academicJournals

Vol. 9(4), pp. 200-207, April, 2015
DOI: 10.5897/AJFS2014.1250
Article Number: DB84B6E51598
ISSN 1996-0794

http://www.academicjournals.org/AJFS

African Journal of Food Science

Full Length Research Paper

Influence of smoking method on quality of traditional smoked Bonga shad (*Ethmalosa frimbriata*) fish from Lagos State, Nigeria

Adeyeye, S. A. O[1]*, Oyewole, O. B.[1], Obadina, A. O.[1] and Omemu, A. M.[2]

[1]Department of Food Science and Technology, Federal University of Agriculture, Abeokuta, Nigeria.
[2]Department of Hospitality and Tourism Management, Federal University of Agriculture, Abeokuta, Nigeria.

Received 12 December 2014; Accepted 18 March 2015

This study was carried out to assess the influence of smoking method on quality attributes of traditional smoked bonga shad fish. Fresh bonga shad fish (100 samples) and smoked bonga shad fish (100 samples) were collected from 20 different processing centres and the fresh samples were smoked with convectional smoking kiln as the control. Laboratory analyses were conducted and each batch was assessed for; proximate and quality analyses. The results obtained show significant variations (p<0.05) for all the proximate composition and quality indices of the smoked bonga shad fish samples. The mean moisture content of fresh bonga shad ranged from 72.96 - 76.89% and that of the smoked bonga shad and control ranged from 10.89 - 14.38% and 8.56 - 10.12%, respectively. The mean protein content of 15.18 - 16.95% was recorded for fresh bonga shad samples and 51.86 - 60.24% and 58.86 - 64.84% for samples of smoked bonga shad. The fat content was determined at 6.46 - 8.84%, while the smoked bonga shad and the control samples were found to have fat content at 16.13 - 20.84% and 12.87 - 17.34%, respectively. The mean pH, thiobarbituric acid value (TBA), total volatile base- nitrogen (TVB-N), TMA, trimethylamine value (TMA) and Free fatty acids values (FFA) values of the smoked bonga shad were lower than the control and the fresh samples. However, all values are within the range of legislative standard.

Key words: Bonga shad, smoking, traditional, proximate, quality indices.

INTRODUCTION

In most sub-saharan Africa countries, traditional fishing is practiced in almost all rivers, lakes, ponds, and seas. It represents an important part of total fish captures and is an important sector in the national strategies of fight against poverty, food security and food safety (Ahmed et al., 2011). Fish is an important dietary component of people all around the world and represents a relatively cheap and accessible source of high quality protein for poorer households (Ikutegbe and Sikoki, 2014). In West Africa, fish has been reported to provide 40–70% of the protein intake of the population (Béné and Heck, 2005; Ikutegbe and Sikoki, 2014) and it is a critical source of

*Corresponding author. E-mail: saadeyeye@yahoo.com.

dietary protein that is not readily available in the carbohydrate-based staple foods of the populations. In Nigeria, fish has an edge over meat because it is cheaper and relatively more abundant (Eyo, 2001) and constitutes about 40% of the animal protein intake (Eyo, 2001; Abolagba and Melle, 2008). Fish can be consumed in several forms; fresh, dried, frozen, fermented, and brined depending on the consumer preference. In a study by Mafimisebi (2012), it was discovered that majority of the Nigerian people had a preference for fresh fish; however limitations such as the low keeping quality of fish after harvested and the tendency of fish to spoil quickly make this very difficult. This results in a higher reported consumption of smoke-dried fish, which has relatively longer shelf life (Mafimisebi, 2012).

Fish is highly perishable and a considerable effort has been directed to extend the shelf-life of fish using presservation and processing techniques, such as refrigeration, freezing, canning, smoking, salting, and drying (Nwachukwu and Madubuko, 2013). Besides, some of these techniques can also be used to enhance the value of fish, such as smoked fish.

The smoking of fish smoldering dates back to civilization (Eyo, 2001). Smoking method mostly imparts a desirable flavour and inhibits the growth of microorganisms (Swastawati, 2008). It has been used for centuries in food preservation, and is still widely used for this purpose among several communities in the third world where up to 70% of the catch is smoked for preservation (Omojowo and Raji, 2010). Consumers are rediscovering the good taste of smoked seafood, including smoked catfish. To satisfy the consumer demand, it is necessary to produce good quality and safe smoked seafood products (Omojowo and Raji, 2010).

There is insufficient data on the quality characteristics of traditional smoked wild fish from Nigeria despite the fact that it constitutes a substantial portion of fish available for Nigerians. This study is carried out to investigate the influence of smoking method on quality of traditional smoked bonga shad from Lagos State.

MATERIALS AND METHODS

Fish used

Fresh bonga shad fish (100 samples) and smoked bonga shad fish (100 samples) were collected from 20 different processing centres from fishing communities of Badagry and Epe Local Government Areas of Lagos State, Nigeria. The fresh bonga shad fish samples were freshly harvested. The fresh samples were taken to the Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR) laboratory, Federal University of Agriculture, Abeokuta for smoking.

Area of study

Using a current geopolitical map of Nigeria, Lagos State (Figure 1) lies to the south-western part of Nigeria and has boundaries with Ogun State both in the north and east. It is bordered on the west by the Republic of Benin and in the south, stretches for 180 km along the coast of the Atlantic Ocean. It therefore has 22.5% of Nigeria's coastline and occupies an area of 3,577 sq km land mass with about 786.94 sq km (22%) of it being lagoons and creeks. The state is endowed with marine, brackish and fresh water ecological zones with varying fish species that provide productive fishing opportunity for fishermen. Two local government areas (Badagry and Epe Local Government) were covered because they are highly densed fish processing centers. They were selected for the study and hazard analyses of the products.

Sampling procedure

Fresh samples (100) and smoked bonga shad samples (100) were collected from each of the 10 processing centres from each of the two local government areas (Badagry and Epe Local Government) by purposive sampling in sterile containers (Ziploc).

All freshly harvested bonga shad samples were kept on ice during transportation to the laboratory and smoked on the same day. Smoked bonga shad fish samples were analyzed immediately.

Fish smoking process

Smoked fish was prepared following the method as described by Crapo (2011) with modifications. Bonga shad fish samples were carefully cleaned to remove slime, blood and harmful bacteria. The fish were eviscerated, leaving the skin on the fish. The fish were cut into uniform pieces (fillet) so that no parts will get overheated.

The bonga shad fish were smoked to 80°C internal temperature for 18 h. The kiln temperature was adjusted as needed throughout this smoking period to maintain the 80°C internal temperature. Hands, utensils and work surfaces were cleaned when transferring fish from smoker to oven to cool down to avoid cross-contamination. Smoking was done for 24 h until the fish is fully dried.

Proximate analysis

The following proximate analyses were carried out on fresh bonga shad and the smoked bonga shad samples collected from the processing centres. The moisture content of the fresh bonga shad and smoked bonga shad were determined by the oven-drying method. Protein contents of the bonga shad were extracted and fractionated by the method of AOAC (2000) method. The crude fat, crude fibre and ash content of the fresh bonga shad and smoked bonga shad were determined by AOAC (2000) method.

Physico-chemical analysis

Kent pH meter (Kent Ind. Measurement Ltd., survey) model 7020 equipped with a glass electrode was used to measure the pH of the flesh, employing 10 g of fish homogenized in 10 ml of distilled water. Triplicate determinations were made in all cases. The pH meter was calibrated using pH 4.0 and pH 7.0 buffers. The total volatile base- nitrogen, trimethylamine value (TMA), thio-barbituric acid value, peroxide value and free fatty acid value of the fresh fish and smoked fish were determined by AOAC (2000) method. All chemicals used in this study were of the analytical grade unless stated otherwise.

Data analysis

All data analyses were done in triplicates. The data obtained were

Figure 1. Map of Lagos State showing the 20 Local Government Areas

subjected to descriptive statistics using IBM SPSS version 21.0 software. One way analysis of variance (ANOVA) was done using Duncan's Multiple Range Test (p<0.05) to study the difference between means.

RESULTS AND DISCUSION

Moisture content of fresh bonga shad samples ranged from 72.96 - 76.89% (Table 1) and that of smoked bonga shad samples obtained using local drum kiln and conventional smoke kiln ranged from 11.22 - 14.64% and 8.64 - 10.32% (Table 2). In contrary to protein, fat, and ash, the moisture content of fresh bonga shad samples decreased sharply after the smoking process. This decrease was due to loss of water during smoking. Moisture content of fish is of great importance as it promotes microbial growth. In the present study, the protein content of the fresh bonga shad samples ranged from 15.18 - 16.95% and that of the smoked bonga shad samples ranged from 51.86 - 60.24% and 58.86 - 64.84%. There was an inverse relationship between the moisture and protein content in the smoked bonga shad. Fat content of fresh bonga shad samples ranged from 6.46% - 8.84% and that of smoked bonga shad samples ranged from 16.13 - 20.84% and 12.87 - 17.34%. Crude fibre content of fresh bonga shad samples ranged from0.21 - 0.37% and crude fibre content of smoked bonga shad samples ranged from 2.14 - 4.32% and 2.26 - 4.56%. Ash content of fresh bonga shad samples ranged from 0.12 - 0.16% and ash content of smoked bonga shad samples ranged from 1.18 - 1.46% and 1.24 - 1.79% . The increase in mineral content, ash and crude fibre can be attributed to an increase in the dry matter content per unit weight following sample dehydration

Table 1. Proximate composition of fresh Bonga shad (*Ethmalosa frimbriata*) samples from 20 different processing centres.

Processing centres	Moisture %	Protein %	Fat %	Crude fibre %	Ash %	Carbohydrate %
Agbalata	74.81_{a}	15.18_{a}	7.81_{cdefg}	0.29_{abc}	0.15_{a}	0.92_{ab}
Ajido	75.68_{a}	15.96_{a}	5.73_{a}	0.26_{abc}	0.12_{a}	1.04_{ab}
Asakpo	76.54_{a}	15.79_{a}	7.86_{defg}	0.3_{4bc}	0.14_{a}	1.01_{ab}
Boguru	73.86_{a}	16.21_{a}	7.90_{fg}	0.21_{a}	0.12_{a}	1.05_{ab}
Fvanoveh	75.87_{a}	16.95_{a}	8.84_{fg}	0.26_{abc}	0.12_{a}	0.94_{ab}
Gberefun	74.69_{a}	15.72_{a}	8.45_{efg}	0.23_{ab}	0.13_{a}	0.99_{ab}
Gbetrome	74.75_{a}	16.78_{a}	8.87_{g}	0.33_{bc}	0.12_{a}	1.01_{ab}
Ilaje	75.91a	16.26_{a}	7.49_{bcde}	0.31_{abc}	0.14_{a}	1.16_{ab}
Kofegameh	74.62_{a}	15.93_{a}	6.73_{abc}	0.24_{ab}	0.14_{a}	1.08_{ab}
Pako	76.72_{a}	16.11_{a}	7.94_{defg}	0.27_{abc}	0.16_{a}	0.95_{ab}
Afuye	74.95_{a}	$16._{89a}$	8.84_{fg}	0.25_{abc}	0.14_{a}	0.92_{ab}
BodinYawa	73.89_{a}	16.61_{a}	6.93_{bcd}	0.31_{abc}	0.12_{a}	1.06_{ab}
Idale	74.63_{a}	16.96_{a}	7.89_{bcd}	0.21_{a}	0.13_{a}	0.95_{ab}
Igbodun	75.36_{a}	16.83_{a}	8.43_{efg}	0.23_{ab}	0.14_{a}	1.04_{ab}
Ilogun	76.52_{a}	15.68_{a}	7.68_{cdef}	0.30_{abc}	0.12_{a}	1.24_{b}
Mejona	74.93_{a}	16.89_{a}	7.74_{cdef}	0.24_{ab}	0.15_{a}	1.12_{ab}
Oluwo	75.84_{a}	16.48_{a}	6.46_{ab}	0.37_{c}	0.14_{a}	1.01_{ab}
Okorisan	77.69_{a}	16.91_{a}	7.90_{defg}	0.34_{bc}	0.12_{a}	0.9_{a}
Orita	76.92_{a}	16.86_{a}	7.82_{defg}	0.31_{abc}	0.14_{a}	1.23_{b}
Orogoro	75.45_{a}	16.62_{a}	7.96_{defg}	0.28_{abc}	0.13_{a}	1.09_{ab}

Data are means of 3 replicates. Data with the same subscript are not significantly different at $p<0.05$.

Table 2. Proximate composition of smoked Bonga shad (*Ethmalosa frimbriata*) from 20 different processing centres using local drum kiln and convective smoking kiln.

Processing centres	Moisture %		Protein %		Fat %		Crude fibre %		Ash %		Carbohydrate %	
	Local	Convect	Local	Convect	Local	Convect	Local	Convect	Local	Convect	Local	Convect
Agbalata	13.37gh	9.23e	56.18h	63.18m	18.09g	13.31c	2.91e	2.98f	1.46hi	1.79j	7.99g	9.51hi
Ajido	13.84i	9.56f	59.06p	64.06p	16.61c	12.98b	2.63c	2.87e	1.18a	1.33ab	6.68b	9.20f
Asakpo	14.31k	10.12h	54.39e	61.39h	18.15gh	14.43f	3.24g	3.56i	1.36efgh	1.54efg	8.55h	8.96e
Boguru	12.59e	8.78bc	57.21k	63.21n	18.20gh	14.60g	2.14a	2.43b	1.24abcd	1.61ghi	8.62h	9.37g
Fvanoveh	12.11d	8.64a	60.24q	64.84q	17.13e	12.87a	2.65c	2.78d	1.19a	1.24a	6.68b	9.63jk
Gberefun	14.26jk	10.06h	53.72c	60.72d	20.58k	14.15d	2.38b	2.59c	1.32cdef	1.68i	7.74e	10.80n

Table 2. Contd

Gbetrome	11.83c	8.89c	55.48g	60.48c	19.27j	15.82l	3.32gh	3.46h	1.21ab	1.43bcde	8.89j	9.59ij
Ilaje	12.67e	8.68ab	58.26n	63.86o	18.15gh	13.36c	3.09f	3.32g	1.40efgh	1.62ghi	6.43a	9.16f
Kofegameh	13.28g	9.09d	57.63l	62.63l	16.43b	14.53g	2.43b	2.57c	1.44ghi	1.73i	8.79i	9.45gh
Pako	11.54b	8.83c	54.11d	61.11g	18.72i	16.87o	2.72cd	2.91ef	1.61j	1.47cde	11.30m	8.81d
Afuye	12.04d	8.78bc	51.86a	58.86a	20.84l	17.34p	4.32j	4.56l	1.42fghi	1.73i	9.52k	8.73d
Bodin Yawa	14.16j	10.32i	58.21mn	61.61i	16.13a	14.28e	3.10f	3.34g	1.18a	1.65hi	7.22c	8.80d
Idale	12.10d	8.65a	52.96b	60.96f	16.84d	16.76n	2.18a	2.26a	1.25abcd	1.54efg	14.67n	9.83l
Igbodun	11.33a	9.68g	58.13m	62.13k	18.25h	16.35m	2.25a	2.41b	1.42fghi	1.38bcd	8.62h	8.05a
Ilogun	13.28g	9.08d	57.18k	60.18b	16.46b	17.82h	3.04f	3.32g	1.16a	1.51def	8.62h	8.01a
Mejona	13.41h	9.23e	54.89f	62.89m	17.73f	15.13j	2.46b	2.64c	1.51i	1.69i	10.00l	8.42c
Oluwo	12.94l	8.88c	58.42o	61.72j	16.12a	14.82h	3.79j	3.91j	1.30bcde	1.43bcde	7.43d	10.24m
Okorisan	11.22i	9.56f	56.94j	60.94f	19.44j	15.58k	3.41h	3.57j	1.23abc	1.36abc	7.76f	8.99e
Orita	14.64	10.23i	53.83c	60.83e	18.64i	13.31c	4.11i	4.23k	1.41fghi	1.71i	7.37d	9.69k
Orogoro	13.89	9.71g	56.18h	63.18m	18.15gh	15.89l	2.82de	2.96ef	1.34defg	1.63ghi	7.46d	8.17b

Local = Local drum kiln; Convect = Convective smoking kiln. Data are means of 3 replicates. Data with the same subscript are not significantly different at p<0.05.

and during the smoking process. In this study carbohydrate content is given by difference that is the percentage of water, protein, fat and ash subtracted from 100. The carbohydrate content of fresh unsmoked bonga shad samples ranged from 0.92 - 1.24% and carbohydrate content of smoked bonga shad and control samples ranged from 6.43 - 10.00% and 8.01 - 10.24%. Carbohydrate content of smoked bonga shad samples is low because it is a proteinous food.

The quality indices of the fresh and smoked bonga shad were studied (Tables 3 and 4). Fats undergo changes during storage which result in production of an unpleasant taste and odour which is commonly referred to as rancidity. The peroxide value (PV) results are similar in pattern to TBA. In this study PV of fresh bonga shad samples was 6.11 – 8.59 mg Eqperoxide/kg and 6.22 – 10.41 mg Eqperoxide/kg and 7.12 – 9.86 mgEq.peroxide/kg for smoked bonga shad and control samples. These values are below the recommended value of between 20 and 40 mgEq.peroxide/kg for rancid taste to begin. Free fatty acids values (FFA) of fresh unsmoked bonga shad samples was 0.86 - 1.13% while that of smoked bonga shad and control samples ranged from 1.05 - 1.26% and 1.00% - 1.19%. These values are very low and below the threshold for rancidity detection in smoked fish. The thiobar-bituric acid value (TBA) is used to assess the degree of fish spoilage especially in fatty fish. The TBA test measures a secondary product of lipid oxidation, malonaldehyde. The TBA values of fresh bonga shad samples ranged from 0.84 – 1.11 mgMol/kg and thio-barbituric acid value (TBA) of smoked bonga shad samples and control samples ranged from 1.01 – 1.23 mgMol/kg and 1.01 – 1.15 mgMol/kg. The TBA (1.00 to 1.15 mg TBA/kg) did not exceed 1 to 2 mg TBA/kg which was well within acceptable limits. The sensory threshold level for detecting rancidity in fresh meat was reported to be between 1 and 2 TBA (Calhoun et al., 1999). The increased TBA values in the smoked fish probably originated from the breakdown of oxidation products, mainly malonaldehyde, during smoking due to the high temperature (Goktepe and Moody, 1998). Beltran and Moral (1991) reported that high TBA values are correlated with the degree of oxidation of fats in hot smoked sardines.

The legislative standard for TVB-N include: 20 mgN/100 g for fresh fish, 30 mgN/100 g stale fish and 40 mgN/100 g for fish that is unfit for human consumption but can be used for animal feed (da Silva, 2002). In this study, the total volatile base-nitrogen (TVB-N) of fresh bonga shad ranged from 13.38 – 15.57 mgN/kg and TVB-N of smoked bonga shad and control samples ranged from 16.43 – 19.36 mgN/kg and 15.49 – 18.83mgN/kg. These values are within the range of legislative

Table 3. Quality indices of fresh Bonga shad (*Ethmalosa frimbriata*) samples from 20 different processing centres.

Processing centres	Peroxide value (PV)(mEq. peroxide/kg)	Free fatty acid (FFA) %	Thiobarbituric acid (TBA) (mg Mol/kg)	Total volatile base-nitrogen (TVB-N) (mgN/kg)	Trimethyl amine value (TMA) (mgN/kg)	pH
Agbalata	6.11$_{a}$	1.03$_{bcdefg}$	0.96$_{abcde}$	13.89$_{e}$	2.42$_{ghij}$	6.96$_{abcd}$
Ajido	6.57$_{ab}$	1.08$_{efgh}$	1.00$_{bcde}$	13.56$_{bc}$	1.98$_{abc}$	7.03$_{bcdef}$
Asakpo	8.04$_{def}$	1.00$_{bcdef}$	1.19$_{g}$	15.38$_{k}$	2.31$_{efghi}$	7.18$_{fgh}$
Boguru	6.38$_{a}$	0.95$_{abc}$	1.07$_{efg}$	13.49$_{ab}$	2.49$_{ijk}$	6.91$_{ab}$
Fvanuveh	7.20$_{bc}$	1.06$_{defg}$	1.11$_{fg}$	15.73$_{l}$	2.26$_{efgh}$	6.93$_{abc}$
Gberefun	7.63$_{cde}$	1.01$_{bcdef}$	0.89$_{abc}$	14.63$_{gh}$	2.03$_{abcd}$	7.11$_{defgh}$
Gbetrome	8.13$_{def}$	1.09$_{efgh}$	0.94$_{abcde}$	14.92$_{i}$	2.51$_{jk}$	6.93$_{abc}$
Ilaje	8.00$_{def}$	1.11$_{fgh}$	1.13$_{efg}$	13.71$_{cd}$	2.43$_{hijk}$	6.82$_{a}$
Kofegameh	6.75$_{ab}$	0.93$_{abc}$	0.86$_{ab}$	13.47$_{ab}$	2.56$_{k}$	6.86$_{a}$
Pako	8.27$_{def}$	0.98$_{bcde}$	1.04$_{def}$	14.78$_{hi}$	2.12$_{abcde}$	7.07$_{bcdef}$
Afuye	7.18$_{bc}$	1.04$_{cdefg}$	0.95$_{abcde}$	15.17$_{j}$	1.94$_{a}$	7.10$_{defgh}$
BodinYawa	6.46$_{a}$	1.07$_{efgh}$	1.02$_{cdef}$	13.79$_{de}$	2.23$_{defg}$	7.13$_{efgh}$
Idale	6.31$_{a}$	1.05$_{defg}$	1.00$_{bcdef}$	13.73$_{de}$	2.16$_{bcde}$	7.24$_{h}$
Igbodun	8.35$_{ef}$	1.18$_{h}$	0.85$_{a}$	15.57$_{l}$	2.11$_{abcde}$	7.00$_{bcde}$
Ilogun	8.49$_{ef}$	0.87$_{a}$	0.97$_{abcdef}$	14.45$_{f}$	1.96$_{ab}$	7.14$_{efgh}$
Mejona	7.59$_{cd}$	0.92$_{ab}$	0.84$_{a}$	15.63$_{l}$	1.93$_{a}$	6.81$_{a}$
Oluwo	8.06$_{def}$	0.86$_{a}$	1.08$_{efg}$	13.85$_{de}$	1.99abc	7.20$_{gh}$
Okorisan	7.61$_{cd}$	1.06$_{defg}$	1.05$_{defg}$	14.91$_{i}$	2.17$_{cdef}$	7.09$_{cdefg}$
Orita	6.38$_{a}$	1.13$_{gh}$	0.91$_{abcd}$	14.57$_{fg}$	2.36$_{fghi}$	7.01$_{bcdef}$
Orogoro	8.59$_{cd}$	1.02$_{bcdef}$	0.94$_{abcdef}$	13.38$_{a}$	2.13$_{abcde}$	7.13$_{efgh}$

Data are means of 3 replicates. Data with the same subscript are not significantly different at $p<0.05$.

Table 4. Quality indices of smoked Bonga shad (*Ethmalosa frimbriata*) from 20 different processing centres using local drum kiln and convective smoking kiln.

Processing centres	Peroxide value (PV)(mEq,peroxide/kg)		Free fatty acid(FFA) %		Thiobarbituric acid (TBA) (mg Mol/kg)		Total volatile base-Nitrogen (TVB-N) (mgN/100g)		Trimethyl amine value (TMA)(mgN/kg)	pH		
	Local	Convect	Local	Convect	Local	Local	Local	Convect	Local	Convect	Local	Convect
Agbalata	9.05$_{ghi}$	8.92 $_{n}$	1.13$_{abc}$	1.10$_{b}$	1.07$_{ab}$	1.02$_{a}$	18.33$_{g}$	16.62$_{c}$	2.61$_{i}$	2.49$_{kl}$	6.41$_{defg}$	6.56$_{a}$
Ajido	8.96$_{gh}$	7.78$_{g}$	1.18$_{cd}$	1.12$_{b}$	1.12$_{ab}$	1.09$_{ab}$	19.06$_{i}$	18.31$_{k}$	2.36$_{def}$	2.18$_{cde}$	6.38$_{cdef}$	6.72$_{bcde}$
Asakpo	9.01$_{ghi}$	8.21$_{hi}$	1.26$_{d}$	1.19$_{b}$	1.18$_{ab}$	1.15$_{bc}$	17.54$_{c}$	16.96$_{d}$	2.56$_{ij}$	2.37$_{ij}$	6.62$_{ij}$	6.93$_{i}$
Boguru	9.13$_{i}$	8.46$_{l}$	1.05$_{ab}$	1.03$_{b}$	1.04$_{ab}$	1.02$_{a}$	17.31$_{b}$	16.63$_{c}$	2.62$_{jk}$	2.51$_{lm}$	6.29$_{abcd}$	6.65$_{abc}$
Fvanuveh	9.94$_{k}$	8.63$_{m}$	1.09$_{abc}$	1.04$_{b}$	1.06$_{ab}$	1.04$_{ab}$	19.11$_{i}$	17.23$_{e}$	2.49$_{hi}$	2.30$_{ghi}$	6.58$_{hij}$	6.90$_{hi}$

Table 4. Contd

Gberefun	9.09_{hi}	8.32_{k}	1.06_{ab}	1.03_{b}	1.02_{ab}	1.00_{a}	17.29_{b}	16.36_{b}	2.27_{abcd}	2.10_{abc}	6.53_{fghi}	6.61_{ab}
Gbetrome	8.77_{f}	7.61_{e}	1.04_{a}	1.01_{b}	1.01_{a}	1.00_{a}	19.36_{j}	17.62_{hi}	2.73_{jk}	2.59_{mn}	6.37_{bcde}	6.72_{def}
Ilaje	8.92_{fg}	7.68_{ef}	1.19_{cd}	1.15_{b}	1.11_{ab}	1.10_{abc}	19.18_{i}	18.23_{k}	2.64_{i}	2.52_{lm}	6.43_{defgh}	6.84_{ghi}
Kofegameh	9.11_{hi}	8.31_{jk}	1.16_{bcd}	1.11_{b}	1.13_{ab}	1.11_{abc}	18.24_{fg}	17.67_{i}	2.81_{l}	2.61_{n}	6.71_{j}	6.63_{abc}
Pako	8.98_{ghi}	8.95_{n}	1.10_{abc}	1.07_{b}	1.08_{ab}	1.06_{ab}	17.96_{d}	16.82_{c}	2.35_{cdef}	2.19_{cde}	6.24_{abc}	6.91_{i}
Afuye	7.99_{d}	7.73_{fg}	1.08_{abc}	1.06_{b}	1.02_{a}	1.01_{a}	17.28_{b}	16.58_{c}	2.32_{cde}	2.14_{bcd}	6.32_{abcde}	6.65_{abc}
BodinYawa	10.41_{l}	9.86_{o}	1.12_{abc}	1.08_{b}	1.05_{ab}	1.03_{ab}	16.43_{a}	15.49_{a}	2.47_{ghi}	2.34_{hij}	6.42_{defgh}	6.71_{bcde}
Idale	6.22_{a}	6.09_{a}	1.06_{ab}	1.02_{b}	1.01_{a}	1.01_{a}	17.91_{d}	16.68_{c}	2.38_{defg}	2.18_{cde}	6.21_{a}	6.64_{abc}
Igbodun	8.43_{e}	8.23_{ij}	1.13_{abc}	1.12_{b}	1.07_{ab}	1.04_{ab}	19.46_{j}	18.34_{k}	2.31_{bcde}	2.22_{def}	6.58_{hij}	6.77_{def}
Ilogun	9.61_{j}	8.47_{l}	1.08_{abc}	1.05_{b}	1.03_{ab}	1.01_{a}	18.21_{efg}	17.53_{gh}	2.17_{a}	2.0_{4a}	6.41_{defg}	6.93_{i}
Mejona	9.59_{j}	8.14_{h}	1.12_{abc}	1.10_{a}	1.08_{ab}	1.06_{ab}	19.06_{i}	18.12_{j}	2.20_{ab}	2.08_{ab}	6.22_{ab}	6.72_{bcde}
Oluwo	8.01_{d}	8.41_{l}	1.10_{abc}	1.05_{b}	1.23_{b}	1.21_{c}	18.19_{ef}	17.32_{f}	2.23_{abc}	2.05_{ab}	6.56_{ghij}	6.80_{efg}
Okorisan	7.69_{c}	7.32_{c}	1.02_{a}	1.00_{b}	1.14_{ab}	1.13_{abc}	18.09_{e}	17.46_{g}	2.42_{efgh}	2.24_{ef}	6.23_{abc}	6.68_{bcd}
Orita	6.66_{b}	7.12_{b}	1.08_{abc}	1.03_{b}	1.01_{a}	1.01_{a}	18.79_{h}	16.31_{b}	2.57_{ij}	2.41_{jk}	6.20_{a}	6.74_{cdef}
Orogoro	7.51_{c}	7.45_{d}	1.11_{abc}	1.10_{b}	1.06_{ab}	1.05_{ab}	19.14_{i}	18.83_{l}	2.35_{cdef}	2.26_{efg}	6.46_{efgh}	6.92_{i}

Local = Local drum kiln; Convect = Convective smoking kiln. Data are means of 3 replicates. Data with the same subscript are not significantly different at $p<0.05$.

standard for TVB-N which is 20 mgN/100 g for fresh fish. This suggests that the level of protein decomposition or breakdown in all the samples is low.

Trimethylamine (TMA) is a reduction product of trimethylamine oxide during spoilage and ammonia is mainly formed as a product of protein break-down. Trimethylamine (TMA) is one of the volatile amines plus ammonia which can be used as an index of spoilage (da Silva, 2002). In this study, the trimethylamine value (TMA) for fresh unsmoked bonga shad samples ranged from 1.93 –2.56 mgN/kg and 2.17 – 2.81mgN/kg and 2.05 – 2.61 mgN/kg for smoked bonga shad and control samples. The trimethylamine value (TMA) of 1.93 –2.56mgN/kg for fresh bonga shad samples and 2.17 – 2.81 mgN/kg and 2.05 – 2.61 mgN/kg for smoked bonga shad samples are within the range of < 3 mgN/100g for fresh fish, >8 mgN/100g for spoiled fish and ≥ 5 mgN/100g for doubtful quality specified U.S.F.D.A (da Silva, et al., 2008). pH is the most critical factors affecting microbial growth and spoilage of foods. The pH value of fresh unsmoked bonga shad samples ranged from 6.81 – 7.24 and pH value of smoked bonga shad samples ranged from 6.20 – 6.71 and 6.56 – 6.93. The pH values of the fresh bonga shad samples was high compared to smoked bonga and control samples; this may be due to biochemical reac-tions and enzyme action as a result of delay in reaching the shore from the sea because most of the fishermen had no cooling system in their boats or canoes. However, the pH in fish tissues drops due to smoking.

Conclusion

This research work revealed that in contrary to protein, fat, and ash, the moisture content of fresh bonga shad samples decreased sharply after the smoking process.

This decrease had been found to be due to loss of water during smoking. Protein content in smoked bonga shad fish and control samples has been found to increase due to an increase in the dry matter content per unit weight following sample dehydration during smoking compared to fresh samples this is important- as so many people in West Africa eat smoked dried fish and are involved in producing smoked dried fish- has a high protein content lends support to national strategies of fight against poverty, food shortage and malnutrition. There was an inverse relationship between the moisture and protein content in the smoked bonga shad fish. There were increases in mineral content, ash, crude fibre, TBA and pH values. Convective smoking kiln did not significantly affect pH and proximate composition of smoked fish. It, however, significantly

($p<0.05$) reduced the moisture content of smoked fish and the quality indices such as FFA, TBA and PV.

Conflict of interests

The authors did not declare any conflict of interest.

REFERENCES

Abolagba OJ, Melle OO (2008). Chemical composition and keeping qualities of a Scaly Fish Tilapia (*Oreochromis niloticus*) Smoked with two Energy Sources. Afr. J. Gen. Agric. KLOBEX 4(2):113-117.

Ahmed A, Dodo A, Bouba AM, Clement S, Dzudie T (2011) Influence of Traditional Drying and Smoke-Drying on the Quality of Three Fish Species (*Tilapia nilotica, Silurus glanis* and *Arius parkii*) from Lagdo Lake, Cameroon. J. Anim. Vet. Adv. 10(3):301-306.

AOAC International (2000). Official Methods of Analysis, 20th ed. AOAC International, Gaithersburg, MD.

Beltran A, Moral A (1991). Changes in fatty acid composition of fresh and frozen sardine (*Sardinella pilchardus*) during smoking. Food Chem. 42:99-109.

Béné C, Heck S (2005). Fish and food security in Africa. World Fish Centre 28(3/4):8.

Calhoun CM, Gaebler DM, Mandingo RW (1999) Storage stability of ground pork containing meat from an advanced meat recovery system. J. Food Sci. 64:69-75.

Crapo C (2011) Smoking Fish at Home. The University of Alaska, Fairbanks Cooperative Extension Service programs. pp.1- 4

da Silva LVA (2002). Hazard Analysis Critical Control Point (HACCP), Microbial Safety, and Shelf Life of Smoked Blue Catfish *(Ictalurus furcatus*). A Master of Science in Food Science Thesis, the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College.

da Silva LVA, Prinyawiwatkul W, King JM, No HK, Bankston JD Jr, Ge B (2008). Effect of preservatives on microbial safety and quality of smoked blue catfish (Ictalurus furcatus) steaks during room-temperature storage. Food Microbiol. 25(8):958-63.

Eyo AA (2001). Fish processing technology in the tropics. University of Ilorin press, Nigeria. 403pp. ISSN 978 1770457

Goktepe I, Moody MW (1998). Effect of modified atmosphere package on the quality of smoked catfish. J. Muscle Foods 9:375-389.

Ikutegbe V, Sikoki F (2014). Microbiological and biochemical spoilage of smoke-dried fishes sold in West African open markets. Food Chem. 161:332-336.

Mafimisebi T (2012). Comparative analysis of fresh and dried fish consumption in rural and urban households in Ondo State, Nigeria. In: Visible possibilities: The economics of sustainable fisheries, aquaculture and seafood trade: Proceedings of the sixteenth biennial conference of the international institute of fisheries economics and trade, July 16–20, Dar es Salaam, Tanzania. Tanzania Proceedings. International Institute of Fisheries Economics & Trade (IIFET), Corvalli.

Nwachukwu VN, Madubuko CU (2013). Microflora Associated With Processing and Storage of the White Catfish (*Chrysichthys nigrodigitatus*). J. Fish. Aquat. Sci. 8:108-114.

Omojowo FS, Raji, A (2010). Assessment of the use of sodium benzoate on the safety and shelf life of smoked tilapia. New York Sci. J. 3:6.

Swastawati F (2008). Quality and safety of smoked catfish (Aries talassinus) using paddy chaff and coconut shell liquid smoke. J. Coast. Dev. 12(1):47-55.