COMPARATIVE STUDY OF THE NUTRITIONAL COMPOSITION AND SENSORY ATTRIBUTES OF SMOKED-DRIED *Heterotis niloticus, Clarias gariepinus* AND *Oreochromis niloticus* FROM LAKE CHAD BASIN, NIGERIA

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ABSTRACT

The nutritional and organoleptic qualities of smoke-dried Heterotis niloticus, Clarias gariepinus and Oreochromis niloticus from Lake Chad basin were evaluated. Twenty fresh samples of each species were collected, pre-processed, and smoked following standard method. The analysis carried out include proximate, amino acid, fatty acid and sensory evaluation using standard procedures. Data obtained was subjected to Analysis of Variance (ANOVA). Results of proximate analysis show significant high crude protein in O. niloticus (67.67±2.10 %) and H. niloticus (67.89±1.64 %) compared to C. gariepinus (62.81±2.21 %). Clarias gariepinus had considerably high ash content (17.40±2.23 %), while crude fat (13.19±1.10 %) and carbohydrate (2.42±0.30 %) were notably high in O. niloticus. A total of eighteen amino acids (AAs) were observed in all the smoked fish samples at varying levels. Glutamic acid (7.20±0.05–9.77±0.06 g 100g^{-1}), aspartic acid (6.13±0.06–8.09±0.13 g 100g^{-1}), leucine (5.90±0.04–7.66±0.05 g 100g^{-1}), and phenylalanine (5.95±0.05–7.46±0.03 g 100g^{-1}) were the most prevalent amino acids in the three fishes. Nine fatty acids (FAs) with different saturation levels were identified in the fish samples and H. niloticus contained significantly higher unsaturated FAs (55.77±0.20 mg g^{-1}). The sensory taste score was significantly higher in C. gariepinus (4.68±0.63) and Oreochromis niloticus (4.54±0.52) than H. niloticus (3.69±1.03). The three smoked fish products especially H. niloticus and O. niloticus were found to be a good source of protein, amino acids, and Omega-6 fatty acid.

Keywords: Proximate, amino acids, Omega-6 fatty acid, sensory properties, freshwater fish, Lake Chad

INTRODUCTION

Fish and fishery products contribute significantly to food security, and provide valuable source of protein and essential micronutrients for balanced nutrition and good health. Fish have obviously become an invaluable dietary source of animal protein, especially among riparian households with low socioeconomic status because of its availability, palatability, and affordability. Fish is nutritionally beneficial to man due to its richness in omega-3-fatty acid and other essential nutrients. Ashraf *et al*. (2011) reported that fishes due to their low-fat content and high protein provide nutritional and therapeutic benefits for health problems of different kinds. Fish is globally consumed among different races, tribes, religion, gender, and ages. The growing knowledge about fish nutritional and therapeutic benefits has led to an increase in its consumption for healthy living (Orisasona *et al*., 2018).

In Nigeria, fisheries provide livelihood, income, and nutritious food for more than 50 million people (Akinrotimi *et al*., 2007). The nutritional content of fish puts it in a position to help fight hunger and malnutrition, as it is one of Africa's cheapest animal protein source. Bradley *et al*. (2020) noted that Nigeria ranks third globally among the countries that depend on coastal fisheries for food and nutrition security. The demand for fish is growing, alongside with growth in population. However, the confluence of aquatic biodiversity, nutrition insecurity and high fish dependence necessitates better understanding of the nutritional composition of species from diverse environments (Byrd *et al*., 2021). African bonytongue (*Heterotis niloticus*), African catfish (*Clarias gariepinus*), and Nile Tilapia (*Oreochromis niloticus*) are economically important inland water fish species that are popular among fish consumers in Nigeria. Commercial quantities of these freshwater fish species are usually sourced from Lake Chad basin and processed as smoked fish to the relish of people in urban and riparian communities. Large quantities of cartons of smoked fish leave the shore of Lake Chad through Doron-Baga fish market in Kukawa Local Government area of Borno State, Nigeria to Southern parts of Nigeria on a daily basis to satisfy consumers taste and want.

The fish value addition through smoking technique is a proven way to extend the shelf life of fish and add retail value for unique culinary experience of consumers. Smoked fish is the commonest and most popular food, both in open market and supermarkets across Nigeria and even in Europe where it has become a delicacy. Siddhnath *et al*. (2022) indicated that smoked fish is increasingly becoming a vital factor in providing high-quality proteins, healthy fats, and a unique source of essential nutrients such as iodine, zinc, copper, selenium, and calcium. However, the nutritional quality of fish differs based on species, age/size, season, geographical region, and value addition. In accord with Ahmed *et al*., (2022) the proximate content can be used to rank different fish species based on their nutritional and functional benefits, which will allow consumers to make better decisions according to their requirements. The analysis of biochemical composition of fish and fish products is crucial to ascertain their nutritional quality and palatability as emphasized by Olanrewaju (2022). According to Sabu and Sasidharan, (2020) the quality of fishery products combines the result of the physical, chemical, biochemical, organoleptic, and bacteriological characteristics of the product. Proximate composition as a basic indicator of fish quality usually involved percentage composition of basic constituents such as water, protein, lipids, carbohydrate, and ash (Olanrewaju and Ajani, 2019). The evaluation of nutritional content of freshly smoked freshwater fish could also provide essential guidance required for consumption and human health protection (Zhang *et al*. (2020). Thus, the knowledge of the biochemical and nutritional composition of smoked fish is important.

There have been studies on the quality and safety of fresh fish from Nigeria inland waters (Abolagba and Melle, 2008; Olagbemide, 2015; Ibrahim, 2017; Paul *et al*., 2021), however, there is little information available for value-added fish in the study area. Therefore, this study evaluates the proximate, amino acid profile, fatty acid compositions and organoleptic quality of three commercially important freshwater fish from Lake Chad Basin area of Nigeria.

MATERIALS AND METHODS

Study area

The Lake Chad is an extensive area of inland water found in the arid zone of West and Central Africa. It lies mainly in the Republic of Chad and partly in Nigeria, Cameroon, and Niger. Its basin covers an area of about 2,434,000 km^2 between latitudes 60° and 24° N and longitudes 80° and 24° E. The water depth of the lake is between 1.5 and 4m, while the altitude ranges between 275 to 284 m above sea level (Olowoyeye and Kanwar, 2023). This lake constitutes an important wetland ecosystem in West and Central Africa used mainly for fishing, agriculture, livestock, and domestic water use (Emeribe *et al*., 2020).

Collection, Identification and Processing of fish Samples

Samples of fish species for this study were randomly collected from artisanal fishers in Doron-Baga fish landing site, (Nigerian portion of Lake Chad in Borno State). The fish samples were transported to the Fish Processing Laboratory at the Federal College of Freshwater Fisheries Technology Baga, Maiduguri Borno State for smoking and further investigation. Twenty samples each of *Oreochromis niloticus* (450.66±174.70 g), *Heterotis niloticus* (1250.80±430.35 g) and *Clarias gariepinus* (800.80±83.35 g) were collected from fishermen's catch at their landing site in August 2023. In the Laboratory, fish were identified using standard key of Olaosebikan and Raji (2013). Specimens were sorted and prepared for smoking following the procedure of Ayeloja *et al*. (2020). Samples from the three fish species were folded into horse shoe shape on separate smoking trays, and smoked in NIOMR smoking kiln.

Proximate analysis

The smoked fish samples were finely grounded, homogenized and analyzed for proximate compositions as described by Association of Official Analytical Chemists (AOAC, 2000). The analysis was conducted in triplicates. The total protein content was estimated using the Kjeldahl method and crude fat content was determined using the Soxhlet method. The moisture content was determined by oven drying samples overnight at 105ºC until constant weight and the ash content was determined by incineration of the samples for 6h at 500ºC in a muffle furnace. The proximate analysis was conducted at the NAFDAC Zonal Office in Maiduguri, Borno State, Nigeria.

Amino and fatty acids analysis

Amino acid extraction from the fish samples was done using Baker and Han (1994) method. The fish samples were processed by removing their viscera, cooked, pressed and dried in an oven drier. The dried samples were grounded into powdered form and used for estimating the amino acids. The results were expressed as percentages of total amino acids in each species. The preparation of the fish samples for fatty acid was adapted from the method described by Bligh and Dyer (1959). Fatty acid compositions were determined by gas chromatography (GC) technique using fatty acid methyl esters (FAMEs) and identified by comparing their retention time with those of several commercial standard mixtures (Supelco, USA). The amino and fatty acids determination were carried out at the Biochemistry Laboratory, Yobe State University, Damaturu, Nigeria.

Organoleptic assessment

The three smoked fish species were taken for sensory evaluation after the fish were allowed to cool. Twelve untrained taste panellists comprise of 6 males and 6 females randomly drawn from Non-Academic staff of Federal College of Freshwater Fisheries Technology Baga, Borno State, Nigeria were used for sensory analysis of the fish. Appearance, odour, taste, texture, and overall acceptability were the sensory quality evaluated based on 5-point hedonic scale ranked as 5 (excellent), 4 (very good), 3 (good), 2 (fair), and 1 (poor).

Statistical analysis

Data analysis was done using SPSS 20.0 Statistical Software (SPSS Inc., Chicago, IL, USA). The data obtained were subjected to descriptive statistics and one-way analysis of variance (ANOVA), while differences in means between the samples were determined at 5% confidence level (α0.05) using Fisher's LSD. The results are presented as mean ± standard deviation.

RESULTS

Proximate composition

Proximate composition of the smoke-dried fish groups in the study is presented in Table 1. The result shows that the highest moisture content (14.40±1.60%) was observed in *Clarias gariepinus* while the lowest (10.71±1.01%) was found in *Oreochromis niloticus* (P<0.05). There was no significant difference (P>0.05) in moisture content of *O. niloticus* and *H. niloticus*. The crude fat of smoke-dried fish samples varied significantly. The African catfish had the lowest value of 4.20±0.30%, whereas the Tilapia fish had the highest value of 13.19±1.10%. The protein contents of the African bonytongue (67.89±1.64%) and Nile tilapia (67.67±2.10%) samples were significantly higher (P<0.05) than that of the African catfish sample (62.81±2.21%). The percentage carbohydrate varied significantly (P<0.05) with the highest value (2.42±0.30%) recorded in Tilapia while the least value (1.19±0.14 %) was recorded in Catfish. However, the Catfish sample has the highest ash content value (17.40±2.23 %), which was significantly different (P<0.05) from the value for the Bonytongue (6.89±0.36 %) and Tilapia (2.42±0.30 %) samples.

Amino acid and Fatty Acid Profile

In all the investigated smoke-dried fish groups, 18 amino acids were profiled in varying quantities (Table 2). The result shows that smoke-dried African bonytongue was significantly higher (p<0.05) in essential amino acid than in tilapia and catfish. However, the mean phenylalanine content found in smoke-dried tilapia (7.46±0.03 g $100g^{-1}$) was markedly higher than values from other fish groups. Also, there was no significant difference (p>0.05) in threonine levels between tilapia and bonytongue. For non-essential amino acids, significant high arginine (5.50±0.05 g $100g^{-1}$) and glycine (4.19±0.04 g $100g^{-1}$) values were recorded in Bonytongue, while Catfish was superior in cysteine (6.59±0.04 g $100g^{-1}$), serine (5.34±0.06 g $100g^{-1}$) and glutamic acid (9.77±0.06 g $100g^{-1}$). The alanine (7.21±0.04 g $100g^{-1}$) and aspartic acid (8.09±0.13 g $100g^{-1}$) values were however highest (p<0.05) in Tilapia. The tyrosine percentages were highest and statistically similar in bonytongue and tilapia, while proline levels were not significantly different in catfish and bonytongue. Further, the results in table 2 show no significant difference in histidine, arginine and glycine levels between smoke-dried tilapia and catfish.

The result of fatty acid analysis of freshly smoked tilapia, bonytongue and catfish in this study is as shown in Table 3. Significant variations (P< 0.05) exist between the smoke-dried fish groups used in the study with respect to fatty acid analysis. The smoke-dried tilapia possesses significant high palmitic acid (12.14±0.06 mg g^{-1}), stearic acid (14.23±0.04 mg g^{-1}), and oleic acid (14.71±0.04 mg g^{-1}) compared to smoke-dried bonytongue and catfish. Capric acid (5.06±0.05 mg g^{-1}) and linoleic acid (28.92±0.11 mg g^{-1}) of smoke-dried bonytongue was comparatively higher than in other fish groups, whereas arachidic acid value (6.34±0.10 mg g^{-1}) was highest in catfish (P<0.05).

Table 1. Proximate composition of three freshly smoke-dried freshwater fish samples

Proximate composition (%)	Smoked fish samples		
	O. niloticus	*H. niloticus*	*C. gariepinus*
Moisture	10.71±1.01^{b}	12.19±0.23^{b}	14.40±1.60^{a}
Crude fat	13.19±1.10^{a}	10.83±0.81^{b}	4.20±0.30^{c}
Crude protein	67.67±2.10^{a}	67.89±1.64^{a}	62.81±2.21^{b}
Carbohydrate	2.42±0.30^{a}	1.99±0.90^{ab}	1.19±0.14^{b}
Ash	6.00±1.20^{b}	6.89±0.36^{b}	17.40±2.23^{a}

Values are Mean±SD (Standard deviation) of triplicate samples. Mean values in the same row with different superscripts are significantly different (p<0.05)

Table 2. Amino acid profile of freshly smoke-dried freshwater fish samples

Amino acid (g $100g^{-1}$)	*Oreochromis niloticus*	*Heterotis niloticus*	*Clarias gariepinus*
EAA			
Lysine	$4.24{\pm}0.03^{b}$	$4.68{\pm}0.27^{a}$	$3.65{\pm}0.36^{c}$
Methionine	$3.66{\pm}0.04^{c}$	$4.66{\pm}0.03^{a}$	$4.02{\pm}0.06^{b}$
Threonine	$4.56{\pm}0.03^{a}$	$4.77{\pm}0.02^{a}$	$4.01{\pm}0.08^{b}$
Isoleucine	$4.23{\pm}0.05^{c}$	$5.22{\pm}0.04^{a}$	$4.95{\pm}0.03^{b}$
Leucine	$7.66{\pm}0.05^{a}$	$5.90{\pm}0.04^{b}$	$7.06{\pm}0.06^{a}$
Phenylalanine	$7.46{\pm}0.03^{a}$	$5.95{\pm}0.05^{c}$	$6.67{\pm}0.04^{b}$
Valine	$6.33{\pm}0.06^{c}$	$7.38{\pm}0.09^{a}$	$6.74{\pm}0.05^{b}$
Tryptophan	$4.83{\pm}0.05^{b}$	$5.90{\pm}0.05^{a}$	$5.53{\pm}0.04^{a}$
Histidine	$4.91{\pm}0.05^{b}$	$5.90{\pm}0.04^{a}$	$4.92{\pm}0.04^{b}$
NEAA			
Arginine	$4.92{\pm}0.03^{b}$	$5.50{\pm}0.05^{a}$	$4.94{\pm}0.06^{b}$
Cysteine	$5.87{\pm}0.08^{c}$	$6.05{\pm}0.03^{b}$	$6.59{\pm}0.04^{a}$
Serine	$4.36{\pm}0.03^{b}$	$4.18{\pm}0.06^{b}$	$5.34{\pm}0.06^{a}$
Tyrosine	$7.21{\pm}0.09^{a}$	$7.26{\pm}0.08^{a}$	$6.69{\pm}0.19^{b}$
Alanine	$7.21{\pm}0.04^{a}$	$5.93{\pm}0.04^{b}$	$5.71{\pm}0.12^{b}$
Aspartic acid	$8.09{\pm}0.13^{a}$	$6.13{\pm}0.06^{c}$	$6.59{\pm}0.05^{b}$
Glutamic acid	$8.63{\pm}0.04^{b}$	$7.20{\pm}0.05^{c}$	$9.77{\pm}0.06^{a}$
Glycine	$3.10{\pm}0.08^{b}$	$4.19{\pm}0.04^{a}$	$3.48{\pm}0.05^{b}$
Proline	$2.63{\pm}0.08^{b}$	$3.14{\pm}0.11^{a}$	$3.36{\pm}0.05^{a}$

Values are Mean±SD (Standard deviation) of triplicate samples. Mean values in the same row with different superscripts are significantly different ($p<0.05$)

As shown in Table 3, the myristic acid and linoleic acid of smoke-dried tilapia and catfish were significantly indifferent but varied markedly with smoke-dried *H. niloticus*. Whereas there was no significant difference ($p>0.05$) in lauric acid levels of all smoke-dried fish group. Statistically, no significant difference exists in capric acid values between tilapia and catfish, while palmitic contents were also similar ($p>0.05$) in *C. gariepinus* and *H. niloticus*.

Results in Table 4 show that, the mean values of appearance, odour, texture, and overall acceptability have nosignificant differences ($p>0.05$) between the smoke-dried fish groups. However, the appearance, odour, texture, and overall acceptability of smoke-dried *H. niloticus* was slightly lower than that of catfish and tilapia (Table 4). The highest score in taste was recorded in smoke-dried *C. gariepinus* (4.68±0.63) and *O. niloticus* (4.54±0.52) having significant difference from *H. niloticus* (3.69±1.03).

Table 3. Fatty acid content of freshly smoked tilapia, bonytongue and catfish

Fatty acids (mg g^{-1})	*O. niloticus*	*H. niloticus*	*C. gariepinus*
Capric acid, C10:0	$4.32{\pm}0.03^{b}$	$5.06{\pm}0.05^{a}$	$4.32{\pm}0.06^{b}$
Lauric acid, C12:0	$4.41{\pm}0.05^{a}$	$4.18{\pm}0.04^{a}$	$4.37{\pm}0.02^{a}$
Myristic acid, C14:0	$3.72{\pm}0.03^{a}$	$3.46{\pm}0.10^{b}$	$3.65{\pm}0.04^{a}$
Palmitic acid, C16:0	$12.14{\pm}0.06^{a}$	$11.48{\pm}0.05^{b}$	$11.67{\pm}0.04^{b}$
Stearic acid, C18:0	$14.23{\pm}0.04^{a}$	$13.38{\pm}0.03^{c}$	$13.83{\pm}0.03^{b}$
Oleic acid, C18:1	$14.71{\pm}0.04^{a}$	$14.08{\pm}0.04^{b}$	$13.51{\pm}0.04^{c}$
Linoleic acid, C18:2	$25.22{\pm}0.04^{c}$	$28.92{\pm}0.11^{a}$	$26.59{\pm}0.06^{b}$
Linolenic acid, C18:3	$13.58{\pm}0.03^{a}$	$12.77{\pm}0.02^{b}$	$13.67{\pm}0.01^{a}$
Arachidic acid, C20:0	$5.62{\pm}0.11^{b}$	$4.64{\pm}0.09^{c}$	$6.34{\pm}0.10^{a}$
ΣTFC	97.95±0.39	97.97±0.53	97.95±0.40
ΣSFA	44.44±0.31	42.20±0.36	44.18±0.29
ΣUFA	53.41±0.09	55.77±0.20	53.77±0.14
ΣMUFA	14.71±0.04	14.08±0.04	13.51±0.04
ΣPUFA	38.70±0.07	41.69±0.13	40.26±0.07

TFC Total fatty acid composition, SFA Saturated fatty acid, MUFA Monounsaturated fatty acid, Polyunsaturated fatty acid, Values are Mean±SD (Standard deviation) of triplicate samples. Mean values in the same row with different superscripts are significantly different ($p<0.05$).

Table 4. Sensory attributes of freshly smoked *O. niloticus*, *H. niloticus* and *C. gariepinus*

Sensory attributes	*O. niloticus*	*H. niloticus*	*C. gariepinus*
Appearance	$4.39{\pm}0.51_a$	$4.23{\pm}0.93_a$	$4.39{\pm}0.77_a$
Odour	$4.23{\pm}0.73_a$	$4.00{\pm}1.08_a$	$4.31{\pm}0.63_a$
Texture	$4.46{\pm}0.52_a$	$3.92{\pm}0.95_a$	$4.31{\pm}0.24_a$
Taste	$4.54{\pm}0.52_a$	$3.69{\pm}1.03_b$	$4.68{\pm}0.63_a$
OA	$4.15{\pm}0.80_a$	$3.92{\pm}0.86_a$	$4.15{\pm}0.56_a$

OA Overall acceptability. Values are Mean±SD (Standard deviation) of triplicate samples. Mean values in the same row with different superscripts are significantly different ($p<0.05$)

DISCUSSION

In the present study, the results from the proximate assessments confirmed the report of Petricorena (2014) that aquatic organisms are low-fat and protein-rich food. The crude fat content recorded in this study ranged from 4.20±0.30 to 13.19±1.10 % while the crude protein was in the range of 62.81±2.21 to 67.89±1.64 %. These results follow similar trends in crude fat (6.96±0.60 – 7.60±0.60 %) and crude protein (48.53±0.04 – 52.13±0.03 %) contents reported in smoke-dried *Clarias gariepinus*, *Oreochromis niloticus* and *Mormyrus rume* by Oyeleye (2020). Daramola *et al*. (2007) however observed higher range of 11.32 – 20.24 % (Crude fat) and 56.82 – 72.78 % (Crude protein) in smoke-dried *Clarias gariepinus*, *Oreochromis niloticus* and *Heterotis niloticus* when compared to present result. The disparity in our findings with other results could be due to various factors, including differences in fishing ground, seasons, fish size, age, sex, and type of feed as identified by Rasul *et al*. (2021).

According to the present results, the smoked *C. gariepinus* contained significantly high amount of crude ash compared to *O. niloticus* and *H. niloticus*, which is consistent with the results obtained by Oyeleye (2020) for freshly smoke-dried *C. gariepinus*, *O. niloticus* and *M. rume.* Daramola *et al*. (2007) however, reported higher ash content in smoke-dried *O. niloticus* than *C. gariepinus* and *H. niloticus*. The crude protein level in smoke-dried *O. niloticus* and *H. niloticus* in the current research was significantly higher than *C. gariepinus.* This observation aligns with the work of Daramola *et al*. (2007) who studied changes in physicochemical and sensory characteristics of smoke-dried fish stored at ambient temperature. These authors found that the crude protein level was highest in smoke-dried *O. niloticus* and *H. niloticus*. Meanwhile, Zenebe *et al*. (1998) considered the variations in fish proximate composition to be differences in environment from which fish were caught and body structure of fish families. African catfish have a cylindrical body with a flattened ventral to allow for benthic feeding, while Nile tilapia has a deep-bodied, compressed shape for surface feeding. On other hand, African bonytongue have an elongated, laterally compressed species for bottom and column feeding (Olanrewaju *et al*., 2017). Since, smoke enhances flavour and increases protein value of the fish (Kumolu–Johnson and Ndimele, 2011), the total protein level in this study (62.81±2.21 – 67.89±1.64 %), implies that these fish products are of good nutritional quality (WHO, 2007). Akhter *et al*., (2009) noted that the protein increase is due to the rapid loss in moisture content at higher temperatures which concentrates proteins and other proximate composition parameters. Also going by these results, the protein content in the scaly fishes (*O. niloticus* and *H. niloticus*) was comparatively better than the scaleless fish (*C. gariepinus*). This could mean that the two scaly fishes in the study have better nutrient composition due to their opportunistic feeding habits, which make food available to them all the time.

The result of the amino acids (AAs) profile (18 amino acids) of the three freshwater fish species used in the current study were within the range observed by Ayeloja *et al*. (2020) in smoked *O. niloticus*. These authors however recorded 10 essential AAs (EAA) and 8 non-essential AAs (NEAA) as against nine EAA and nine NEAA in this study. This result is also similar with the study done by Mohammed and Alim (2012) where total number of AAs detected in dried muscle of the four freshwater fishes was eighteen, with EAA and NEAA having nine components each. Also, the variations in the AAs content between the study fishes may not be unconnected to differences in their body structures and their families as pointed out by Mohammed and Alim (2012). The smoke-dried bonytongue in this study contained significantly higher percentages of AAs, followed by tilapia. The feeding habits classification of *H. niloticus* as planktivore and omnivore fish might contribute to its high nutritive materials leading to high AAs percentages. Whereas *O. niloticus* is herbivore and show better AAs composition than *C. gariepinus* in the study. Ghaseem *et al*., (2009) however reported superior AAs properties in fresh *O. niloticus* when compared with *C. batrachus*, *Channa striatus* and *Pangasius sutchi* in Malaysia. Proline is the least AAs while glutamic acid, leucine and aspartic acid are the major AAs in the investigated fish, which indicates that they are rich in AAs and good for human consumption. In contrast, Ayeloja *et al*.

(2020) found glutamic acid (12.64±2.99 %), Lysine (9.18±0.08 %) and Aspartic acid (8.75±0.26 %) as the most abundant amino acids in smoked *O. niloticus*.

In the current study, nine types of fatty acids (FAs) with different saturation levels were found in the three smoked freshwater fish species. These results are however different from those obtained by Salaudeen *et al*. (2018) who recorded 29 FAs for smoked *C. gariepinus* in Lagos. Though, these authors obtained their fish sample from aquaculture facility unlike wild source samples in this study. The dominance of the identified FAs in all smoked fish groups is in the order of SFA>PUFA>MUFA, which contradicts the sequence (MUFA>SFA>PUFA) observed by Salaudeen *et al*. (2018) in freshly smoked *C. gariepinus*. This study also indicate that Linoleic acid (Omega-6) was the most dominant fatty acid in all the smoked fish group (ranged between 26.59±0.06–28.92±0.11 mg g^{-1}) followed by Oleic acid (13.51±0.04–14.71±0.04 mg g^{-1}), Stearic acid (13.38±0.03–14.23±0.04 mg g^{-1}) while Myristic acid composition was least (3.46±0.10–3.72±0.03 mg g^{-1}). Salaudeen *et al*. (2018) however observed the major FAs in freshly smoked *C. gariepinus* as Palmitic acids, Stearic acids, Oleic acids, Linoleic acids, Arachidic acids and Behenoic acids, respectively. The differences in fatty acids of fish and their products could likely be due to variations in their environment, richness in terms of food availability, maturity, body structures and families. Although, FAO (2010) generally reported palmitic acids as the main fatty acid present in products of animal and vegetal origins. The significantly higher values of stearic acids, oleic acids, myristic acids, and linolenic acids in *O. niloticus* compared to the other two smoked fish species indicated that this species may probably be very good for human diet and it may be related to its opportunistic feeding habits.

There were no significant differences in appearance, odour, texture, and overall acceptability, this implies that they all have good organoleptic quality that can attract consumer to eat as postulated by Adebowale *et al*. (2008). However, the smoke-dried catfish and tilapia had significant high performance in taste as compared to smoke-dried bonytongue. This is an indication that smoke-dried catfish and tilapia had better acceptance in terms of taste, which makes them the consumers' choice at all times. The lower taste ranking in Bonytongue in this study coincided with the assertion of Ekanem *et al*. (2020), that the greatest setback of *H. niloticus* to the consumers demand has been the poor taste despite its excellent meat quality. Although the problem has been resolved through improved fish techniques and value addition (Amuneke *et al*., 2020) using different spices such as ginger, garlic, nutmeg, mustard, cinnamon etc.

CONCLUSION

The three smoked fish products especially *O. niloticus* and *H. niloticus* from the study area were found to be a good source of protein, amino acids, and fatty acids. All the examined fish species shows good sensory quality but *H. niloticus* ranked less in taste acceptability. However, this study showed smoke-dried *H. niloticus* as the best product for healthy diet due to its relatively high essential amino acids and unsaturated fatty acid.

AUTHOR CONTRIBUTION

OAN and KG design the study, interpreted the data and wrote the draft of the manuscript; OKK and MOA contributed to original draft, review and editng of the manuscript, ATS and AA collated, and analysed the data. All authors approved the manuscript for submission.

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