widely used in fish processing. However, the conventional smoking process is now being substituted by the use of smoke flavourings. In addition, the quantitative composition of smoke depends upon the kind of wood used and predominantly on the temperature and air supply, but also on the cleaning

procedure applied after generation (Guillen and Ibargoita, 1998; Stolyhwo and Sikorski, 2005). The preservation effect of salt has been recognized as being due to a decrease in water activity, less availability to microbial attack, and enhancement of functional properties, leading to increase of the shelf-life time. Although salt allows prolonged storage, its contact with fish has been reported to enhance lipid oxidation of the highly unsaturated lipids, directly related to the production of off-flavours and odours, protein denaturation and texture change (Harris and Tall 1994; Leroi and Joffraud,2000). Smoke is produced by the process of incomplete combustion of wood and contains numerous individual components namely: aldehydes, ketones, alcohols, acids, hydrocarbons, esters, phenols, ether, etc (Guillen and Errecalde 2002). These components are transferred to the smoked goods by deposition on their surface and subsequent penetration into their flesh (Doe, 1998). Salting time was an important processing variable influencing product moisture content and the water content or crude protein of fish markedly decreased while ash and NaCL was increased during smoking (Nktesia-Tabiri and Sefa-Dedeh, 1995 and Ibrahim, 1999). Smoking process was affected on the total volatile base nitrogen (TVB-N) and trimethylamine (TMA). In this concern EL-Akel *et al*. (2005) reported that after smoking of bayad and herring fish the amount of TVB-N and TMA-N was increased. In the traditional technique of smoking to preserve fish, phenolic compounds are of considerable importance for the preservation and organoleptic properties of the smoked products (Kjhallstrand and Petersson, 2001). The relative concentration of phenolic compounds in these products depends on the nature of the wood used in the smoking process, the method of smoke generation and the smoke process used (Guillen and Marzanos, 1999 and Serot *et al*., 2004). The composition of the smoke and the conditions of processing affect the sensory quality, shelf- life, and wholesomeness of the product. On the other hand, sensory attributes of quality and the shelf- life of smoked fish are affected mainly by the initial microbial contamination, processing conditions, handling of the product after processing and storage temperature (Sikorski *et al*., 1998)

Polycyclic aromatic hydrocarbons (PAHs) are generally considered to be carcinogenic compounds and, as these also end up in the finished product after smoking. The carcinogenicity of several PAH compounds is known. The most thoroughly studied PAH compounds is benzopyrene (Santodonato *et al*., 1980). Potential health hazards associated with smoked foods, may be caused by carcinogenic components of wood smoke- mainly PAH compounds, derivatives of PAH such as nitro- PAH or oxygenated PAH, and to a lesser extent also N-nitroso compounds and heterocyclic aromatic amines (Stolyhwo and Sikorski, 2005). Hot smoking used for treating, a main part of meat production, brings about higher concentrations of polycyclic aromatic hydrocarbons than cold smoking .Heavy or wild smoking increases PAHs concentration to high levels. Furthermore, smoke flavourings, which have been produced commercially since about the middle of the last century for use in the meat and fish industries contain only trace amounts of PAHs (Miler and Sikorski, 1990 and Simko, 2002). Therefore, the main objective of this work was to study the effects of smoking processes; traditionally and

liquid smoke on the quality of smoked mullet (physico-chemical, bacteriological and sensory properties) and to confirm the possible relationship between polycyclic aromatic hydrocarbons (PAHs) content and smoking method applied.

MATERIALS AND METHODS

Materials

Fresh fish: mullet fish (*Mugil cephalus*) with average weight approximately 200-250 g were obtained from Shakshouk Station of Fish Research, El-Fayium Governorate, Egypt, National Institute of Oceanography and Fisheries and transferred within three hours to the laboratory, using ice box. The fish were washed carefully by tap water and half fish were blended, gutted manually and then washed.

***Sodium chloride*:** salt fine refined table (EL-Nasr Co.) was purchased from local market, Nasr City, Cairo, Egypt.

***Sawdust*:** Beech wood sawdust was obtained from the local market, Nasr City, Cairo, Egypt, and then used for the generation of gas smoke in traditional smoking method.

Liquid smoke: the liquid smoke condensate was produced by Namirei Co. LTD., Tokyo, Japan.

Methods

Smoking methods:

Fish were divided into two groups. Each group contained whole and gutted fish. The first group was brined (20%w/v) overnight at 4ºC, rapidly rinsed with tap water, drained at 35º C for 3h and then cold smoked in a conventional smoking house (rectangular cabinet approximately 55x60x140 cm. equipped with an automatic control for temperature and humidity) at 22-32º C for 7 h (smoking was done at 22ºC for 1h, at 28ºC for 2h and at 32ºC for 4h) and 70-90% relative humidity. The second group was brined (20%w/v) in presence of liquid smoke (at ratio 18 part of brine solution to one part of purified liquid smoke condensate and then heated at 70-80º C for 2h as reported by EL-Badry (2005) and Varlet *et al.* (2006). All smoked samples were cooled at room temperature and then packaged. The flow sheet of traditional and liquid smoking methods of whole and gutted mullet fish is illustrated in Fig. (1).

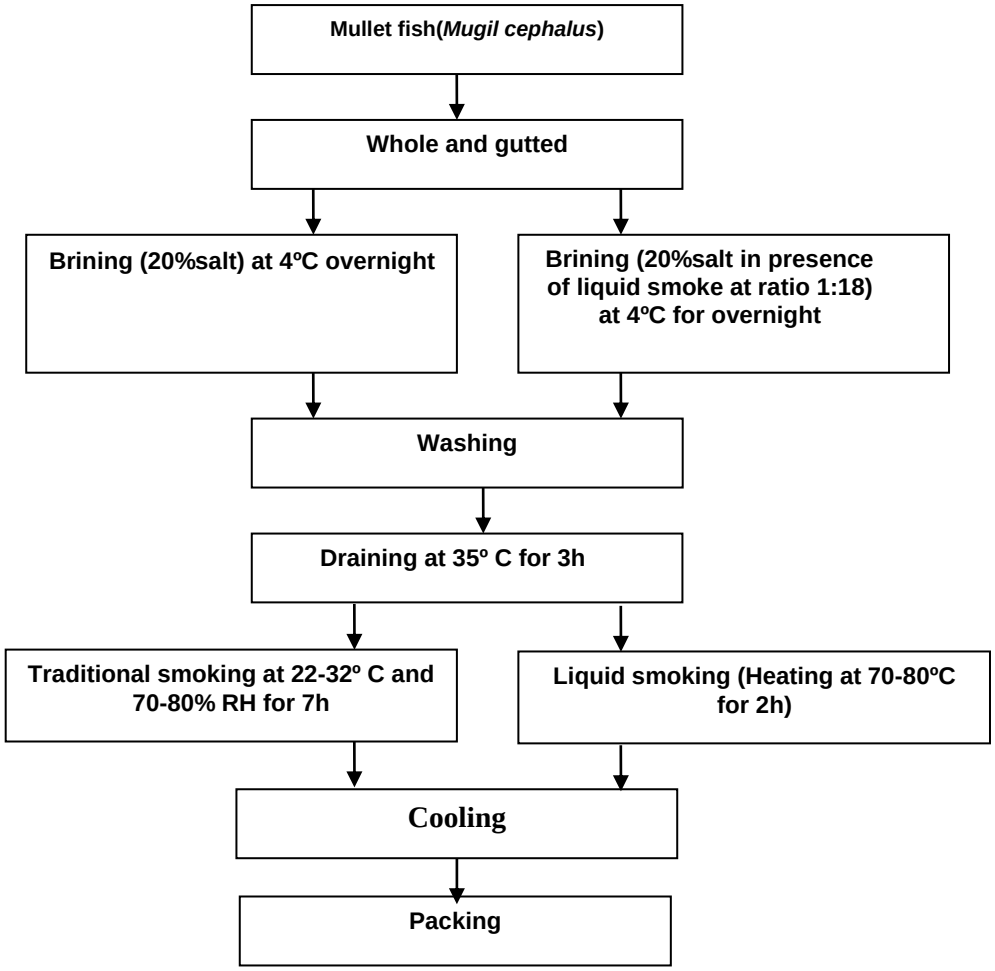

Fig. (1):The flow sheet of traditional and liquid smoking methods of whole and gutted fish.

Analytical methods

Moisture, crude protein, lipid, ash and Trimethylamine nitrogen (TMA-N) contents were determined according to the methods of AOAC (2000). pH value was measured using a pocket-sized pH meter (Woyewoda, *et al.,* 1986). Total volatile base nitrogen (TVB-N) was determined according to the method described by Botta, *et al.* (1984). Thiobarbituric acid TBA was determined according to Pearson (1976). Salt content was determined using the method of Anon (1981).

Determination of Polycyclic aromatic Hydrocarbons (PAHs):

a) Extraction: The PAHs were extracted according to the method described by Howared *et al*. (1966 a&b) with slight modifications carried out by Egyptian Petroleum Research Institute, Egypt. In brief, sample (200 g) was digested in ethanol 95% (40ml) and KOH (25g) and then distilled

water (250 ml) were added, and the PAHs partitioned into iso-octan. Interfering materials were removed by column chromatography in florsil60-100 mesh, followed by selective extraction of PAHs into dimethylsulfoxide (DMSO). Further interfering materials where removed by column chromatography on sephadex LH 20, utilizing a solvent mixture of toluene at ratio of 1 :1 to obtained the purified extracts of PAHs which used for determination of PAHs components.

b) Determination: The 16 individual PAHs listed by the reference reported by the United States (US-EPA), in the purified extracts of tested samples were determined qualitatively and quantitatively by using HPLC (model waters HPLC 600 E, dual up absorbance detector waters 2487 and auto samplers 717 plus attached to computerized supelco) according to the method mentioned by Lal and Khanna (1996). The PAHs identification and system with millennium 3.2 software PAHs standard were obtained from quantification performed using HPLC. The condition of separation is as follow: Column supelcosil LC/PAH, 5 m particles, 15 cm length and 4.6 mm ID. Mobile phase: Graient acetonitrile; water 60 to100 % acetonitrile (v/v) over 45 min. Flow rate: 0.2 m/ min, 2-45 min. 1.0 ml/ min. Detector: it was set at 254 nm.

Microbiological analysis:

Both total viable count and halophilic bacteria were enumerated on plate count agar and the same agar with 10% salt, respectively as recommended by the Anon (1992).

Sensory evaluation:

Sensory characteristics (colour, odour, tast, texture, tenderness and overall acceptability) were evaluated by ten staff members of the Department of Food Science and Technology Fac. of Agric.AL-Azhar Univ. A ten point scale was used where 10 = excellent and 1 = extremely poor. Accuracy and precision were statistically analyzed.

Statistical analysis:

The data analysis of this experiment was carried out. One way analysis of variance and Least Significant Differences test (LSD) were conducted to test significant among the treatment means (Steel and Torrie, 1980).Significant was assumed at ($P \leq 0.05$)

RESULTS AND DISCUSSION

Proximate analysis

The proximal analysis of raw, salted and smoked samples is presented in Table (1). The initial moisture value of raw mullet was 78.79%, the corresponding mean values for salted whole and gutted samples were 66.78% and 61.05%, respectively. This loss in moisture is due to the effect of salt osmosis during brining process. In addition, the same trend was found in all smoked samples. This decrease in moisture of smoked samples is due to partial dehydration during smoking. The variation in moisture values for smoked samples is refer to fish from (whole or gutted) and smoking method

applied (traditional or liquid). Our results are in complete agreement with those of Cardinal *et al*. (2001), who reported that industrial specifications for "smoked finished products" generally recommended water content in the fish flesh of moisture for smoked fish products less than 65%. Similar findings have been reported by Ibrahim (1999); Kolodziejska *et al.* (2002); El-Akel *et al.* (2005) and Goulas and Kontominas (2005).

Table (1): Proximate composition (on wet wt. bases) of raw, salted, traditional and liquid smoked fish products.

Constituents %	Raw fish	Salted fish		Smoked fish			
				Traditional		Liquid	
		Whole	Gutted	Whole	Gutted	Whole	Gutted
Moisture	78.79 ± 0.02	66.78 ± 0.27	61.05 ± 0.09	58.61 ±0.45	55.17 ± 0.88	59.25 ± 1.49	55.74 ± 0.67
Crude protein	18.13 ±1.77	23.12 ±1.32	27.50 ±0.92	24.38 ±1.20	26.25 ±0.89	26.88 ±1.33	29.38 ±0.88
Lipid	0.79 ± 0.13	1.56 ±0.20	1.19 ± 0.04	2.49 ± 0.09	2.43 ± 0.18	2.09 ± 0.45	2.02 ± 0.16
Ash	1.51 ±0.07	8.36 ± 0.05	10.2 ± 0.14	14.29 ± 0.18	15.70 ±0.05	11.28 ± 0.16	12.22 ± 0.02
Salt	Traces	8.19 ± 1.17	8.98 ± 0.59	13.16 ± 0.62	14.04 ± 0.41	10.12 ± 1.17	11.70 ± 0.42

Also, from Table (1), it was found that protein, lipid and ash increased clearly in all salted and smoked samples comparing with initial values. This increase is due to water loss during salting and smoking. In addition, there is little change in salt content for smoked whole and gutted samples either in traditional or liquid smoking methods. The increase in salt content of smoked samples is due to partial dehydration of smoked fish. Furthermore, most of the microorganisms normally associated with fish spoilage are halophobic and will not grow in salt concentration exceeding 5%. Even though salting effectively prevents the growth of both spoilage and pathogenic bacteria (Horner, 1997; Doe, 1998 and Leroi *et al.,* 2001). However, it has been reported that salt content in fish flesh accelerates oxidation of the highly unsaturated lipids (Aubourg and ugliano, 2002). Similar results were reported by Ibrahim, (1999); Gomez-Guillen *et al.* (2000); El-Akel *et al.* (2005) and Yanar *et al.* (2006). On the other hand, the salt content of smoked fish samples ranged from 10.12 to 14.04 % (on wet wt.) in this study.

Physico-chemical quality attributes

The physico-chemical quality attributes of studied raw and smoked samples are shown in Table (2).

pH value

The initial pH value of raw mullet was 6.14. This value of pH is in agreement with those found by Metin *et al*. (2001) and Goulas and Kontominas (2005) for fresh chub mackerel. The pH values of salted whole and gutted samples were 5.25 and 5.20, respectively. The pH decrease in salted samples can be explained by the ionic strength of the solution inside

of the cells (Leroi and Joffraud, 2000), who reported that salt had a highly significant linear decreasing effect on the pH value. A progressive decrease was observed in the pH values of smoked samples by different methods. Its value was remained constant (4.81) in both liquid- smoked whole and gutted samples. On the other side, the pH values of whole and gutted samples smoked by traditional method were 5.37 and 4.94, respectively. This increase in pH value of whole and gutted smoked fish by traditional method may be attributed to the production of volatile basic components (Hyytia *et al.*, 1999 and Ruiz-Capillas and Moral, 2001).

Total volatile basic-Nitrogen (TVB-N)

The initial TVB-N content of raw fish was 11.24 mg/l00g flesh, and then increased in salted whole and gutted sample to record 21.47 and 19.60 mg/100g flesh, respectively. On the other hand, the value of TVB-N decreased in the samples smoked by liquid method and increased in those smoked by traditional method. Moreover, its value in smoked whole samples was higher than smoked gutted samples. However, the TVB-N content of smoked samples remained lower than permissible limit of 35 mg/100g flesh set by the EU Anon (1995). In addition, various authors have reported different acceptability levels for TVB-N value ranged from 20 to 40 mg/ 100g (Connell, 1990; Lopez- Caballero *et al.,* 2000 and Kim *et al.,* 2002). This wide range reflects smoking method, fish species and whole or gutted form.

Table (2):Physico-chemical quality attributes of raw, salted, traditional and liquid smoked fish products.

Constituents %	Raw fish	Salted fish		Smoked fish			
				Traditional		Liquid	
		Whole	Gutted	Whole	Gutted	Whole	Gutted
pH value	6.14 ± 0.02	5.25 ± 0.03	5.20 ± 0.01	5.37 ± 0.03	4.94 ± 0.02	4.91 ± 0.02	4.91 ± 0.02
[1]TVB-N (mg/ 100 g)	11.24 ± 1.98	21.47 ± 1.40	19.60 ± 1.08	25.20 ±1.88	23.80 ± 0.85	16.80 ± 1.62	16.80 ± 1.40
[2]TMA-N(mg/ 100 g) flesh	0.19 ± 0.04	1.05 ± 0.18	1.02 ± 0.18	0.86 ± 0.04	0.12 ± 0.08	0.75 ± 0.03	0.02 ± 0.06
[3]TBA (mg/ 100 g) flesh	0.43 ± 0.05	1.41 ± 0.11	1.30 ± 0.07	1.61 ± 0.13	1.54 ± 0.09	1.58 ± 0.08	1.50 ± 0.03

[1]TVB-N: Total volatile base nitrogen [2]TMA-N: Trimethylamine nitrogen
[3]TBA: Thiobarbituric acid

Trimethylamine-Nitrogen (TMA-N)

From the same table (2), the original value of TMA-N in raw fish flesh was 0.19 /100g and after that, its value increased in salted fish samples to be 1.05 and 1.02 mg/100g flesh in both whole and gutted samples, respectively (Reddy *et al*., 1997 and Rodriguez *et al*., 1999). In contrast, TMA-N content was decreased in all smoked samples particularly in liquid smoked gutted samples (0.02 mg/ 100g flesh).While TMA-N content was 0.86 and 0.75 mg/ 100g flesh in whole smoked fish, respectively using both traditional and liquid methods. These results are highly lower than the permissible limit of TMA-N (not exceed 10mg /100g flesh) reported by Egyptian Standards Specifications (Anon, 1996) for smoked fish.

Thiobarbituric acid (TBA)

The initial value of TBA in raw mullet was 0.43 mg Malonaldhyde (MA)/kg flesh (Table, 2). Data show a strong effect of salt and fish form on the values of TBA since it was in salted whole and gutted samples about 1.41 and 1.30 mg MA/kg flesh, respectively. A number of studies have demonstrated that salt stimulates lipid oxidation via iron activation. Sodium ions may displace iron from macromolecules such as myoglobin, providing free irons for the catalysis of lipid oxidation (Kanner *et al.,* 1991). On the other hand, the values of TBA were increased in all samples smoked by liquid and gas methods. In addition, whole samples smoked had high values of TBA comparing with gutted samples smoked under the same conditions. The TBA value in the samples smoked by gas method was higher than those of smoked samples by liquid method. The increase in TBA value in the smoked samples may be attributed to the increased oxidation of unsaturated fatty acids as a result of smoking at relatively high temperature (up to 70^0C). These results are in agreement with those reported by Goktpe and Moody (1998); Ibrahim (1999); Goulas and Kontominas (2005) and Yanar *et al.* (2006). In general, these data of TBA values in smoked samples are highly lower than the permissible limit (4.5 mg /kg flesh) reported by Egyptian Standards Specifications (ESS, 1996) for smoked fish.

Polycyclic aromatic hydrocarbons (PAHs)

The contents of PAHs in the raw, salted and smoked samples are presented in Table (3). Sixteen components of PAHs were detected however; fourteen of them could be identified in the investigated samples. Data showed that the total average concentration of five components in raw fish muscle was 0.78 µg /kg flesh. The presence of these components in raw fish is in agreement with Stolyhwo and Sikorski (2005), who reported that fish and marine invertebrates may naturally contain small amounts of different PAHs absorbed from the environment. However, the concentrations of 11 individual PAHs in raw muscle of mullet have not been detected. Moreover, the concentrations of 9 individual PAHs in traditional-smoked whole and gutted samples were 13.37 and 16.36 µg/kg flesh, respectively.

On the other hand the concentrations of 9 individual PAHs were about 1.72 to 1.81 µg/kg flesh for whole and gutted samples smoked by liquid method, respectively indicating that the treatment of fish by liquid smoking led to lowering the concentration of total PAHs in fish flesh to be more than 90% of its amount found in fish smoked by traditional method. The dominant components of PAHs were fluorene and acenaphthene in smoked samples by traditional method particularly in smoked gutted samples to be 10.05 and 5.52 µg/kg, respectively. In addition, the smoked samples contained much more PAHs than the raw fish muscle, since it increased from 0.02 to about 0.26 µg of Penzo(a) pyrene (BaP) /kg of product, fish form (whole or gutted), smoking method (traditional and liquid flavorings), composition of smoke and the exposure time to the smoke. Moreover, the concentration of BaP as marker for PAHs in this study was sharp low comparing with the permissible limit (not exceed 1 µg/kg) and the upper limit of 0.03 µg/kg for meat products

treated with smoke preparations as recommended by the European Union (Hartmann, 2000 and Simko,2002). Similar findings were reported by (Kannppan *et al.*, 2000; Hattula *et al.*, 2001 and Varlet *et al*., 2006).

Table(3):Polycyclic aromatic hydrocarbons (PAHs) concentration (µg/ kg flesh)of raw,traditional and liquid smoked fish products.

Component	Raw fish	Smoked fish			
		Traditional		Liquid	
		Whole	Gutted	Whole	Gutted
Naphthalene	ND	ND	0.42	ND	ND
Acenaphthylene	0.01	ND	0.12	ND	0.05
Acenaphthene	ND	3.60	5.52	ND	ND
Fluorene	0.63	7.78	10.05	0.22	0.19
Phenethene	ND	ND	0.03	0.16	0.01
anthracene	0.02	0.07	0.02	0.10	0.02
Fluoranthene	ND	0.27	0.11	0.09	1.12
Pyrene	ND	1.28	ND	0.19	0.17
Benzo(a)anthracene	ND	ND	ND	ND	ND
Chrysene	ND	0.01	0.05	0.04	ND
Benzo(b)fluoranthene	ND	ND	ND	0.03	0.04
Benzo(k)fluorancene	ND	0.09	ND	0.60	ND
Benzo(a)pyrene	0.02	0.26	0.04	ND	0.13
Dibenzo(a,h)anthracene	0.10	ND	ND	0.29	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	ND	0.01	ND	ND	0.07
TOTAL	0.78	13.37	16.36	1.72	1.80

ND: Not detectable.

Bacteriological aspects

The bacteriological aspects of raw, salted and smoked fish samples are given in the Table (4). The initial aerobic plate count of raw mullet was 5.45 $\log_{10}$ CFU/g flesh, and was reduced sharply in the whole and gutted salted samples to be 4.70 and 4.52 $\log_{10}$ CFU/g flesh, respectively. A high decrease in the bacterial load was found in the samples smoked by gas and liquid methods. The reduction rate of bacterial count in all salted and smoked samples is in agreement with Kolodziejska *et al.* (2002) who reported that the growth retarding and lethal effect of smoking on the spoilage and pathogenic microflora depends on the contents of salt in the watery phase of the product, temperature, humidity, and density of the smoke preparations and the time of temperature of heating. In addition, the gutted samples had low count of bacterial load comparing with whole samples under the same conditions of smoking. However, total bacterial count in the smoked fish products in this study was lower than the recommended count (10^5 cells/g) set by Egyptian Standards Specifications (Anon, 1996) for smoked fish.

From the same table, the initial count of halophilic bacteria of raw mullet was 4.16 $\log_{10}$ CFU/g flesh. Also, their counts in the investigated samples have been taken the same trend of total bacterial count. The presence of this bacteria indicated that tolerates the high salt concentration used in this study. Similar results were reported by Skjerdal, (2001).

Table (4): Bacteriological aspects (log_{10} cfu/ g flesh) of raw, salted, traditional and liquid smoked fish products.

Bacteriological aspects	Raw fish	Salted fish		Smoked fish			
				Traditional		Liquid	
		Whole	Gutted	Whole	Gutted	Whole	Gutted
Total viable count	5.45	4.70	4.52	3.96	3.40	4.59	3.72
Halophilic bacterial count	4.16	4.01	3.97	3.40	3.11	3.39	3.30

Sensory evaluation

Sensory characteristics i.e. color, odor, texture, taste, and overall acceptability of traditional and liquid-smoked mullet products are given in Table (5). It could be observed that gutted fish samples smoked by gas and liquid method were scored as excellent for acceptability comparing with those whole samples under the same conditions. In addition, the traditional smoking method improved some characteristics such as color, odor, taste and overall acceptability when compared with liquid flavoring method. There are high significant differences ($P \leq 0.05$) between gutted and whole fish samples smoked by gas and liquid methods. Similar sensory characteristics obtained using the two methods of smoking may be attributed to the adequate cooking provided by the smoking process used (Goulas and Kontominas, 2005 and Varlet *et al*., 2006).

Table (5): Sensory evaluation of traditional and liquid smoked fish products.

Characteristics	Smoking method				LSD at P ≤ 0.05
	Traditional		Liquid		
	Whole	Gutted	Whole	Gutted	
Color	6.8	9.2	6.5	8.7	0.99
Odor	6.4	9.0	6.8	8.5	0.93
Texture	6.4	8.5	7.2	8.2	0.65
Taste	7.6	8.6	6.6	8.8	0.89
Overall acceptability	6.2	9.0	7.0	8.0	0.46

Conclusion

This study revealed that smoking of mullet fish by the liquid method was preferred from the point of view of hydrocarbons (PAHs) content, since the amounts of PAHs in fish treated with liquid smoking was lowering more than 90% that of traditional method. Also, the obtained results showed that the smoked gutted mullet fish was characterized by good quality from the point of view of physico-chemical, bacteriological and sensory properties as compared with smoked whole fish.

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تـأثير طـرق التـدخين علـى جـودة سـمك البـورى المـدخن ومحتـوى المركبـات الهيدروكربونية عديدة الحلقات

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يهدف هذا البحث إلى دراسة تأثير طريقتي التدخين (الغازي والسائل) على جودة سمك البوري في صورة كاملة وأخرى منزوعة الأحشاء، وكذلك محتوى المركبات الهيدروكربونية عديدة الحلقات والتى تمثل خطرا على صحة المستهلك حيث أنها تسبب الأورام السرطانية. ولقد أجريت بعض معايير الجودة الطبيعية والكيميائية والميكروبيولوجية والحسية للعينات موضع الدراسة. وأوضحت النتائج مايلى:

حدوث نقص فى محتوى كلا من الرطوبة والبروتين وزيادة محتوى كل من الدهن والرماد والملح.أيضا حدث نقص واضح فى قيمة الأس الأيدروجينى فى جميع المعاملات المدخنة، بينما حدث زيادة فى محتوى القواعد النيتروجينية الكلية وثلاثى ميثايل الأمين و قيم حمض الثيوباربتيوريك فى العينات المدخنة بطريقة التدخين الغازى مقارنة بتلك المدخنة بطريقة الدخان السائل سواء فى الأسماك الكاملة أو منزوعة الأحشاء. وبالنسبة للمركبات الهيروكربونية عديدة الحلقات فقد وجد ٥ مركبات فى عينات البورى الطازجة بتركيز ٠,٧٨ ميكروجم/كجم لحم بينما وجد ٩ مركبات فى الأسماك الكاملة والمنزوعة الأحشاء والمدخنة بطريقتى الغاز والسائل وكان تركيزها ١,٧٢،١٣,٣٧ ميكروجرام/كجم على التوالى فى الأسماك الكاملة وكان تركيزها ١,٨٠،١٦,٣٦ ميكروجرام/كجم فى الأسماك منزوعة الأحشاء على التوالى، ومن الناحية الميكروبيولوجية فقد حدث إنخفاض فى العدد الكلى للبكتريا وكذلك البكتريا المحبة للملوحة وذلك فى جميع العينات المدخنة خاصة العينات المنزوعة الأحشاء والمدخنة بالطريقة العادية، وحسياً فقد سجلت العينات المدخنة بالطريقة التقليدية قيما أعلى من حيث اللون والطعم فى حالة الأسماك سواء الأسماك الكاملة أو المنزوعة الأحشاء. ودلت التجارب على أن الأسماك المدخنة بالطريقة التقليدية تحتوى على تركيز أعلى (أكثر من ٩٠ %) من محتوى المركبات الهيدروكربونية الضارة مقارنة بتلك العينات المدخنة بالدخان السائل.

وعلى ذلك ينصح الباحثون بإستخدام طريقة التدخين السائل لأسماك البورى خاصة المنزوعة الأحشاء حيث أنها تعطى منتجاً ذات صفات جودة عالية ومقبولة حسياً ويحتوى على تركيزات منخفضة جداً من المواد التى قد تسبب ضرراً للمستهلك.

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