Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 27(6): 1165– 1181 (2023)
www.ejabf.journals.ekb.eg

Effect of Hot Smoking on the Chemical Composition and Quality Criteria of Some Fish Species from Lake Nasser, Egypt

Sayed Ibrahim[1], Nabil Farah[2], Olfat Habib[2], Alaa El-Far[1]*, Harrison Charo-Karisa[2], Ahmed Nasr-Allah[2]

[1]Fisheries Division, National Institute of Oceanography and Fisheries (NIOF), Egypt
[2]WorldFish Center, Cairo, Egypt

*Corresponding Author: alaa-elfar@hotmail.com

ARTICLE INFO

Article History:
Received: Dec. 12, 2023
Accepted: Dec. 26, 2023
Online: Dec. 30, 2023

Keywords:
Freshwater fish,
Smoked fish,
Quality criteria,
Lake Nasser

ABSTRACT

The effect of hot smoking conditions was investigated on the chemical composition and quality criteria of six fish species collected from Lake Nasser, Egypt. The results revealed that fresh *Oreochromis niloticus*, *Lates niloticus*, *Hydrocynus forskalii*, *Alestes dentex*, *Mormyrus* spp. and *Chrysichthys* spp. contained 79.39, 78.46, 75.83, 74.95, 69.48 and 70.79% of moisture, 17.72, 19.16, 19.24, 18.57, 16.63 and 15.82% of crude protein, 1.33, 0.84, 3.62, 5.18, 9.52 and 8.90 of lipids, 1.04, 1.16, 1.02, 1.17, 3.85 and 3.76% of ash content, respectively. Additionally, the values of their quality criteria; total volatile basic nitrogen (TVB-N) and thiobarbituric acid reactive substances (TBARS), pH and microbial load were within the international recommended limits. After the hot smoking process, these values underwent marked changes according to fish species investigated and the reduction rates of weight recorded of 40.63, 39.81, 36.65, 35.92, 39.56 and 37.84%, respectively. In addition, values of TVB-N and TBARS increased, while pH values and microbial load decreased in smoked samples. Both *E. coli* and *salmonella* spp. were not detected in raw and smoked samples. Sensory evaluation showed that smoked *H. forskalii* and *A. dentex* fish were better than others. In general, based on the results obtained, the values of moisture content and microbial load decreased, while crude protein, lipids, ash, TVN and TBARS increased in all smoked fish samples.

INTRODUCTION

Lake Nasser is the most important fishery in Upper Egypt, providing important sources of income and livelihood for fishers, traders and processors in Aswan Governorate **(Nasr-Allah *et al.*, 2016)**. In addition, it has a diverse fishery with 52 fish species belonging to 15 families **(van Zwieten *et al.*, 2011)**. Fish and its products are one of the most important foods due to their high digestibility, nutritional value and minerals, such as phosphorus, calcium, magnesium, etc. Furthermore, fish harvesting, handling,

processing and distributing provide livelihood for people, as well as economic benefits for many countries **(Abisoye *et al.*, 2011; Sarower-E-Mahfuj *et al.*, 2012)**. However, fish are a perishable food material that deteriorates soon after harvest at high ambient temperature **(Aberoumand, 2010)**. Therefore, it should be preserved by using chilling, freezing, salting, drying, smoking, canning and biopreservation methods **(Asiedu & Sanni, 2002)**.

Concerning fish smoking, smoking is one of the oldest methods used to process and preserve fish. Smoked fish is a traditional part of the diet of a large section of the world's population. However, the gap between the demand and supply of fish is widening due to the increase in population, poor postharvest handling, low facilities of processing and storage, and utilization of unconventional fish species. Additionally, smoking method varies between different countries and within the same country, and it depends on the species of fish used and the type of product desired. Besides, smoking can inhibit the formation of toxins in products, reduce the growth of bacteria, and also change the color and flavor of fish **(Swastawati *et al.*, 2000; University of Florida, 2004; Visciano *et al.*, 2008)**. The quality of smoked fish is affected by processing conditions **(Duffes, 1999)**, raw material **(Cardinal *et al.*, 2001)**, smoking method **(Cardinal *et al.*, 2006)**, smoke agent **(Siskos *et al.*, 2007)** and storage conditions in addition to salting method **(Alcicek & Atar, 2010)**. Therefore, this work was performed to investigate the effect of hot smoking conditions on the chemical composition and quality criteria of some fish species obtained from Lake Nasser, Egypt.

MATERIALS AND METHODS

Fish samples

About 5kg of each six freshwater fish species were purchased from the fishermen in Lake Nasser (Landing site), Egypt. The average (mean ± SE) length and weight of fish species were 26.20± 0.37cm and 372.4± 22.57gm for the Nile tilapia *(Oreochromis niloticus)*, 34.11± 0.52cm and 428.50± 22.62gm for the Nile perch *(Lates niloticus)*, 35.04± 0.28cm and 299.60± 13.84gm for Tiger fish *(Hydrocynus forskalii)*, 33.13± 0.42cm and 284.80gm for Characin *(Alestes dentex)*, 36.38± 0.52cm and 358.40± 19.63gm for bottle nose (*Mormyrus* spp.), and 25.32± 0.19cm and 252.10± 7.28gm for

claroteid catfish (*Chrysichthys* spp.), respectively. They were transferred in icebox, gutted and carefully washed with tap water. Scales and viscera were manually removed.

Edible salt

Edible salt (Sodium chloride) packets were purchased from a local market.

Sawdust

Sawdust wood pieces used to produce smoke are acacia wood, it is available to fishing boat makers.

Packaging materials

Polyethylene bags were purchased from a local market.

Salting and drying processes

Cleaned gutted fish samples were immersed in 15% salt solution for 1h at ambient temperature (29.0^0 C) in Misr-Aswan Company for Fishing and Fish processing. After salting, samples were carefully washed with tap water to remove the excessive salt and partially dried for 2h under ambient conditions.

Hot smoking process

Salted fish species samples were hot smoked in stainless steel smoking chamber (dimensions; 2m height×70cm length×60cm width), 4 shelves, hooks and ironed-fire box (50×50×50cm) connected to smoking chamber by flexible tube. Furthermore, its capacity is approximately 50kg of fish. Hot smoking process could be divided into three stages: preliminary drying and smoking at 40^oC for 2h, drying and smoking at 55- 60^oC for 2h, and cooking at 85^oC for 1h. Subsequently, all smoked fishery products were left at ambient conditions to cool and packed in polyethylene bags.

Analytical methods

Chemical composition (moisture, crude protein, lipid, ash, sodium chloride and carbohydrates content) of raw and smoked fish products were determined according to the official method of analysis of the **AOAC (2000)**.

Quality criteria

The pH value of fish samples was measured using a digital pH meter, following the method outlined by **Zaika *et al.* (1976)**. Total volatile basic nitrogen (TVB-N) content was determined according to the recommended method outlined by **AOAC (2000)**. Thiobarbituric acid reactive substances (TBARS) value was determined

according to the guidelines of **Vyncke (1970)**. TBARS value was calculated using the following formula: mg Malondialdehyde/kg of sample = 7.8× O.D. at 538nm.

Microbiological examination

Total bacterial count was determined according to the guidelines of **ICMSF (1998)** using nutrient agar medium. Inoculated dishes were incubated at 37^{o}C for 2- 3 days. *Escherichia coli* count was done using MacConkey agar, and the plates were incubated at 37^{o}C for 24h. Colonies with pinkish red growth having a metallic sheen or reflection confirm the presence of *E. coli*. *Salmonella* count, and samples for detection of *salmonella* were plated out on brilliant green agar. The plates were incubated at 37^{o}C for 24h, and reddish white colonies with a pinkish zone confirmed the presence of *Salmonella* spp.

Sensory evaluation

Sensory attributes score for smell, texture, taste, appearance and overall acceptability were evaluated, following the method of **Afolabi *et al.* (1984)** for each product by 15 panelists of Misr-Aswan Company for Fishing and Fish processing, using a five points hedonic scale with five representing liked extremely and one representing disliked extremely.

Statistical analysis

The results obtained were statistical analyzed according to Statistical Package for the Social Sciences (SPSS), Ver. 20.

RESULTS AND DISCCUSION

Proximate composition

Data presented in Table (2) show the proximate composition of raw fish and hot-smoked fish samples. *O. niloticus*, *L. niloticus*, *H. forskalii*, *A. dentex*, *Mormyrus* spp. and *Chrysichthys* spp. contained 79.39, 78.46, 75.83, 74.95, 69.48 and 70.79% of moisture, 17.72, 19.16, 19.24, 18.57, 16.63 and 15.82% of crude protein, 1.33, 0.84, 3.62, 5.18, 9.52 and 8.90 of lipids, 1.04, 1.16, 1.02, 1.17, 3.85 and 3.76% of ash content, respectively. It could be observed that, the *O. niloticus* had the highest moisture content, while the *Mormyrus* spp. had the lowest moisture content; which might be due to lipid content, and this

confirms the inverse relationship between moisture and fat content in fish flesh. Similar trends were reported in the studies of **Rahman *et al.* (1995)**, **Owaga *et al.* (2010)**, **Adedeji *et al.* (2014)**, **Koral *et al.* (2015)** and **Mostafa *et al.* (2023)**.

Table 1. Chemical composition (mean, ww) of raw and smoked fish products

Fish species	Item	Chemical composition			
		Moisture %	Protein %	Lipid %	Ash %
O. niloticus	Fresh	79.39	17.72	1.33	1.04
	Smoked	37.64	53.88	4.12	3.76
L. niloticus	Fresh	78.46	19.16	0.84	1.16
	Smoked	37.78	55.47	3.31	3.65
H. forskalii	Fresh	75.83	19.24	3.62	1.02
	Smoked	39.22	49.06	9.24	2.68
A. dentex	Fresh	74.95	18.57	5.18	1.17
	Smoked	38.73	45.87	12.84	2.97
***Mormyrus.* spp.**	Fresh	69.48	16.63	9.52	3.85
	Smoked	32.08	37.23	21.34	9.62
***Chrysichthys* spp.**	Fresh	70.79	15.82	8.90	3.76
	Smoked	31.11	37.48	21.19	9.31

Samples of *H. forskalii* had the highest crude protein, while the *Chrysichthys* spp. had the lowest content than others. The results of crude protein content are in accordance with those reported by **Jim *et al.* (2017)**. Concerning variation lipid content, our results coincidewith those of **Steffens (2006)**; the lipid content depending on species, size and nutrition the lipid level of the flesh in freshwater fish can vary considerably. Samples of *Mormyrus* spp. had the highest ash, while the *H. forskalii* had the lowest ash content compared to others. These results are harmonized with those of **Sigurgisladottir *et al.* (2000)**, **Kumolu-Johnson *et al.* (2010)**, **Adedeji *et al.* (2014)**, **Al-Reza *et al.* (2015)**, **Amos and Paulina (2017)** and **Mostafa *et al.* (2023)**, who reported that chemical composition of fish varied according to size, sex, season of the year, genetic makeup, feed intake, metabolic efficiency and environment. Additionally, **Okeyo *et al.* (2009)** found that proximate composition of the Nile perch (*L. niloticus*) was 78.5– 79.5% of moisture, 17.7– 19.8% of crude protein, 0.59– 0.63% of lipid, and 0.5– 0.63% of ash content. With regard to the effect of hot smoking on the proximal analysis, smoked *O. niloticus*, *L. niloticus*, *H. forskalii*, *A. dentex*, *Mormyrus* spp. and *Chrysichthys* spp. samples contained 37.64, 37.78, 39.22, 38.73, 32.08, and 31.11% of moisture, 53.88,

55.47, 49.06, 45.87, 37.23, and 37.48% of crude protein, 4.12, 3.31, 9.24, 12.84, 21.34, and 21.19% of lipids, 3.76, 3.65, 2.68, 2.97, 9.62, and 9.31% of ash content, respectively. Smoked *H. forskalii* recorded the highest moisture (39.22%) after hot smoking, while the *Chrysichthys* spp. showed the lowest moisture (31.11%) than others. The moisture content percentage differences between species may be traced back to certain factors, including size, sex, feed intake, genetic makeup, metabolic efficiency, and season of the year. These results are in line with the results reported by **Amos and Paulina (2017)**. On the other hand, samples of *L. niloticus* exhibited the highest protein (55.47%), while *Mormyrus* spp. had the least protein (37.23%). An increase in protein content of smoked samples may be due to product dehydration which concentrated the protein during the heat temperature, thus increasing the nutritive value of the fish. Similar findings have been detected in the studies of **Kumolu-Johnson *et al.* (2010)** and **Amos and Paulina (2017)**. *Mormyrus* spp. had the highest fat (21.34%), while the *L. niloticus* displayed the lowest fat (3.31%) compared to others. Fat content increased as a result of heat produced by smoking, resulting in moisture loss, increasing the concentration of nutrient in the reaming mass of fat as related to lipid oxidation, which produced volatile compounds of the fish samples. These findings concur with those reported by **Salán *et al.* (2006)**; during fish smoking and sun drying fish lose its moisture content, which results in an increase in the concentration of nutrient in the remaining mass of fats. It was noticed that, *Mormyrus* spp. had the highest ash content (9.62%), while the *H. forskalii* had the lowest ash content (2.68%) than others. Furthermore, the ash content increased in all smoked fish samples. This could be attributed to factors such as fish species, season, sex, and food availability, as reported by **Bilgin *et al.* (2008)**. Additionally, the increase in ash content may be associated with an increase in the dry matter content followed by dehydration during salting and smoking processes.

Weight loss%

Table (2) displays the initial average weight of raw fish samples; *O. niloticus*, *L. niloticus*, *H. forskalii*, *A. dentex*, *Mormyrus* spp. and *Chrysichthys* spp. were 372.44, 428.50, 299.63, 284.81, 358.38 and 252.13g, respectively, and the reduction rates of weight recorded were 40.63, 39.81, 36.65, 35.92, 39.56 and 37.84%, respectively. The

smoked *O. niloticus* samples exhibited the highest loss, while *A. dentex* samples experienced the lowest loss. This loss% is due to the gutting, loss in water content as affected by salting, partially drying and smoking.

Table 2. Effect of hot smoking on weight loss% of fish samples

Fish species	Fish no.	Initial weight (g)	Final weight (g)	Loss %
Oreochromis niloticus	16	372.4±22.57	221.1±13.26	40.63±0.22
Lates niloticus	16	428.5±22.62	257.9±12.77	39.81±0.22
Hydrocynus forskalii	16	299.6±13.84	189.8±8.32	36.65±0.24
Alestes dentex	16	284.8±16.03	182.5±9.84	35.92±0.43
***Mormyrus* spp.**	16	358.4±19.63	216. 6±11.91	39.56±0.15
***Chrysichthys* spp.**	16	252.1±7.28	156.7±4.16	37.84±0.27

These results are in line with those of **Sigurgisladottir *et al.* (2000)**, **Magawata and Musa (2015)** and **Amos and Paulina (2017)**, who reported that the yield and quality of the final product are based on species, weight, smoking time, temperature, heat source, evaporation of water content of fish. However, our results showed values of moisture contents significantly lower than the recommended value (65%) for smoked fish, as reported by **Cardinal *et al.* (2001)**.

Some quality criteria

Total volatile basic nitrogen (TVB-N) is one of the most widely used measurements of seafood quality and is thought to be an important parameter for determining the freshness of fish products **(Huss, 1995)**. The effect of hot smoking on some quality criteria of fish species are shown in Table (3).

Table 3. Mean of some chemical parameters and pH value of raw and smoked fish flesh

Fish species	TVB-N (mg/ 100g)		TBARS (mg MDA/ kg)		pH	
	Raw	Smoked	Raw	Smoked	Raw	Smoked
Oreochromis niloticus	14.83	18.39	0.39	0.82	6.73	6.41
Lates niloticus	13.74	19.11	0.32	0.77	6.84	6.45
Hydrocynus forskalii	15.12	19.68	0.52	0.89	6.71	6.39
Alestes dentex	14.45	17.66	0.48	0.82	6.83	6.52
***Mormyrus* spp.**	14.92	19.35	0.51	0.96	6.75	6.47
***Chrysichthys* spp.**	14.30	19.14	0.43	0.91	6.88	6.58

Values of TVN in raw *O. niloticus*, *L. niloticus*, *H. forskalii*, *A. dentex*, *Mormyrus* spp. and *Chrysichthys* spp. samples were 14.83, 13.74, 15.12, 14.45, 14.92 and 14.30mg/ 100g, respectively, and increased in smoked fish samples to 18.39, 19.11, 19.68, 17.66, 19.35 and 19.14mg/ 100g, respectively. According to **EEC (1995)**, the TVB-N values of fresh fish are much lower than the acceptable upper limits of 25– 35mg/ 100g for some fish species. An increase in TVB-N after hot smoking is related to bacterial spoilage **(Connell, 1995)** and the endogenous proteases and microbial contamination are the main sources causing the increase in TVB-N value during the preservation and processing of fish and fish products. Furthermore, these results are in agreement with the findings of **Zhang *et al.* (2013)**. The increment in TVN content in smoked fish products compared to raw fish is in agreement with the findings of **Mostafa *et al.* (2023)**. The TBA index is widely used as an indicator of the degree of lipid oxidation. Based on data presented in Table (3), TBA values of raw *O. niloticus*, *L. niloticus*, *H. forskalii*, *A. dentex*, *Mormyrus* spp., and *Chrysichthys* spp. samples were 0.39, 0.32, 0.52, 0.48, 0.51, and 0.43mg MDA/ kg and increased in smoked samples to 0.82, 0.77, 0.89, 0.82, 0.96 and 0.91mg MDA/ kg sample, respectively. An increase in TBA value in smoked samples may be attributed to the partial dehydration of fish and oxidation of unsaturated fatty acids as a result of smoking at relatively high temperatures. These results are in accordance with **Bilgin *et al.* (2008)** and **Mostafa *et al.* (2023)**. Additionally, Table (3) shows the pH values of raw *O. niloticus*, *L. niloticus*, *H. forskalii*, *A. dentex*, *Mormyrus* spp. and *Chrysichthys spp.* samples were 6.73, 6.84, 6.71, 6.83, 6.75, and 6.88, and they decreased slightly to 6.41,

6.45, 6.39, 6.52, 6.47, and 6.58 in smoked fish samples, respectively. The decrease in pH values after smoking is due to the degradation of proteins and amino acid. Furthermore, a relationship exists between pH values and acidity, possibly attributed to lactic acid oxidation and the presence of phenolic compounds of smoke. These results agree with those of **da Silva *et al.* (2008)** and **Mostafa *et al.* (2023)**.

Microbial load

Results presented in Table (4) show the total plate count (TPC), *E. coli* and *Salmonella* spp. of raw and smoked *O. niloticus*, *L. niloticus*, *H. forskalii*, *A. dentex*, *Mormyrus* spp. and *Chrysichthys* spp. samples. The TPC recorded values of 4.4, 4.6 , 3.9, 3.7, 4.8, and 4.9×10^3cfu/ g, respectively. The TPC of *Chrysichthys* spp. sample was recorded the highest, while it was the lowest for *A. dentex* sample compared to other species. However, these results are within the International Commission on Microbiological Specification for food **(ICMSF, 1998)**; the maximum recommended bacteria count for good quality product is 5.0×10^5cfu/ g. Furthermore, **NFSA (2021)** reported that the average of TPC in fresh fish is 10^5- 10^6cfu/ g sample. The total bacterial count of some fish species varied from 10^5– 10^8cfu/ g **(Shinkafi & Ukwaja, 2010; Ajayi, 2012; Adedeji *et al.*, 2014; Adeyeye *et al.*, 2015)**. Our data of TPC follow atrend similar to the results obtained by **Mostafa *et al.* (2023)**. Variation in TPC of raw fish samples may be due to water conditions and temperature, the method of catch, poor handling, using dirty canoes, equipment, fish boxes and basket, washing fish in dirty water, and placing fish on dirty surfaces **(Chytiri *et al.*, 2004; Diei-Ouadi & Mgawe, 2011)**.

In addition, Table (3) shows that *E. coli* and *Salmonella* spp. were absent in all raw fish samples. These results agree with the finding of **Chattopadhyay (2000)**; *E. coli* including other coliforms and bacteria as *Staphylococcus* spp. and sometimes *enterococci* are commonly used as indices of hazardous conditions during processing of fish. *E. coli* and *Salmonella* spp. are fecal borne pathogens, and they could occur as a result of contamination from the handlers. Fish harvested from contaminated water can harbor *Salmonella* spp. **(Alexander & Austin, 1986)**. On the other side, smoked *O. niloticus*, *L. niloticus*, *H. forskalii*, *A. dentex*, *Mormyrus* spp. and *Chrysichthys* spp. samples contained 2.1, 2.6, 2.3, 2.1, 2.9, and 2.7×10^2cfu/ g, respectively. The TPC (2.9×10^2cfu/ g) in

smoked *Mormyrus* spp. was recorded the highest, while it was the lowest (2.1×10^2cfu/ g) in smoked *A. dentex* and *O. niloticus* than other species.

Table 4. Microbiological analysis (cfu/ g) of raw fish and smoked samples

Species	TPC		*E. coli*		*Salmonella* spp.	
	Raw	Smoked	Raw	Smoked	Raw	Smoked
O. niloticus	4.4×10^3	2.1×10^2	Absent	Absent	Absent	Absent
L. niloticus	4.6×10^3	2.6×10^2	Absent	Absent	Absent	Absent
H. forskalii	3.9×10^3	2.3×10^2	Absent	Absent	Absent	Absent
A. dentex	3.7×10^3	2.1×10^2	Absent	Absent	Absent	Absent
***Mormyrus* spp.**	4.8×10^3	2.9×10^2	Absent	Absent	Absent	Absent
***Chrysichthys* spp.**	4.9×10^3	2.7×10^2	Absent	Absent	Absent	Absent

These results are lower than the results obtained by **Adelaja *et al.* (2013)**, **Akinwumi and Adegbehingbe (2015)** and **Oranusi *et al.* (2018)**; TPC ranged 4.9×10^4 – 4.0×10^6 in smoked fish, they are within the limits according to the International Commission on Microbiological Specification for Food **(ICMSF, 1998; NFSA, 2021)**, and the maximum recommended bacteria count for good quality product is 5.0×10^5cfu/ g. *E. coli* and *Salmonella* spp. were absent in smoked fish samples too. This may be caused due to quality of fresh fish, salting period, partial drying and high temperature during hot smoking. The absence of *E. coli* and *Salmonella* spp. in smoked samples may be attributed to the effects of salting, dehydration, and heating during hot smoking. The results agree with the outcomes of **da Silva (2002)**, who reported low water activity, absence of moulds, low microbial loads, and better shelf-stability when smoked fish were treated with salt. Furthermore, **Salihu-Lasisi *et al.* (2013)** recommended that the processed fish should be exposed to a drying temperature that will provide insufficient moisture content for the growth of micro-organisms. The absence of both *E. coli* and *Salmonella* spp. in all raw and smoked fish products in this work agrees with the guidelines of the **NFSA (2021)**.

Sensory attributes

In this experiment, a comparison between six fish species from Lake Nasser was carried out using hot smoking method. To evaluate the good quality for the final product, sensory attributed were evaluated using a hedonic score of 5 points, considering a taste panel test that was also conducted. Indicators taken into account for fixing the quality of the finished product were taste, texture, smell, and appearance, besides the general acceptability. Fig. (1) shows the scores of sensory attributes given by panelists of hot smoked products processed from the Nile tilapia (*O. niloticus*), the Nile perch (*L. niloticus*), tiger fish (*H. forskalii*), characin (*A. dentex*), bottle nose (*Mormyrus* spp.) and claroteid catfish (*Chrysichthys* spp.). It was observed that, the taste scores were 4.57, 4.00, 4.21, 4.70, 3.84, and 3.88, respectively. Texture scores were 4.14, 4.00, 4.14, 4.40, 4.20, and 4.00, smell scores were 3.29, 3.38, 3.79, 4.00, 3.62, and 3.38, moreover the total average degrees were 3.95, 3.67, 4.05, 4.32, 3.86, and 3.72, respectively. Based on those results, it could be concluded that, smoked tiger fish and characin were the best among other species. In this study, the TVB-N content is within the acceptable quality and it can be used to support of sensory scores, as reported in the study of **Koral *et al.* (2015)**.

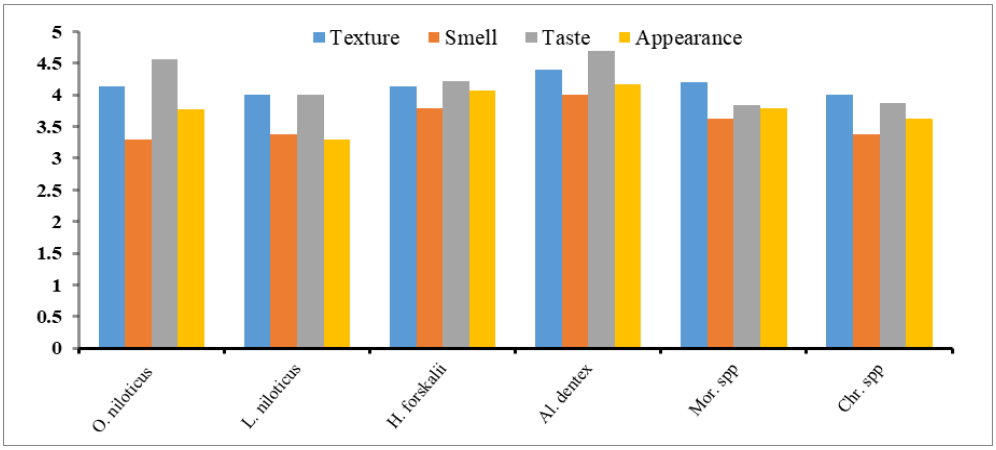

Fig. 1. Sensory attributes of hot smoked fish samples

CONCLUSION

In conclusion, the process of hot smoking caused a decrease in values of moisture content and microbial load. However, crude protein, lipids, ash, TVN, and TBA increased

compared with raw fish samples. Furthermore, no pathogen microbes indicated that raw and smoked fish samples are of a high quality, safety, and fitting for human consumption.

ACKNOWLEDGEMENT

This publication was undertaken in the framework of Youth Employment in Aswan Governorate project, funded by the Swiss Agency for Development and Cooperation (SDC). The current research is a contribution to the CGIAR Research Program on Fish Agri-Food Systems (FISH).

REFERENCES

Aberoumand, A. (2010). Estimation of microbiological variations in minced lean fish products. World J. Fish and Marine Sci., 2(3):2014-207.

Abisoye, B.F.; Ojo, S.K.S.; Adeyemi, R.S. and Olajuyigbe, O.O. (2011). Bacteriological assessment of some commonly sold fishes in Lagos metropolis market Nigeria.Prim.j.Microbial.Res.1 (2): 23-26.

Adedeji, F.A.; Ibrahim Z.B.; Abdulsalami, S.A. and Akinkunmi A.A. (2014). Comparison of Microbiological and Proximate Analysis of *Synodontis nigrita, Chrysichthys nigrodigitatus* and *Mormyrus rume* in Olomore Market, Abeokuta, Ogun State, Nigeria. Journal of Fisheries and Aquatic Science, 9: 496 – 500.

Adelaja, O.A.; Olaoye, O.J.; Ikenweiwe, N.B. and Ashley-Dejo, S.S. (2013). Comparison of microbial load associated with smoked fish (*Chrysichthys nigrodigitatus*) from Oyan Lake and Ogun Waterside in Ogun State, Nigeria. Global J. Sci. Frontier Res. Agri. and Vet., 13(8): 34 – 39.

Adeyeye, S.A.O.; Oyew Ole, O.B.; Obadina, A.O. and Omemu, A.M. (2015). Influence of smoking method on quality of traditional smoked Bonga shad (*Ethmalosa frimbriata*) fish from Lagos State, Nigeria. Afr. J. Food Sci., 9(4): 200 – 207.

Afolabi, D.O.; Arawomo, O.A. and Oke, O.L. (1984). Quality changes of Nigerian traditionally processed fresh water fish species 1-Nutritive and organoleptic changes, J. of food Technology, 19, 333 – 340.

Ajayi, O.A. (2012). Bacteriological study of catfish, *Clarias gariepinus*, from fish pond sources in Akungba-Akoko community, Nigeria. British Microbiology Research Journal, 2(1): 1 – 9.

Akinwumi, F.O. and Adegbehingbe, K.T (2015). Microbiological Analysis of three of smoked fish obtained from the Ondo State, Nigeria Food and Public Health, 5 (4): 122-126.

Alcicek, Z. and Atar, H.H. (2010). The effects of salting on chemical quality of vacuum packed liquid smoked and traditional smoked rainbow trout (*Oncorhyncus mykiss*) fillets during chilled storage. Journal of Animal and Veterinary Advances, 9: 2778-2783.

Alexander, B. and Austin, B. (1986). Bacterial microflora associated with a commercial fish smoker. FEMS Microbial. Lett., 34: 309 – 312.

Al-Reza, S.; Karmaker,S.; Hasan, M.; Roy,S.; Hoque,R. and Rahman, N. (2015). Effect of traditional fish processing methods on the proximate and microbiological characteristics of *Laubuka dadiburjori* during storage at room temperature. Journal of Fisheries and Aquatic Science, 10: 232-243.

Amos, S.O. and Paulina, I. (2017). Assessment of smoked fish quality using two smoking kilns and hybrid solar dryer on some commercial fish species in Yola, Nigeria. . J Anim Res Nutr., 2(6):1-7.

AOAC (2000). The Association of Official Analytical Chemists, Official Methods of Analysis. 17th Edition, Gaithersburg, MD, USA.

Asiedu, M. and Sanni, A.I., (2002). Chemical composition and microbiological changes during spontaneous and starter culture fermentation of Enam Ne-Setaakye, a West African fermented fish-Carbohdrate product Euro. Food Res.Tech., 215(1):8-12.

Bilgin, F.; Ünlüsayin, M.; Izci , L.; Günlü, A. (2008). Determination of the self-life and somnutritional component of Gilthead seabrem (*Sparus aurata* L., 1758) after Cold and Hot smoking. Turk J Vet Anim Sci 32:49 – 56.

Cardinal, **M.; Cornea, J.; Se'rot, T. and Baron, R. (2006)**. Effects of the smoking process on odour characteristics of smoked herring (*Clupea harengus*) and **relationships** with phenolic compound content. Food Chemistry, 96, 137-146.

Cardinal, M.; Knockaert, C.; Torrissen, O.; Sigurgisladottir, S.; Mørkøre, T.; Thomassen, M., and Valle, J.L. (2001). Relation of smoking parameters to the yield, colour and sensory quality of smoked Atlantic salmon (*Salmo salar*). Food Research International, 34, 537-550.

Chattopadhyay, P. (2000). Fish – catching and handling in: Robinson P.K. (ed.) Encyclopedia of Food Microbiological. Vol. 2 Academic Press, London 1547 pp.

Chytiri, S; Chouliara, E.; Savvaidis, I.N. and Kontominas, Michael. (2004). Microbiological, chemical and sensory assessment of iced whole and filleted aquacultured rainbow trout. Food Microbiology. 21. 157-165. 10.1016/S0740-0020(03)00059-5.

Connell, J.J. (1995). Methods of assessing and selecting for quality. In: Control of Fish Quality. 4th Ed. Oxford: Fishing News Books. 1995, 135 – 164.

da Silva, L.V.A. (2002). Hazard Analysis Critical Control Point (HACCP), microbial safety, and shelf life of smoked blue catfish (*lctalurus furcatus*). M.Sc. Thesis, Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College, U.S.A.

da Silva, L.V.A.; Prinyawiwatkul, W.; King, J.M.; No., H.K.; Bankston, J. D Jr.; Ge, B. (2008). Effect of preservatives on microbial safety and quality smoked blue catfish (*Lctalurus furcatus*) steaks during room-temperature storage. Food Microbiol. 25(8): 958 – 963.

Diei-Ouadi, Y. and Mgawe, Y.I. (2011). Post-harvest Fish Loss Assessment in Small-Scale Fisheries: A Guide for the Extension Officer. FAO Fisheries and Aquaculture Technical Paper No. 559. FAO, Rome. 93 pp.

Duffes, F. (1999). Improving the control of *listeria monocytogenes* in cold smoked salmon. Trends in Food Science and Technology, 10 (6-7): 211-216.

EEC (1995). Total volatile basic nitrogen (TVB-N) limit values for certain categories of fishery products and specifying the analysis methods to be used. Commission Decision 95/149/EEC of 8 March 1995, Official Journal of European Communities L97, 84–87.

Huss, H.H. (1995). Quality and quality changes in fresh fish. In: FAO Fisheries Technical Paper – 348. Food and Agriculture Organization of the United Nations, Rome.

ICMSF (1998). The International Commission on Microbiological Specification for Foods. Sampling for microbiological analysis: Principles and specific applications. University of Toronto Press, Toronto, Canada. 2:142.

Jim, F.; Garamumhango, P. and Musara, C. (2017). Comparative analysis of nutritional value of *Oreochromis niloticus* (Linnaeus), Nile Tilapia, meat from three different ecosystems. Journal of Food Quality, 2017, 8 pages.

Koral, S.; Tufan, B.; Başçınar, N. and Köse, S. (2015). Quality changes and shelf-life of cultured and wild hot-smoked Mediterranean Horse Mackerel (*Trachurus*

mediterraneus, Steindachner, 1868) at frozen storage (-20±2°C). Turkish J. Fisheries and Aquatic Sciences, 15: 495-504.

Kumolu-Johnson, C.A.; Aladetohun, N.F. and Ndimele, P.E. (2010). The effects of smoking on the nutritional qualities and shelf life of *Clarias gariepinus* (Burchell 1822). Afr. J. Biotechnol., 9 (1):73 – 76.

Magawata, I. and Musa, T. (2015). Quality characteristics of three hot-smoked fish species using locally fabricated smoking kiln. International Journal of Fisheries and Aquatic Studies. 2(5): 88-92.

Mostafa, M.M.; Youssef, K.M.; Abouzied, A.S. and Amin, H.F. (2023). Quality Changes during Frozen Storage of Hot Smoked Fillets and Spreads Processed from Indian Mackerel (*Rastrelliger kanagurta*) and Pangasius (*Pangasius hypophthalmus*) Fish. Egyptian Journal of Aquatic Biology & Fisheries, Vol. 27(1): 47 – 67.

Nasr-Allah, A.M.; Habib, O.A.; Dickson, M. and Dickson, C. (2016). Value chain analysis of Lake Nasser fisheries in Aswan, Upper Egypt. Penang, Malaysia: World fish. Program Report: 2016-11.

NFSA (2021). National Food Safety Authority, 9. Fish and fish products, including molluscs, crustaceans and echinoderms. ARE (In Arabic), No. 75 (A): 76-88.

Okeyo, G.; Lokuruka, M.N. and Matofari, J.W. (2009). Nutritional composition and shelf life of the lake victoria Nile perch (*Lates niloticus*) stored in ice. Afr. J. Food, Agri., Nut. and Devel., 9: 901 – 919.

Oranusi, S.; Onibokun, E.A.; Obafemi, Y.D. and Dureke, G. (2018). Microbiology, heterocyclic amines and polycyclic aromatic hydrocarbons profiles of some grilled, roasted and smoked food in Lagos and Ogun Sates, Nigeria. African Journal of Food Science, 12(11): 336-346.

Owaga, E.E.; Onyango, C.A. and Njoroge, C.K. (2010). Influence of selected washing treatments and drying temperatures on proximate composition of dagaa (*Rastrineobola argentea*), a small pelagic fish species. African Journal of Food, Agriculture, Nutrition and Development. 10 (7): 2834 – 2847.

Rahman, S.; The, S. H.; Osman, H. and Daud, N. M. (1995). Fatty acid composition of some Malaysian fresh water fish. Food Chemistry, 54: 45–49.

Salán, O.E.; Juliana, A.G. and Marilia, O. (2006). Use of smoking to add value to salmoned trout. Braz. Arch. Biol. Technol. 49(1): 57-62.

Salihu-Lasisi, M.; Akpanio, C.J. and Ogunsola, M.O. (2013). Comparative nutritional studies on fresh and smoked *Clarias gariepinus* (Catfish) and *Tilapia niloticus* (Tilapia) fishes. Euro. J. Exper. Bio., 3(5): 183 – 185.

Sarower-E-Mahfuj, Md., Hossain, M.B. and Minar, M.H. (2012). Biochemical composition of an endangered fish, *Labeo bata* (Hamilton, 1822) from Bangladesh waters. Am. J. Food Technol., 7(10): 633-641.

Shinkafi, S.A. and Ukwaja, V.C. (2010). Bacteria associated with fresh Tilapia (*Oreochromis niloticus*) sold at Sokoto central market in Sokoto, Nigeria. Nigerian Journal of Basic and Applied Science, 18(2): 217 – 221.

Sigurgisladottir, S.; Sigurdardottir, M.S.; Torrissen, O.; Vallet, J.L. and Hafsteinsson, H. (2000). Effects of different salting and smoking processes on the microstructure texture and yield of Atlantic Salmon (*Salmo salar*) Fillets. Food Res. Int. 33: 847 – 855.

Siskos, I.; Zotos, A.; Melidou, S. and Tsikritzi, R. (2007). The effect of liquid smoking of fillets of trout (*Salmo gairdnerii*) on sensory, microbiological and chemical changes during chilled storage. Food Chemistry, 101 (2): 458-464.

Steffens, W. (2006). Freshwater fish-wholesome foodstuffs. Bulgarian J. Agric. Sci., 12: 320 – 328.

Swastawati, F.; Suzuki, T.; Dewi, E.N. and Winarni, T. (2000). The effect of liquid smoke on the quality and omega-3 fatty acids content of tuna fish (*Euthynnus affinis*). Journal of Coastal Development, 3, 573-579.

University of Florida (2004). Guidance for processing smoked seafood in retail operations. Florida: IFAS Communication Services. AFDO January 22-2004.

van Zwieten, P.A.M.; C. Béné; J. Kolding; R. Brummett and J. Valbo-Jergensen. (2011). Review of tropical reservoirs and their fisheries. The cases of Lake Nasser, Lake Volta and Indo-Gangetic Basin reservoirs. FAO Fisheries and Aquaculture Technical Paper No. 55. Rome: FAO. 148 pp.

Visciano, P.; Perugini, M.; Conte, F. and Amorena, M. (2008). Polycyclic aromatic hydrocarbons in farmed rainbow trout (*Oncorhynchus mykiss*) processed by traditional flue gas smoking and by liquid smoke flavourings. Food and Chemical Toxicology, 46, 1409-1413.

Vyncke, W. (1970): Direct determination of the thiobarbituric acid value in trichloroacetic acid extracts of fish as a measure of oxidative rancidity. European J. of Lipid Science and Technology, 72 (12): 1084 – 1087.

Zaika, L.L.; Zell, T.E.; Smith, Z.L.; Palumbo, S.A. and Kissinger, J.C. (1976). The role of nitrite and nitrate in Lebanon Bologna, a fermented sausage. J. Food. Sci., 41: 1457-1460.

Zhang, J.; Fang, Z.; Cas, Y.; Xu, Y.; Hu, Y.; Ye, X.; Yang, W. (2013). Effect of different drying processes on the protein degradation and sensory quality of laýu: A Chinese dry – curing grass carp. Dry. Technol., 31(13 – 14): 1715 – 22.