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Assessment of Microbiological Profile and Public Health Implications of Smoked Fish Sold In Wuse, Bwari, Dutse And Karmo Markets, Abuja, Nigeria

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Abstract

The consumption of smoked fish usually obtained from the open markets in developing countries has raised some public health concerns. As part of checking the public health risks associated with the consumption of smoked fish, microbiological profile and public health implications were studied. A total of 80 samples of *Clarias gariepinus* (African mud catfish), *Oreochromis niloticus* (tilapia), *Sardinella eba* (herring) and *Scombia scombia* (mackerel) sold in Wuse, Bwari, Dutse and Karmo markets, Abuja, Nigeria randomly collected (20 from each market representing 5 of each fish) were investigated. Samples were analyzed using standard microbiological techniques. The bacterial diversity identified include *Staphylococcus aureus*, *Klebsiella* sp., *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella* sp., *Streptococcus pyogenes*, *Shigella dysenteriae*, *Bacillus subtilis*, *Enterobacter aerogenes*, *Lactobacillus acidophilus*, *Lactococcus garvieae*, *Corynebacterium* sp. and *Pediococcus acidilacti* while fungi identified are *Aspergillus niger*, *A. flavus*, *A. fumigatus*, *Saccharomyces* sp., *Rhizopus stolonifer*, *Mucor* sp. and *Penicillium* sp. Results show that the highest total viable count (TVC) ($6.82x10^8$cfu/g) was found in the samples (African mud catfish) obtained from Wuse market while the lowest count (5.50×10^4cfu/g) was observed in the samples (mackerel) got from Bwari market. A similar trend was also observed in the coliform count of the African sharptooth catfish samples with the highest value ($5.55x10^4$cfu/g) and lowest ($3.40x10^4$cfu/g) obtained in the Wuse and Dutse markets, respectively. Fungal, Staphylococci, *Salmonella-Shigella* and lactic acid bacteria (LAB) counts also had high microbial counts. These values revealed high microbial contamination in all the samples, which exceeded standard. Statistical analysis indicates that there is significant correlation between pH and bacterial counts (staphylococci and LAB counts) at 0.0l level of significance. Moisture content correlates significantly with staphylococci count at 0.05 level of significance and with LAB at 0.0l significance level. In addition, there is significant difference ($P \leq 0.05$) amongst the means of TVC obtained from the markets. This high level of microbial contamination is traceable to handlers and environment to which these fishes are exposed to during smoking and selling activities, and considering the danger it portends to

human health, public health and food safety authorities should intensify their monitoring efforts toward controlling such contamination.

Keywords: microbiological, enteric, market, spoilage, bacteria, fungi, pathogenic.

1.0. Introduction

Fish is a major source of food for humans, providing a significant portion of protein (which is essential for healthy human growth), fats and fat-soluble vitamins intake in the diets of a large proportion of the people, particularly so in the developing countries. It is also used as a source of valuable medicinal, feeding and technical products (Olusegun and Jacob, 2013; Akinwumi and Adegbehingbe, 2015). However, it is a suitable medium for growth of microorganisms, if poorly processed (Oparaku and Mgbenka, 2012).

Escherichia coli including other coliforms and bacteria such as *Staphylococcus* species and sometimes enterococci are commonly used as indices of hazardous conditions during processing of fish. Scientists have shown that the contamination of fish with pathogenic *E. coli* probably occur during handling of fish and during the production process (Abolagba and Mella, 2008). The autochthonous bacterial flora of fish is dominated by Gram-negative genera including: *Acinetobacter, Flavobacterium*, *Moraxella*, *Shewanella* and *Pseudomonas*. Members of the families Vibrionaceae (*Vibrio* and *Photobacterium*) and the Aeromonadaceae (*Aeromonas* spp.) are also common aquatic bacteria, and typical of the fish flora. Gram-positive organisms such as *Bacillus*, *Micrococcus*, *Clostridium*, *Lactobacillus* and Coryneform can also be found in varying proportions (Adebayo-Tayo et al., 2008; Tiamiyu et al., 2011; Felix and Kehinde, 2015). The fungal species isolated from smoked fish according to scientific reports are *Penicillium expansum*, *Saccharomyces* spp., *Aspergillus niger*, *Fusarium* spp., *Rhizopus stolonifer* and *Mucor piriformis* (Ayolabi and Fagade, 2010; Udochukwu et al., 2016).

Spoilage of fish is occasioned by an increase in the ambient temperature that triggers favourable conditions for microorganisms to strive, hence the need for immediate preservation. The methods by which fish could be preserved include, freezing, salting, sun-drying, oven-drying, fermentation, canning and smoking (Dutta et al., 2018).

In industrialized countries, however, fish smoking is done for enhancement of flavour and texture, often producing value added products whose preservation is achieved by other means (Adelaja et al., 2013). In Nigeria, fish either obtained from a cultured pond or from the wild is sold to consumers as fresh, frozen, smoked or sun-dried. Smoked fish is highly desirable because it gives the product a desirable colour, taste, aroma, a longer shelf-life through its anti-microbial and oxidative effect, lowering of pH and water activity in the fish is lowered to the point where the activity of spoilage microorganisms is inhibited. In addition, the wood smoke add some microbial inhibitory substances like formaldehyde and alcohols (Akinwumi and Adegbehingbe, 2015; Udochukwu et al., 2016). The smoked fish products have gained a popular market at commercial basis due to its attractive organoleptic properties and have a high potentiality as a processed item in Nigeria for commercialization, hence the need for proper handling and preservation to increase its shelf life, retain its quality and nutritional attributes and of no pernicious effect to consumers.. This study is therefore undertaken to assess the microbiological profile and public health implications of smoked fish sold in Wuse, Bwari, Dutse and Karmo markets, Abuja, Nigeria.

2.0. Materials and Methods

2.1. Sample Collection

Four (4) common dried fish species were used in this study: they are *Clarias gariepinus* (African mud catfish), *Oreochromis niloticus* (tilapia), *Sardinella eba* (herring) and *Scombia scombia* (mackerel) sold in Wuse, Bwari, Dutse and Karmo markets located in Abuja, north central of Nigeria. A total of 80 samples were collected from the markets (20 from each market). The fish were purchased in batches and placed in labelled sterile containers and transported to the laboratory for microbial analysis.

Smoked African mud catfish (*C. gariepinus*)

Smoked mackerel (*Scombia scombia*)

Smoked tilapia fish (*O. niloticas*)

Smoked herring (*Sardinella eba*)

2.2. Preparation of Samples and Enumeration of Microorganisms

The fish samples were surface sterilized separately in 3.5% (w/v) sodium hypochlorite solution with constant agitation for 7 minutes, rinsed thoroughly with distilled water until the traces of hypochlorite were removed and were then dried in an oven at 45°C for 24 h (ICMSF, 1996). The heads, muscles and the tails of the fish samples were pulverized together using a blender (maker). Ten grams (10g) of the ground fish was dissolved in a test tube containing 90ml of 0.8% (w/v) of sterile peptone physiological saline to form a stock culture

(1 part of sample in 9 parts of deionized water). The sample bottles were placed on a rotator shaker at 120 revolution per minute for 1 hour. 10-fold dilutions were subsequently prepared with 0.8% (w/v) peptone physiological saline. 0.1mL aliquots of 10^{-2}, 10^{-3} and 10^{-4} dilution (triplicate) were aseptically removed with a sterile pipette and transferred into labelled sterile Petri dishes and then about 18 – 20ml melted Nutrient agar were added by pour plate method for the enumeration of aerobic mesophilic bacteria, which was reported as mean total viable count. After rotating gently, the plates were incubated at 37°C for 24 hours. The above procedure was repeated for the culture and counting of different groups of organisms as follows: Lactic acid bacteria were counted on Sharpe Agar (Merck) after anaerobic incubation at 30°C for 48 hours. Presumptive lactic acid bacteria was confirmed by oxidase and catalase tests, and counts were reported as lactic acid bacteria (LAB). Staphylococci were counted on mannitol salt agar (Oxoid) after incubation at 30°C for 48 hours. *Salmonella* and *Shigella* organisms were enumerated on *Salmonella-Shigella* agar after 24 hours incubations at 37^{o}C. Coliforms were counted on Eosin Methylene Blue (EMB, Oxoid) after 24 hours incubation at 37^{o}C. Yeasts and molds were enumerated on Potato dextrose agar (PDA) which was supplemented with Chloramphenicol to inhibit bacterial growth and incubated at 25°C for 72–120 hours (Cheesbrough, 2000).

2.2.1. Identification of Bacteria

Isolates were repeatedly sub-cultured to produce pure cultures by using streak plate technique. Bacterial plates were incubated at 37^{o} C for 24 hours while fungal plates at 25°C for 72 hours. Pure cultures were preserved in the refrigerator at 4^{o}C for identification and characterization. A 24 hour old culture was prepared from each plate for identification and characterization. Bacteria isolates were identified based on their cultural, morphological, Gram reaction, biochemical reactions and sugar fermentation according to the techniques described by Holt *et al*. (1994). Lactic acid bacteria were also identified by carbohydrate fermentation test in API 50 CHL galleries (BioMerieux).

2.2.2. Identification of Fungi

Fungal isolates (yeasts and molds) were cultured by three point inoculation on PDA at 25°C for 5 days. The young cultures of the isolates were stained with lactophenol-blue and identified to the genus level by colony and cell morphology and biochemical tests described by Essien *et al.* (2005).

2.2.3. Determination of pH and moisture content of the fish

The pH of fish was determined using a digital pH meter after blending 10g of homogenized fish with 90 ml of distilled water. The moisture content of sample was determined using the AOAC official methods for analysis (AOAC, 2000). Ten grams (10g) sample was weighed in a pre-weighed ceramic crucible on an analytical balance and dried to a constant weight at 105°C for 24 hours in an oven. The sample was allowed to cool to room temperature in a desiccator and was accurately weighed to determine the dry weight. The loss in weight was attributed to moisture content.

Moisture content was calculated as follows:

$$\text{Percentage (\%) of moisture} = \frac{W_2 - W_3}{W_2 - W_1}$$

W1= Weight of empty crucible in grams,
W2= Weight of sample + crucible before drying in grams

W3= Weight of sample + crucible after drying, in grams.

2.3. Data analysis

Results were presented in mean and standard deviation. IBM SPSS statistical tool (version 21.0) was used to carry out analysis of variance (ANOVA) to compare the mean differences of Total Viable counts from samples in the markets at 95% confidence limit ($P \leq 0.05$) while Pearson correlation was used to compare means of microbial counts and physicochemical parameters (pH and moisture content) of smoked fish.

3.0. Results

The mean values of the total viable, coliform, fungal, staphylococci, *Salmonella-Shigella* and lactic acid bacteria (LAB) counts of the smoked fish samples are presented in Table 1. The highest total viable count ($6.82x10^8$cfu/g) was found in the samples (African mud catfish) obtained from Wuse market while the lowest count (5.50×10^4cfu/g) was observed in the samples got from Bwari market. A similar trend was also observed in the coliform count of the African mud catfish samples with the highest value ($5.55x10^4$cfu/g) and lowest ($3.40x10^4$cfu/g) obtained in the Wuse and Dutse markets, respectively. Again, the highest fungal count ($5.10x10^5$cfu/g) and Staphylococci count ($2.70x10^3$cfu/g) were obtained in the African mud catfish samples displayed in Wuse market in comparison to the lower counts of $3.18x10^3$cfu/g (fungal count) and $1.80x10^2$cfu/g (Staphylococci) found in the Wuse and Dutse samples, respectively. However, the highest *Salmonella-Shigellla* count ($3.10x10^2$cfu/g) was observed in herring (*Sardinella eba*), which was obtained from Bwari market while the lowest count ($1.00x10^2$cfu/g) was obtained from African mud catfish but from the same market (Bwari). The highest LAB count ($2.78x10^2$cfu/g) was observed in African mud catfish obtained from Karmo market while the lowest count ($1.04x10^2$) came from mackerel in Bwari market.

Table 2 shows the various bacteria and fungi isolated from the smoked fish samples. The identified bacterial genera include *Bacillus* species, *Shigella dysenteriae*, *Lactobacillus garvieae*, *Pseudomonas aeruginosa*, *Klebsiella* sp., *Escherichia coli*, *Staphylococcus aureus*, *Lactobacillus acidophilus*, *Enterobacter aerogenes*, *Salmonella* sp., *Corynebacterium* sp., *Pediococcus acidilacti*, *Streptococcus pyogenes* and *Bacillus subtilis*. Fungi genera identified are as follows: *Sacchromyces* sp., *Aspergillus niger*, *Rhizopus stolonifera*, *Aspergillus fumigatus*, *Aspergillus flavus*, *Penicillium* sp. and *Mucor* species.

Pearson correlation of microbial counts and physicochemical parameters (pH and moisture content) is represented in Table 3. The statistical analysis indicates that there is significant correlation of pH and moisture content (0.843) at 0.00l level of significance; and pH also correlates significantly with LAB (0.663) at the same level of significance. In addition, moisture content correlates significantly with staphylococci count (0.524) at 0.05 level of significance and with LAB (0.692) at 0.0l significance level.

Table 4 shows the analysis of variance (ANOVA) of total viable counts of samples from the markets. Result reveals that there is significant difference at $P \leq 0.05$ amongst the means of total viable counts obtained from the different markets.

Implicated fungal genera identified from the samples according to the study areas (markets) is presented in Table 5. According to the result, a variety of fungal species were observed in the fish samples obtained from the study areas. *Aspergillus nger*, *A, fumigatus* and *A. flavus* features prominently in three markets (Wuse, Dutse and Karmo). *Penicillium* sp. has 50% presence in Bwari, Dutse and Karmo markets. *Mucor* species features averagely in Wuse, Bwari and Dutse markets. *Rhizopus stolonifer* was isolated from mackerel and herring (*Sardinella eba*) in Wuse market and less frequently isolated in other markets. *Saccharomyces* species is prominently present in Wuse and Karmo markets.

Table 1: Mean Microbiological Counts (cfu/g) in Smoked Fish Samples per Market

Market/Fish	Total viable count	Coliform	Fungal	Staphylococci	*Salmonella-Shigella*	*Lactic Acid Bacteria*
Wuse						
C. gariepinus	6.82×10^8	5.44×10^4	5.10×10^5	2.70×10^3	2.00×10^2	2.10×10^2
O. niloticas	7.50×10^7	4.37×10^3	6.23×10^3	1.52×10^2	1.50×10^3	1.50×10^2
Scombia scombia	8.50×10^7	2.11×10^3	5.42×10^4	2.50×10^3	1.21×10^3	1.34×10^2
Sardinella eba	6.42×10^6	1.80×10^3	3.34×10^5	1.25×10^3	2.11×10^2	1.78×10^2
Bwari						
C. gariepinus	5.21×10^6	4.00×10^3	4.20×10^4	2.20×10^3	1.00×10^2	2.34×10^2
O. niloticas	6.45×10^5	3.01×10^4	4.45×10^3	1.76×10^2	2.10×10^3	1.90×10^2
Scombia scombia	7.30×10^6	3.14×10^2	5.00×10^4	2.60×10^2	2.61×10^2	1.04×10^2
Sardinella eba	5.20×10^6	2.35×10^3	4.67×10^4	1.39×10^3	3.10×10^2	2.56×10^3
Dutse						
C. gariepinus	4.29×10^6	3.40×10^4	3.18×10^3	1.80×10^2	1.90×10^2	1.23×10^2
O. niloticas	4.30×10^6	2.34×10^3	3.23×10^4	1.02×10^2	1.70×10^3	1.80×10^2
Scombia scombia	5.50×10^4	3.31×10^3	3.32×10^4	2.10×10^3	1.61×10^3	1.40×10^2
Sardinella eba	6.02×10^6	3.00×10^4	5.22×10^5	2.33×10^3	2.88×10^3	2.22×10^2
Karmo						
C. gariepinus	7.02×10^7	3.44×10^4	4.64×10^5	2.25×10^3	2.01×10^3	2.78×10^2
O. niloticas	7.42×10^7	2.70×10^3	2.34×10^5	1.50×10^3	2.17×10^2	1.08×10^2
Scombia scombia	6.76×10^6	4.40×10^3	4.84×10^5	2.25×10^3	2.11×10^2	2.18×10^2
Sardinella eba	7.32×10^6	3.80×10^4	4.36×10^5	1.23×10^3	2.00×10^2	1.45×10^2

Cfu/g: Colony forming unit per gram

Table 2: Bacterial and Fungal Isolates Identified from Smoked Fish

Bacterial Isolates	Fungal isolates
Shigella dysenteriae	*Saccharomyces* species
Pseudomonas aeruginosa	*Aspergillus niger*
Escherichia coli	*Rhizopus stolonifer*
Staphylococcus aureus	*Penicillium* species
Lactobacillus acidophilus	*Mucor* species
Enterobacter aerogenes	*Aspergillus fumigatus*
Salmonella species	*Aspergillus flavus*
Corynebacterium species	
Klebsiella species	
Bacillus subtilis	
Lactococcus garvieae	
Bacillus species	
Pediococcus acidilacti	
Streptococcus pyogenes	

Table 3: Pearson correlation of microbial counts and physicochemical parameters (pH and moisture content) of smoked fish

Parameter	pH level	Moisture content	Total viable count	Total coliform count	Fungal count	Staphylococci	*Salmonella-Shigella*	Lactic Acid Bacteria
pH level	1.000							
Moisture content	0.843**	1.000						
Total viable count	-0.227	-0.036	1.000					
Total coliform count	0.281	0.467	0.025	1.000				
Fungal count	0.405	0.441	0.291	0.182	1.000			
Staphylococci	0.268	0.524*	0.353	0.341	0.274	1.000		
Salmonella-Shigella	-0.008	0.013	-0.071	-0.240	-0.239	-0.255	1.000	
Lactic Acid Bacteria	0.663**	0.692**	-0.202	0.330	0.303	0.128	-0.003	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4: Analysis of Variance (ANOVA) of Total Viable Counts of Samples from the Markets

Smoked Fish	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
C.gariepinus	4	5.8350	1.31048	.65524	3.7497	7.9203	4.29	7.02
O.niloticas	4	6.4175	1.49015	.74508	4.0463	8.7887	4.30	7.50
S. scombia	4	7.0150	1.24455	.62227	5.0346	8.9954	5.50	8.50
S. eba	4	6.2400	.88106	.44053	4.8380	7.6420	5.20	7.32
Total	16	6.3769	1.20206	.30051	5.7363	7.0174	4.29	8.50

Differences in means from the four markets is significant (0.734) at $p \leq 0.05$.

Table 5: Implicated Fungi on Smoked Fish in the Study Areas (Markets)

Study Area/Fish	*A. niger*	*A. fumigatus*	*A. flavus*	*Penicillium* sp.	*Mucor* sp.	*Saccharomyces* sp.	*R. stolonifer*
Wuse							
Clarias gariepinus		+	+			+	
O. niloticas	+		+		+	+	+
Scombia scombia		+		+	+	+	
Sardinella eba	+	+	+			+	+
Bwari							
Clarias gariepinus		+	+	+			+
O. niloticas	+			+		+	
Scombia scombia	+				+		
Sardinell		+			+		
Dutse							
Clarias gariepinus	+	+	+	+	+	+	
O. niloticas	+		+		+		+
Scombia scombia		+	+	+			
Sardinella eba	+						
Karmo							
Clarias gariepinus	+	+	+		+	+	
O. niloticas		+	+			+	+
Scombia scombia			+	+			
Sardinella eba	+	+		+	+		

+: positive (present) in fish

4.0. Discussion

This study is primarily aimed at assessing the microbiological profile and public health implications of smoked fish sold in randomly selected markets in Abuja, Nigeria. There were remarkable variations amongst the different microbial counts in the four markets. The highest total viable count was observed in African mud catfish obtained from Wuse market. Result showed high coliform contamination ($1.80x102^3$ – $5.55x10^4$ cfu/g), compared with the standard (Food and Agriculture Organization of the United Nations, 2015). The high count, especially observed in Wuse and Karmo markets (mostly from African mud catfish) could be attributed to improper pre/post handling, smoking procedures and the way they were exposed in large quantities to the environment on probably untidy tables and other surfaces in the different markets. This is in agreement with Akinwumi and Adegbehingbe, (2015) who reported similar bacterial counts after investigating the microbiological quality of three smoked fish obtained from the Ondo State, Nigeria. It has also been reported that smoking is a mild preservative treatment process, which kills bacteria and prevents microbial proliferation due to combined effects of heating, drying, pH and antimicrobial smoke components (Adelaja et al., 2013). Hence, as a mild treatment, smoking does not achieve complete elimination of microbial load of a fresh fish which has been proved to be naturally high due to the high microbial load of their habitat (water) (Adelaja et al., 2013). The highest counts observed among the samples from Wuse market can be attributed to the fact that it is the largest study area, which may imply that there is more contaminating pre-disposing factors and perhaps less sanitary practices compared to other markets. These factors expose the fish to more possibilities of contamination than in any of the other sampling sources. This supports the observation of Anihouvi et al. (2019), which stated that the handling of large quantity of fish and the accompanying sanitary practice from the point of harvesting to when they are displayed (after smoking process) on tables, baskets and other containers can potentially contribute to the microflora on the final product. Furthermore, the fungal, staphylococci, *Salmonella-Shigella* and LAB counts were high and above recommended standard (Udochukwu et al., 2016).

Statistically, ANOVA showed that there is significant difference ($P \leq 0.05$) in the total viable counts of smoked fish from the different markets (Table 4). This could be due to sanitary conditions under which the fish samples were handled and kept (Tiamiyu et al., 2011). Also, Pearson correlation of microbial counts and physicochemical parameters (pH and moisture content) revealed that moisture content and pH influenced the microbial load (staphylococci and LAB) of fish samples (Table 3). This could also imply that staphylococci and LAB may have come from the same contamination source (Dike-Ndudim et al., 2019).

In this study, the fish samples which were smoked on charcoal/wood barbecue were usually displayed on untidy tables, dirty floor, mats, trays and open containers in the markets for sale. Mondo et al. (2020) reported that processed fish are easily contaminated with microorganisms in nature, through handling, during processing and if the post-processing handling is not properly done under hygienic conditions. The quality of smoked products is dependent on several factors, including, the quality of the fish at the time of smoking, the preparation of the raw material, the nature of wood and the type of the smoking procedure employed (Aba and Ifannyi, 2013). The isolation of *E. coli*, *Salmonella* sp. and *Klebsiella* sp. are indications of feacal contamination and this is in agreement with the report of Akinwumi and Adegbehingbe (2015), which linked fish contamination to handlers who lack personal

hygiene. Moreover, Wogu and Iyayi (2011) has proven that water sources (streams and rivers) in neighboring Kogi State where a preponderance of the fish sold in Abuja is purchased are contaminated with coliform organisms. Hence the isolation of these feacal contaminant from fishes sold in Abuja markets is traceable to those water sources. Udochukwu et al. (2016) reported that *E. coli* causes diarrhea and kidney damage as well as uncomplicated community acquired urinary tract infections while *Salmonella* causes gastroenteritis and typhoid fever. *Klebsiella* species such as *K. pneumoniae* is known to possess histidine decarboxylase activity, enabling the bacterium to produce histamine in fish products, which causes various health disorders to humans (Maintz and Novak, 2007; Visciano et al., 2012). Again the isolation of bacterial pathogens such as *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Bacillus subtilis* is an indication of poor handling or cross contamination of smoked fish products, since the three organisms have been culprits of food poisoning (Tiamiyu et al., 2011). *Staphylococcus aureus* and *Shigella dysenteriae* (dysentery causative organism) have ability to produce enterotoxins and *S. aureus* is notorious for its capacity to survive extended periods of time in adverse environments (Ehiri et al., 2006; Doyle et al., 2014). *P. aeruginosa* is an opportunistic pathogen, which is implicated in pneumonia, septicemia, endocarditis, etc. Tiamiyu et al. (2011) also isolated and identified *Staphylococcus aureus*, *Bacillus* sp., *Salmonella* sp. *Corynebacterium* sp. and *Streptococcus pyogenes* from the skin of *Clarias gariepinus*. *Streptococcus pyogenes* and *Corynebacterium* sp. were also isolated in this work. It was suspected that these pathogenic organisms may have contaminated the smoked fish through human handlers, air and soil. *Corynebacterium diphtheriae* produces a very potent toxin that causes difficulty in breathing, heart failure, paralysis, and even death (Kerry-Williams and Noble, 2009).

The occurrence of *Aspergillus niger*, *A. flavus*, *A. fumigatus*, *Rhizopus stolonifer*, *Saccharomyces* sp. and *Penicillium* sp. in the smoked fish species could be due to the fact that during storage in various shops in the markets, the fish sample had reabsorbed moisture from the environment which promoted their growth (Ikpi and Ofem, 2008). The presence of *A. flavus* and *A. fumigatus* in the studied fish samples is of great health concern because of their mycotoxigenic potentials. It has been reported that *A. flavus* and *A. fumigatus* produced aflatoxins, which destroy the liver and kidney in man resulting to death (Chistianah et al., 2010). There are serious public health implications related to the consumption of contaminated smoked fish because of the presence of biological (bacteria and fungi) and chemical (biotoxins) hazards. However, several techniques exist in the prevention of the growth of pathogenic microorganisms during distribution and storage of processed fish. Nieto-Lozano et al. (2010) observed that the hazards related to contamination, recontamination or survival of biological hazards during processing could be controlled by applying good manufacturing practice and good hygiene practice. Smoking at adequately high temperatures is capable of controlling microbial contamination in fish, although, the heat supplied might not be sufficient enough to kill all the microbial contaminants. While temperatures for hot smoking (>600°C) can inactivate vegetative microorganisms, the process may produce a finished product with undesirable organoleptic properties (Ineyougha et al., 2015). Plahar et al. (2012) recommended that the processed fish should be exposed to a drying temperature that will provide insufficient moisture content for the growth of microorganisms. A combination of smoking and treatments with antimicrobial agents and antioxidants have been found to retard microbial spoilage, extend shelf life, and enhance safety of smoked fish in industrialized countries (Adetimehin et al., 2019). Also, we are

recommending that regulatory agency in Nigeria such as NAFDAC should look into the environmental condition of our food handlers as it concerns the smoking factories, the markets where our foods are sold and even the hawkers that carry the food from one place to another. Their hygienic condition must be ascertained before authorizing them to handle public food. Finally, we are recommending that people should properly cook their fish before

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