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Research Article

Comparative Evaluation of Proximate and Microbial Composition of Smoked Dried Fishes Sold in Oil Mill and Eleme-Ncha Markets, Port Harcourt, Nigeria

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ABSTRACT
Evaluation of proximate and microbial composition of smoked fishes, Catfish (*Clarias gariepinus*) and Bonga fish *Ethmalosa fimbriata*) sold in Oil Mill and Eleme-Nchia markets, Port Harcourt were studied. Two replicates of the sample, *C. gariepinus* and *Ethmalosa fimbriata* were randomly obtained from the retailers in the selected markets and transported to the laboratory for analysis. Proximate and microbiological analysis were carried out following standard methods. Results showed that moisture content (MC) of *Ethmalosa fimbriata* and *Clarias gariepinus* in Oil Mill market ranged from 31.40-34.20% and 32.50-36.50% while that of Eleme-Nchia market ranged from 32.40-34.20% and 35.20-36.50% respectively. pH values varied from 6.10-6.50 and 6.30-6.65% for *E. fimbriata* and *C. gariepinus* respectively in Oil Mill market while that of Eleme-Nchia market varied from 6.25-6.52 and 6.40-6.50 without significant difference between the mean ash, crude fibre and carbohydrate contents unlike those of their fat and crude protein contents. The mean value of THB load in ***C. gariepinus*** (2466.67±57.74cfu/g) significantly differed from that of *E. fimbriata* (1950.00±304.14 cfu/g) in both markets. The mean value of **bacteria** varied in the order, THB>TCB>Salmonella. The mean fungal load on both fishes was higher in Eleme-Nchia than Oil Mil market. Fourteen bacteria and seven fungi some of which included *Enterobacter spp, Klebsellas spp, Bacillus spp, Staphyloccocus spp, Aspergillus niger, Rhizopus oligosora* etc were observed. The fishes in Eleme-Nchia market were nutritionally richer and microbially higher than those from the Oil Mill market. There should be proper monitoring of the handling processes and the processing techniques used.

Keywords: *Clarias gariepinus;* Eleme-Nchia market; *Ethmalosa finmbriata;* Microbial properties; Oil Mill market; Proximate composition; Smoked dried fish

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INTRODUCTION

Fish provides high-quality protein, essential fatty acids, vitamins, and minerals, making it crucial for nutrition in developing countries like Nigeria (Ogunbanwo and Olawale, 2017). Smoking is a common preservation method due to its low cost, moisture reduction, and flavor enhancement (Eguavoen and Omoregie, 2019). In Port Harcourt, Rivers State, smoked dried fish is widely sold in markets such as Oil Mill and Eleme-Nchia, often under poor sanitary conditions. Oil Mill and Eleme-Ncha are among the busiest fish markets in Port Harcourt. Comparing fish samples from these markets provides insights into differences in processing, storage and microbial loads, which can guide interventions for safer fish marketing

Smoked fish, though nutritious, is prone to microbial contamination during processing and storage.

Nigerian market samples often contain high microbial loads, including coliforms and aerobic bacteria, posing health risks if unmanaged (Akinwumi and Adegbehingbe, 2015). Its microbial quality depends on hygiene, environmental exposure, and the wood used for smoking. In addition to microbial safety, the proximate composition of smoked fish comprising moisture, protein, fat, ash, and carbohydrate content is crucial for assessing its nutritional value. Variations in drying techniques and market conditions can significantly affect these parameters. For instance, a study on *Scomber scumbrus* in Port Harcourt revealed that different drying methods led to notable differences in moisture and nutrient retention (Johnson *et al*.,2025).

Only nutritionally safe food can ensure a healthy balanced diet to consumers. Dried fish is a popular processed fishery product not only in our country, but also in many countries of the world. It is a very good source of dietary protein, lipid and minerals necessary for a healthy body. The consumers of dried fish at a national and international level are losing interest in buying dried fish due to poor quality and safety of the products.

Previous studies have shown that smoked catfish generally contains higher protein and fat levels compared to Bonga fish, which tends to have lower moisture content due to its thinner flesh structure (Ubaka *et al.,*2019). Microbial assessments have also revealed the presence of pathogenic organisms such as *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella spp.*, particularly in samples exposed to poor handling and storage practices. These findings underscore the need for continuous monitoring of smoked fish quality in local markets to safeguard public health. Kwaghvihi *et al.* (2025) studied smoked catfish in Benue State and found contamination with *Salmonella* and *E. coli*, stressing the need for improved hygiene

Smoked catfish typically has higher protein and fat than Bonga fish, which contains less moisture due to thinner flesh (Ubaka *et al.,* 2019). Microbial studies have identified pathogens such as *E. coli*, *Staphylococcus aureus*, and *Salmonella spp.*, especially in poorly handled or stored samples. To address these risks, this study compares the proximate and microbial composition of smoked fish from Oil Mill and Eleme-Nchia markets, aiming to reveal differences in nutritional quality and safety to guide public health and food safety improvements.

MATERIALS AND METHODS

Study Area

This study was carried out in the two major markets, in Rivers State with the Oil Mill market located in Rumukwurusi community in the Obio/Akpor Local Government Area while Eleme-Nchia is located in Eleme Local Government Area where fish is sold in large quantity to consumers.

Sample Collection

The study took place for three months between June and August 2025. The population comprised smoked fish samples sold by different vendors in both Eleme-Nchia and Oil-Mill markets. The study focused on the most smoked species identified in the markets, particularly catfish (*Clarias gariepinus)* and Bonga fish *(Ethmalosa fimbriata)* which are frequently consumed by the local population. These samples were transported to the Food Science and Technology laboratory at Rivers State University, Port Harcourt (RSU) for microbial and proximate analysis. These samples were classified into two experimental groups and stored at 20^0C before analysis was done. Prior to the bio-chemical analysis, the fish samples were thoroughly washed with running water to remove extraneous materials from the body surface after which the fishes were carefully dissected with a sterilized blade with the proximal profiled values well tabulated.

Proximate and mineral analysis

Proximate composition was determined according to the method of Association of Official Analytical Chemists (AOAC,1998) which includes determination of moisture content, pH, ash content, fat, crude fibre, crude protein, and carbohydrates.

Microbiological Analysis

Upon arrival at the laboratory, the fish samples were processed for microbiological examination. The skin, gills, and intestinal contents of the fish were aseptically homogenized, and serial dilutions were prepared using sterile saline solution (0.85% NaCl) (ICMSF,1998).

Preparation of Culture Media

For the isolation and identification of pathogenic bacteria, the fish samples were inoculated onto selective media, including Salmonella-Shigella (SS) Agar for the isolation of *Salmonella* and *Shigella*

species (Obemeata *et al*.,2011), Mannitol Salt Agar (MSA) for the isolation of *Staphylococcus species* (Huss,1997) and Eosin Methylene Blue (EMB) Agar for the isolation of *Escherichia coli* (Scallan *et al*.,2011). The inoculated plates were incubated at 37°C for 24-48 hours. Presumptive colonies were further identified using standard biochemical and morphological tests, such as Gram staining, catalase, oxidase, and API identification systems (Omeize *et al*., 2011, Olaleye and Abegunde, 2015). All were prepared according to the manufacturer's instruction

Enumeration of Total Viable Bacterial and Fungal Count

Two grams (2 g) of each smoked fish was weighed using a sterile filter paper on a weighing balance. A five-fold serial dilution was made. That is, for each fish sample, five test tubes were used for the serial dilution. The test tubes were filled with 9 ml of distilled water. 1g of these samples were transferred into the assigned test-tube (making it 10 ml) and thoroughly mixed. Further sequential dilutions were made by taking 1 ml of 10 ml mixture to other test-tubes using a sterile pipette. The viable heterotrophic bacterial and fungal counts were done using pour plate method on nutrient agar (NA) and potato dextrose agar (PDA) media respectively. The agar plates were incubated at 37 °C for 24-48 h, while the agar plates for fungi (that is, containing potato dextrose agar) were incubated inverted for 3-5 days (ICMSF, 1998; Odu and Imaku, 2013; Abolagba and Igbinevbo, 2014; Dike-Ndudim *et al*., 2014).

Data Analysis

Data recorded during the study period were summarized. Descriptive and inferential statistics were used where applicable for detection of significant differences among sample values. Statistical analyses were carried out using SPSS Version 25.0. The level of statistical significance was set at $p < 0.05$ (Nyarku *et al*., 2011).

RESULTS

Proximate Composition

Table 1 and 2 showed the proximate compositions of smoked dried fishes from the Oil Mill and Eleme-Ncha markets. The moisture content (MC) of *Ethmalosa fimbriata* and *Clarias gariepinus* in Oil Mill market ranged from 31.40-34.20% and 32.50-36.50% while that of Eleme-Ncha market ranged from 32.40-34.20% and 35.20-36.50% with the mean values which differed significantly at $P<0.05$. pH values varied from 6.10-6.50 and 6.30-6.65% respectively in the Oil Mill market while that of Eleme-Ncha market varied from 6.25-6.52 and 6.40-6.50 respectively without significant difference in mean values at $P<0.05$ between the fishes in both markets. There was no significant difference between the mean ash, crude fibre and carbohydrate contents unlike those of the fat and crude protein contents which varied significantly between the fishes in both markets.

Table 1: Proximate Composition of Smoked Dried Fishes in Oil Mill Market

Fishes	MC	pH	Ash	Fat	CF	CP	CH
A	31.24±0.24^{b}	6.28±0.18^{a}	2.46±0.05^{a}	1.36±0.02^{b}	2.44±0.01^{a}	16.77±0.46^{b}	1.37±0.16^{a}
Range	31.40-34.20	6.10-6.50	2.30-2.50	1.25-1.45	2.35-2.50	16.00-17.50	1.20-1.55
B	33.00±0.71^{a}	6.35±0.07^{a}	2.47±0.17^{a}	1.45±0.00^{a}	2.50±2.50^{a}	18.50±0.01^{a}	1.35±0.07^{a}
Range	32.50-36.50	6.30-6.65	2.35-2.60	1.45-1.60	2.40-2.61	16.50-18.50	1.25-1.50

A= *Ethmalosa fimbriata***, B=*Clarias gariepinus*, Different superscripts across the same column shows significant difference**

Table 2: Proximate Composition of Smoked Dried Fishes in Eleme-Ncha Market

Fishes	MC	pH	Ash	Fat	CF	CP	CH
A	33.30±1.90^{b}	6.36±0.14^{a}	2.32±0.03^{a}	1.37±0.10^{b}	2.43±0.08^{a}	16.68±0.76^{b}	1.30±0.13^{a}
Range	32.40-34.20	6.25-6.52	2.30-2.35	1.25-1.45	2.35-2.50	16.00-17.50	1.20-1.45
B	35.73±1.68^{a}	6.52±0.13^{a}	2.48±0.06^{a}	1.53±0.06^{a}	2.51±0.08^{a}	17.50±1.00^{a}	1.35±0.13^{a}
Range	35.20-36.50	6.40-6.65	2.45-2.55	1.50-1.60	2.40-2.61	16-50-18.50	1.25-1.50

A= A= *Ethmalosa fimbriata*, B=*Clarias gariepinus*, Different superscripts across the same column shows significant difference

Microbiological Composition

Table 3 shows the microbial status of the fishes in Oil Mill and Eleme-Ncha markets. The microbial load of the fishes in the two markets varied in the same trend. The mean value of THB in ***C. gariepinus*** (2466.67±57.74cfu/g) significantly differed from that of *E. fimbriata* (1950.00±304.14 cfu/g) in Eleme-Ncha market just like that of Oil Mill market. The microbial load of both fishes in Eleme-Ncha markets were higher than those of the Oil Mill market. TCB load of *C. gariepinus* (2600.00±500.00CFU/g) was also significantly higher than that of *E. fimbriata* (1933.33±378.59cfu/g) in Eleme-Ncha market just like those of the Oil Mill market with the mean values, 1650.00±28.99cfu/g and 1283.33±332.92cfu/g for *C. gariepinus and E. fimbriata respectively.* The mean value of salmonella species also varied significantly in similar pattern but recorded the lowest value among the observed groups of bacteria in the order, THB>TCB>Salmonella.

The observed mean fungal load was highest on both fishes in both markets and also higher in the Eleme-Ncha market (4103.33±1273.59cfu/g and 4243.33±903.12cfu/g) than the Oil Mill market (2925.00±459.62 cfu/g and 2541.67±394.7cfu/g) for *C. gariepinus* and *E. fimbriata* respectively. Generally, fishes in Eleme-Ncha market recorded higher microbial load than those of the Oil Mill market.

Table 3: Mean Microbial Loads(cfu/g) of Smoked Dried Fishes Sold in Oil Mill and Eleme-Ncha Markets

S/N	Eleme-Ncha			Oil Mill			NESREA (2011
	Microbe	***C. gariepinus***	***E. fimbriata***	***C. gariepinus***	***E. fimbriata***	**WHO (2012)**	
1	THB	2466.67±57.74^{a}	1950.00±304.14^{b}	1650.00±353.55^{a}	1150±180.27^{b}	≤1000	≤1000cfu/g
2	TCB	2600.00±500.00^{a}	1933.33±378.59^{b}	1650.00±28.99^{a}	1283.33±332.92^{b}	ABS/100g	ABS/100g
3	*Salmonella*	490.00±101.49^{a}	330.00±36.06^{b}	330.50±139.44^{a}	188.067±161.28^{b}	ABS/100g	ABS/100g
4	Fungi	4103.33±1273.59^{a}	4243.33±903.12^{a}	2925.00±459.62^{a}	2541.67±394.73^{b}	≤100cfu/g	ABS/100g

Key: THB=Total hetetrotrophic bacteria, TCB=Total coliform bacteria, WHO=World Health Organisation, NESREA= National Environmental Standards and Regulations Enforcement Agency. Means with similar superscripts along the same row are not different significantly at P<0.05

Table 4-5 showed the biochemical test of bacteria, macroscopic and microscopic characteristics of fungal isolates in smoked fishes from the two markets. The result showed that fourteen bacteria and seven fungi some of which included *streptococcus spp, Pseudomonas spp, Enterobacter spp, Klebsiellas spp, Bacillus spp, Staphyloccocus spp, Aspergillus niger, Rhizopus oligosora, Mucor spp* etc were present on the fishes in the markets.

Table 6 showed that more bacteria and fungi were observed on fishes in Eleme-Ncha market than the Oil Mill market. It also showed the species of bacteria and fungi found on fishes in both markets.

Table 4: Biochemical test of Bacteria Isolates in Smoked Dried Fishes Sold in Oil Mill and Eleme-Ncha Markets

SN	A	B	C	D	E	F	G	H	I	J	K	Suspected Bacteria
1	Cocci	-ve	-ve	-ve	-ve	+ve	+ve	-ve	+ve	-ve	-ve	*Streptococcus spp*
2	Rods	+ve	+ve	+ve	-ve	-ve	+ve	-ve	-ve	-ve	-ve	*Pseudomonas spp*
3	Rods	+ve	-ve	+ve	-ve	+ve	+ve	+ve	+ve	+ve	-ve	*Enterobacter spp*
4	Rods	+ve	-ve	+ve	+ve	+ve	-ve	+ve	+ve	+ve	-ve	*Klebsiella spp*
5	Rods	+ve	Variable	+ve	Variable	+ve	+ve	+ve	+ve	+ve	-ve	*Bacillus spp*
6	Cocci	+ve	-ve	+ve	+ve	+ve	-ve	+ve	+ve	+ve	-ve	*Staphylococcus spp*
7	Rods	+ve	-ve	+ve	-ve	+ve	+ve	Variable	+ve	+ve	-ve	*Bacillus cereus*
8	Rods	+ve	Variable	+ve	Variable	+ve	+ve	+ve	+ve	+ve	-ve	*Bacillus subtilis*
9	Rods	+ve	-ve	-ve	-ve	+ve	+ve	-ve	+ve	-ve	-ve	*Salmonella typhi*
10	Rods	+ve	+ve	+ve	Variable	+ve	+ve	+ve	+ve	Variable	+ve	*Vibrio cholera*
11	Cocci	+ve	+ve	-ve	-ve	+ve	-ve	-ve	+ve	-ve	-ve	*Micrococcus luteus*
12	Rods	+ve	+ve	+ve	Variable	+ve	+ve	+ve	+ve	+ve	+ve	*Aeromonas spp*
13	Rods	+ve	-ve	-ve	+ve	+ve	+ve	+ve	+ve	-ve	+ve	*Escherichia coli*

Key: A=Cell morphology, B=catalase, C=oxidase,D=Citrate, E=Lactose, F=fructose, G= motility, H=sucrose, I=glucose, J=voges proskaul test, K=Indole, +ve=positive, -ve=negative

Table 5: Macroscopic and Microscopic Characteristics of Fungi Isolates in the Smoked Dried Fishes

S/N	Macroscopic Characteristics	Microscopic	Bonga	Catfish	Suspected Fungi
1	Dark brown colony with dense growth grow to cover plate	Conidia head are radiated, conidiosphore is unbranched, no rhizoid, hyphae is septate	+ve	+ve	*Aspergillus niger*
2	Pale brownish grey colour and fast-growing whitish colony seen	Black pigmentation, sporangium sporangiosphore unbranched	+ve	+ve	*Rhizopus oligosporc*
3	Green pigmentation with white black ground powdery surface in shape with elevated centre seen.	Conidiophore is septate, erect, and branched	+ve	+ve	*Penicillium spp*
4	White colony with mass rapid growth covering the surface	Short cresent shaped conidiophores microcomidia hyphae septate	-ve	+ve	*Fusarium solani*
5	Cotton wool like aerial mycelia first grey white in colour later become darker	Non-septate mycelia bear sporangio scattered over the mycelia. Sporangio are erect and branched	+ve	+ve	*Mucor spp*
6	Lemon yellow apron seen with pigments	Grabnules on the surface of the conidia are many	+ve	+ve	*Micrococcus caris*
7	Light green and powdery light	Long, erect septate, condiophores	+ve	-Ve	*Aspergillus flavour*

Key: +ve=present, -ve=absent

Table 6: Microbial Isolates (Bacteria and Fungi) of Fishes in the selected Markets

S/N	**Microbes (Bacteria)**	**Eleme-Nchia**		**Oil Mill**		**Microbes (Fungi)**	**Eleme-Nchia**		**Oil Mill**	
	Bacteria Species	A	B	A	B	**Fungal Species**	A	B	A	B
1	*Streptococcus spp*	+	-	-	+	*Aspergillus niger*	+	-	-	+
2	*Pseudomonas spp*	-	+	+	-	*Rhizopus oligosora*	+	+	-	-
3	*Enterobacter spp*	+	+	+	-	*Pennicilium spp*	-	+	-	+
4	*Klebstella Spp*	-	+	-	+	*Fusarium solani*	-	+	+	-
5	*Bacillus Spp*	+	+	+	+	*Mucor spp*	+	-	-	+
6	*Stapylococcus sp*	-	+	-	+	*Micrococcus caris*	-	+	+	-
7	*Bacillus cercus*	+	-	-	-	*Aspergillus flavour*	+	+	+	-
8	*Bacillus substilis*	+	+	+	+					
9	*Micrococcus spp*	-	+	-	+					
10	*Salmonella typhi*	+	+	+						
11	*Vibrio cholera*	+	+	+	+					
12	*Micrococcus luteus*	-	+	-	+					
13	*Aeromonas sp*	+	-	+	-					
`4	*Escherichia coli (E. coli)*	-	+	+	+					

Key: A = *Ethmalosa fimbriata*, B=*Clarias gariepinus*, (-) represent Absent while (+) represent Present

DISCUSSION

The low moisture content observed in the fishes differed significantly between the two markets, contrasting with findings from Benin City (Ubaka *et al*., 2019). Similar results were reported by Ahmed *et al.* (2011), who explained that smoke-drying causes water loss in the early phase (about 3 h at 80 °C) and forms a protective coating from partial carbonization by wood smoke. Moisture content, together with pH,

plays a key role in shaping the microbial ecology of fish (Omojola, 2005).

The low percentage crude fibre in this study is in line with that reported by Ubaka *et al*. (2019) which disagreed with the assertion by Katola and Kapute (2017) that high ash content is consistent with bony fish such as catfish and tilapia species. According to Daramola *et al. (*2007) and Kapute *et al.* (2013) ash content is generally influenced by size of fish and that smaller sized fish species tend to have higher ash content due to the higher bone to flesh ratio.

The relatively low crude protein observed in this study contrasts with the moderately high values typically reported, as fishes are recognized as rich sources of pure protein. This variation may be linked to differences in nutrient absorption and conversion potentials influenced by their diets or local environmental conditions (Adewoye and Omotosho, 1997). This finding is in agreement with the work of Adeosun *et al.* (2015) and Ogbonaya and Ibrahim (2009) who reported high percentage protein content.

The low-fat levels observed in the sampled fishes agree with Adeyeye and Adamu (2005), suggesting they are good sources of fish oil (Kefas *et al*., 2014). This reduction is attributed to oxidation of polyunsaturated fatty acids, leading to breakdown into peroxides, aldehydes, ketones, and free fatty acids (Daramola *et al*., 2007).

Variation in crude protein, fat, fibre, and other proximate components of smoked fish is influenced by species biology, environmental factors, and processing methods. Significant differences in protein and fat have been reported among *Clarias gariepinus*, *Oreochromis niloticus*, and *Mormyrus rume*, with storage and location further affecting nutrient retention (Oyedokun, 2020). These findings align with Huss (1988), who noted that fish composition varies by species, sex, age, environment, and season.

The range of observed microbial load in this study is considered high (especially THB) since it exceeded the permissible limits of $1x10^3$cfu/g of ICMSF (1998) which is in line with the finding of Otene and China (2024) from the selected markets in Port Harcourt Metropolis and was attributed to the hygienic condition under which they were handled (Tiamigu *et al*., 2011). This is in line with the assertions by the researchers (Huss 1995, Mez-Guillen *et al.,* 2002, Adebayo-Tayo *et al.,* 2008; FAO, 2009; Sattar *et al.,* 2000) that maintaining high hygienic standard at every stage from harvesting to consumer handling is essential for controlling microbial load of both fresh and dried fish. Findings from the current study about the higher microbial load levels in fish sampled smoked fishes from the study areas are in line with those of Abolagba *et al*. (2020), who reported a similar pattern in smoked fish from a few Benin City markets. Processing staff usually did not wash their hands before taking the smoked fish out of the oven (Ashanos and Ajayi., 2008). Other processors helped remove the fish from the oven, but they failed to change their clothes or wash their hands. Additionally, there may be a higher chance of post-smoking microbial contamination if smoked fish are placed on trays close to exposed ground. In addition to posing a physical risk to the fish, physical hazards like sand may also encourage the growth of soil microbes. Food safety is an issue because the fish are not given any serious attention before presenting it for sale, including washing, sorting, and packing (Mehemet *et al.*,2003).

There was also a significant difference (p<0.05) in microbial load of the fishes from different locations. The total heterotrophic count obtained for the smoked samples were above the range of specified microbiological limits recommended by International Commission on Microbiological Specification for Food (ICMSF, 1998) for fish and fishery products, the maximum recommended bacterial counts for good quality products is 5×10^3 cfu/g (Adelaja *et al.,* 2013; Adeyeye *et al.,* 2005). The high bacterial count on smoked fishes from Eleme-Ncha market may be due to the environmental conditions and the influx of dust resulting from the heavy traffic from which the fishes may be contaminated.

The diversity of microorganisms associated with these smoked fishes in this study could be attributed to some features such as exposure at market place as the tissues of fish is capable of reabsorbing moisture from the atmosphere. This is in line with the finding by Eyo (2001) who opined that smoked fish samples may have a relatively high-water activity level which is a prerequisite for microbial growth and that the introduction of the organisms into foods from water used for washing, utensil or wrapping materials. This is supported by the observation of Eklund *et al.* (1993) who stated that any handling of fish and the associated sanitary practice from the point of

harvesting can potentially contribute to the micro flora on the final product. The presence of the bacteria such as *Bacillus substilis, Klebsiella spp*, *Staphylococcus aureus* and *Streptococcus spp* on smoked fish in this study is in consonance with the observation of Udochukwu *et al* (2016) in Benin city. According to Adesiyun *et al* (2006) the presence of *Staphylococcus aureus* is safe because they produce enterotoxins that lead to food poisoning and can be introduced into fish through contaminated hands, surfaces or processing equipment. Claucus and ward (1996) reported *Staphylococcus aureus* to occur naturally as microflora of fish and shellfish. Kosygin *et al* (1990) also reported *Bacillus substilis, Staphylococcus aureas Proteus mirabilis Klebsiella spp, Salmonella typical* and *Streptococcus spp* to be associated with smoked fish through human handlers, air and soil. Adebayo-Tayo *et al* (2009) opined that the presence of *Enterobacter spp* in the fish sample is a strong indication of faecal contamination which poses risks for food safety and public health. Efstathiou *et al*; (2011) also regarded *Enterobacter spp* as indicator organisms in seafood products. *Bacillus* sp. produces toxins that withstand high temperatures and are spore forming which germinate and release enterotoxins (Odu and Imaku, 2013). Some *Bacillus* species are pathogenic and can cause food poisoning, their presence in some of the fresh and smoked fish samples may be because they are sold openly in the market and are exposed to the spores of the organism which are dormant in that environment and are highly resistant to the lethal effects of heat drying and ultraviolet radiation (Udochukwu *et al.,* 2016). *Bacillus cereus* and to a lesser extent *Bacillus subtilis* are intermittently allied with bacteremia, meningitis, and infections of wounds, the ears, eyes, respiratory tract, urinary tract, and gastrointestinal tract (Ineyougha *et al.,* 2015).

Several species of *Streptococcus* are known to cause diseases. For instance, *Streptococcus pyogenes* are known to cause otitis media, sinusitis, sore throat, cellulitis, erysipelas, impetigo etc. (Levison, 2008). Some species of *Proteus species* such as *P. mirabilis* can cause urinary tract infection and on prolong cases without treatment could lead to kidney disorder. Other microbes found in the fish samples such as *Pseudomonas spp*. can cause other diseases. Pseudomonas infections depend on portal of entry and the patient's vulnerability and can occur in several anatomic sites, such as skin, subcutaneous tissue, bone, ears, eyes, urinary tract, and heart valves. Some of the diseases caused by some species of *Pseudomonas* such as *P. aeruginosa* includes folliculitis, ecthyma gangrenosum, ventilator-associated pneumonia, bacteremia etc. (Bush and Perez, 2014). The microbial isolate from this study is also similar to the isolates previously identified from different smoked fish species in Nigeria. Daniel *et al*. (2013) report microbial diversity of smoked fish sold in Benin City, Nigeria to include *S. aureus, Pseudomonas, Streptococcus, Bacillus,* (Bacteria) and Yeast*, Aspergillus niger* and *Penicillium* spp. (fungi).

Majority of the fungal isolates identified in this study were said to produce mycotoxins and are in agreement with the finding of Adebayo-Tayo *et al.* (2008) reported *Aspergillus flavus, A. tereus, A. fumigatus, Absidia* spp., *Rhizopus* spp., *A. niger, Mucor* spp., *Cladosporum* spp., *Penicillium italicum, P. viridatus, Candida tropical*is and *Fusarium moniliformis* as fungal isolates found in smoked dried fishes sold in different market in Uyo, Nigeria.

Mycotoxins are produced by *Aspergillus species* and are known to produce many types of toxins such as aflatoxins, ochratoxins and sterigmato cystine (Hashem, 2011). Acute aflatoxicosis in humans has been reported in different part of the world and are characterized symptoms like vomiting, abdominal pain, pulmonary oedema, convulsions, coma, and death with cerebral oedema and fatty involvement of the liver, kidney, and heart (Akinyemi *et al.,* 2011). Most of the fungal species isolated such as *Penicillium*, *Fusarium* and *Aspergillus spp*. are known to produce mycotoxins in food products especially carbohydrates. Mycotoxins are secondary metabolites produced by microfungi that could cause disease condition. Aflatoxin can occur in diversity of protein sources including plants and animals (Adebayo-Tayo *et al*., 2008). Pratiwi *et al.* (2015) stated that *A. flavus* produces aflatoxin that contaminates plants such as cereal grains and legumes such as peanuts, corn, and rice. Aflatoxin in food affects its nutritional quality and safety (Pratiwi *et al*., 2015). The health challenges associated with aflatoxin is due to the fact that is carcinogenic, teratogenic, toxigenic, immunotoxigenic, and mutagenic to animals including humans (Pratiwi *et al*., 2015; Akinyemi *et al.,* 2011; Cheikyula and

Awobode, 2014). The consumption of food contaminated with mycotoxins could lead to liver disease (Hashem, 2011), which is the primary target organ (Akinyemi *et al*., 2011). Generally, toxin producing fungi causes diseases in immune compromised individuals and as such the diseases caused by this fungus are rare. Most of the pathogenic microorganism especially bacteria that invades *T..trachurus*, could be detrimental to humans when such fish is consumed.

CONCLUSION

The present study showed that the fishes sampled from the two markets (Eleme-Ncha and Oil Mill markets) in Port Harcourt were nutritionally rich but contain unacceptable quantum of micro-organisms above the permissible limits of World Health organization (WHO) and National Environmental Standards and Regulations Enforcement Agency (NESREA) set for seafood and drinking water. The fishes in Eleme-Ncha market were nutritionally richer and microbially higher than those from the Oil Mill market. Similarly, the sampled smoked *Clarias gariepinus* from both markets were nutritionally richer and microbially higher than the *Ethmalosa fimbriata.* There should be proper monitoring of the handling processes and the processing techniques used in the two markets to avoid further contamination of fish. Due to so many health concerns involved with direct human consumption, fish handlers must adhere to basic sanitary rules when handling smoked fish.

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