Quality Attributes, Chemical and Microbial Safety of Street-Vended Smoked West Africa Ilisha (Ilisha africana) from Major Markets in Ibadan, Oyo State, Nigeria

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Abstract This study was carried out to assess the quality and safety of street-vended smoked West African Ilisha fish from major markets in Ibadan, Oyo State, Nigeria. Fifty smoked fish samples were collected from ten major markets in Ibadan, Oyo State, Nigeria and the samples were analyzed in the laboratory for proximate, quality and rancidity indices (PV, TBA, TVB-N, TMA and FFA), polycyclic aromatic hydrocarbon (PAH), heavy metals and microbiological (coliorm, fungi, Listeria monocytogenes, Salmonella paratyphi and Staphylococcus aureus) analyses. The results revealed that the mean moisture, protein, fat, crude fibre, ash and carbohydrate contents (%) of smoked fish samples were 11.35-15.18, 52.13-60.22, 11.56-16.13, 1.74-2.52, 1.12-1.54 and 9.53-16.25 respectively. The values of PV, TBA, TVB-N, TMA and FFA of smoked fish samples were 8.96-9.18 meq peroxide/kg, 1.13-1.62, 1.04-1.16 mg Mol/kg, 17.29-19.36 mgN/kg and 2.15-2.68 mgN/kg respectively. The results also revealed the presence of sixteen (16) PAHs compounds in the smoke fish samples. However, ten of the sixteen PAHs compounds were above the 5.0 μg/kg B(a)P maximum permissible levels set by EU Regulation 1881/2006. The concentrations of Hg, Pb, Cd, and Cr in the smoked fish samples showed that quantities detected were generally below the maximum permissible levels and hence pose no risk to consumers. The results of microbiological analysis indicated the presence of Staphylococcus aureus in the smoked fish samples which may be due to post-processing handling. In conclusion, the study revealed that consumption of street-vended smoked fish may expose consumers to chemical and microbiological risks.

Keywords smoked fish; street-vended; quality; safety; PAHs; heavy metals.

1 Introduction Fish and fishery products constitute an important food component for a large section of world population, more so in developing countries, where fish forms a cheap source of protein (Amusan et al., 2010; Odu and Imaku, 2013). In the last two decades there has been an increase in awareness about the nutritional and health benefits of fish consumption (Amusan et al., 2010, Odu and Imaku, 2013). The low fat content of some fish and the presence of polyunsaturated fatty acids in red meat fishes which are known to reduce the risks of coronary heart diseases, have increased the dietary and health significance of seafood consumption (Amusan et al., 2010; Odu and Imaku, 2013). The Food and Agriculture Organization (1994) asserted that fish contributes about 60% of the world’s supply of protein and that 60% of the developing world derives more than 30% of their annual protein from fish (Amusan et al., 2010). However, in Nigeria, fish constitute 40% of the animal protein intake (Olatunde, 1998; Amusan, et al., 2010). They are prone to contamination at various stages of handling and processing and the quality is a major concern to food processors and public health authorities (Oramadike, et al., 2010; Amusan, et al., 2010; Odu and Imaku, 2013).

The smoked fish has become so popular in Nigerian dishes and there is need for corresponding concern for safety issues in smoked fish consumption (Riches, 2012; Adeyeye et al., 2015). Although several researchers have...
worked on quality and safety of smoked fish, there is drought of data on the quality and safety of street-vended smoked fish in Nigeria. Da Silva et al., (2008) examined the microbial safety and quality of smoked blue catfish (Ictalurus furcatus) steaks treated with antimicrobials and antioxidants during 6 weeks ambient storage. Fafioye et al., (2002) studied the fungal infestation of five traditionally smoked dried freshwater fish in Ago-Iwoye, Nigeria and isolated and identified eleven different fungal species of which Aspergillus flavus was the most frequently encountered fungi on the fish species. Adebayo-Tayo et al., (2008) reported the presence of aflatoxin and other metabolites in smoked fish due to Aspergillus flavus in smoked fish sold in Uyo, Akwa Ibom State, Nigeria and confirmed that consumers could have been at risk of aflatoxin poison.

Certain heavy metals such as lead, cadmium, mercury and chromium have been detected in smoked fish and have also been recognized to be potentially toxic within specific limiting values (Smirjakova et al., 2005). Cadmium is spread by air and water (sewage sludge) far over sea and land, but especially in the vicinity of heavy industrial plants. Cadmium is today regarded as the most serious contaminant of the modern age. It is absorbed by many plants and sea creatures and, because of its toxicity, presents a major problem for fish. Cadmium, like lead, is a cumulative poison, that is, the danger lies primarily in the regular consumption of foods with low contamination (Zeleznik, 1994).

There are also strong pressures on chemical safety for smoked, barbecued and fried fish products from the EU institutions. Thus the Codex Alimentarius Commission on contaminants in food, at its 29th session from 16 to 20 April 2007 established a reflection on reducing levels of Polycyclic Aromatic Hydrocarbons (PAHs) in food dried and smoked (EC, 2007). In addition, the EU Regulation 1881/2006 requires a formal setting new stricter rule on the content of PAH in smoked products. The presence of PAHs, especially benzo[a]pyrene, in smoked fish has previously been reported (Simko et al., 2002) but little information is available concerning the influence of the smoking and frying processes.

This study was therefore carried out to assess the quality, presence and concentration of PAHs and heavy metals as well as microbial hazards in smoked fish.

2 Materials and Methods

2.1 Sample collection

A total of 50 samples of smoked West African Ilisha fish were collected from ten major markets in Ibadan, Oyo State, Nigeria by purposive sampling method. The smoked fish samples were taken to the Federal University of Agriculture, Abeokuta, Nigeria for laboratory analysis.

2.2 Proximate analysis

The proximate composition of all the samples were carried out in triplicates according to the standard method AOAC (2000).

2.3 Physico-chemical analysis

Kent pH meter (model 7020, Kent Ind. Measurement Ltd., Surrey, U.K) equipped with a glass electrode was used to measure the pH of the flesh in triplicates, employing 10 g of smoked fish homogenized in 10 ml of distilled water. The rancidity (quality) indices of all the samples were carried out in triplicates according to the standard method AOAC (2000). All chemicals used in this study were of the analytical grade unless stated otherwise.

2.4 Determination of PAHs by Gas Chromatography (GC)

To start the cold extraction 2 g of each sample was weighed into a clean extraction container and 10 ml of dichloromethane was added, thoroughly mixed and allowed to settle. The mixture was carefully filtered into clean solvent and rinsed into extraction bottle, using filter paper fitted into Buchner funnel. The extract was concentrated to 2 ml and then transferred for clean-up and separation (this involved further purification of the extract prior to gas chromatographic analysis). To achieve this, 1 cm of moderately packed glass wool was placed at the bottom of 10 mm ID × 250 mm long chromatographic column. Slurry of 2 g activated silica in 10 ml dichloromethane was prepared and placed into the chromatographic column. To the top of the column 0.5 cm of sodium sulfite was added. The column was rinsed with additional 10 ml of dichloromethane. The column was pre-eluted with 20 ml of dichloromethane and this was allowed to flow
through the column at a rate of about 2 minutes until the liquid in the column was just above the sulfite layer. Immediately, 1 ml of the extracted sample was transferred into the column. The extraction bottle was rinsed with 1 ml of dichloromethane and added to the column as well. The stop-cork of the column was open and the eluant was collected with a 10 ml graduated cylinder. Prior to exposure of the sodium sulfite layer to air, dichloromethane was added to the column in 1-2 ml increments. Accurately measured 10 ml of the eluant was collected and labeled aliphatic. The concentrated aliphatic fractions were transferred into labeled glass vials with rubber crimps caps for GC analysis. 1 µL of the concentrated sample was injected by means of syringe through a rubber septum into the column. Separation occurs as the vapour constituents’ partition between the gas and liquid phases. The sample components were automatically detected as they emerge from the column (at a constant flow rate) by the Flame Ionization Detection (FID) detector whose response was dependent upon the composition of the vapor.

2.5 Heavy metal analysis
Heavy metal, such as Cu, Cd, Hg and (Pb) in smoked fish samples were determined by AOAC (2000) method using atomic absorption spectrophotometer. All chemicals used in this study were of the analytical grade unless stated otherwise.

2.6 Microbiological studies
The presence of pathogens in smoked fish samples was investigated in the microbiology laboratory. These include: Listeria monocytogenes, Salmonella paratyphi, Escherichia coli, Staphylococcus aureus and Fungal count. The microbiological procedures recommended in the International Commission on Microbiological Specification for Foods (ICMSCF, 1986) were applied. Culture media were those of Oxoid, Biolife and Difco. For each sample, 25 g were weighed out and transferred to a sterile blender with 225 ml of 0.1% peptone and mixed thoroughly for 2 minutes to prepare fish homogenate. The samples were then analysed as follows.

2.6.1 Total viable bacterial counts
Appropriate dilutions of the fish homogenate were prepared and inoculated onto sterile Petri dishes. Plate count agar (Oxoid) media were then poured. Plates were incubated at 37°C for 48 hours and colonies were then counted and reported as total colony count/ml. A second set of plates was incubated at 37°C for 48 hours in a carbon dioxide incubator or under anaerobic conditions using a gas pack anaerobic jar. Colonies were then counted and reported as anaerobic total bacterial count. In case of spore formers count, the food homogenate was boiled first at 75–80°C and then rapidly cooled. Appropriate serial dilutions were prepared and inoculated onto the surface of sterile and dried plate count agar media. These were incubated finally at 37°C for 48 hours.

2.6.2 Detection of Escherichia coli
One ml of each of the decimal dilutions of the smoked fish homogenate was plated on poured Eosine Methylen Blue Agar (Oxoid) and then incubated at 37°C for 24 hours. Counts were calculated from the number of growth on the plates. The colonies with green metallic sheen were counted as Escherichia coli.

2.6.3 Detection of Staphylococcus aureus
A sample of 0.1 ml of the smoked fish homogenate and dilutions was inoculated on Baird-Parker (Difco) agar plates and incubated at 37°C for 48 hours. Colonies appearing to be black and shiny with narrow white margins and surrounded by clear zones were identified by coagulase test reactions. The coagulase test was carried out by first inoculating typical colonies in brain heart infusion broth (Difco) and incubating at 37°C for 24 hours. From the resulting cultures, 0.1 ml was then added to 0.3 ml of rabbit plasma in sterile tubes and incubated at 37°C for 4 hours. The formation of a distinct clot was evidence of coagulase activity.

2.6.4 Detection of Salmonella paratyphi
Samples of smoked fish homogenate and dilutions were inoculated in Salmonella-shigella agar (Oxoid) and incubated at 37°C for 24 hours. For identification, 2–3 suspected colonies were inoculated into tryptone broth for indole test, triple sugar iron agar slant (Oxoid), urea broth and lysine iron agar. These were incubated at 37°C for 24 hours. Salmonella species is indole negative, on triple sugar iron it produces acid (yellow) and alkaline (red) with or without gas and hydrogen sulfide, is urea negative, and on lysine iron agar shows an alkaline (purple) reaction throughout
the medium. Serological tests were then carried out.

2.6.5 Listeria monocytogenes.
A sample of 0.1 ml of the smoked fish homogenate and dilutions was inoculated on Brilliant Listeria Agar (Oxoid) plates and incubated at 37°C for 24 hours. Colonies appearing were counted and reported as *Listeria monocytogenes*.

2.6.6 Enumeration of fungi
Appropriate dilutions of Sabouraud dextrose agar plates (Oxoid) were poured over 1 ml of the fried fish homogenate and dilutions. Plates were incubated at 25°C for 3 days and then colonies were counted and reported as fungal count/ml.

2.7 Data analysis
The data obtained were subjected to descriptive statistics using IBM SPSS version 21.0 software. One way analysis of variance (ANOVA) was performed followed by Duncan’s Multiple Range Test (p<0.05) to find the difference between means. Significant level was set at P<0.05.

3 Results
The results of moisture, crude protein, crude fat, crude fibre, ash and carbohydrate contents (%) of smoked fish samples (Table 1) ranged from 11.35-15.18, 52.13-60.22, 11.56%-16.13, 1.74-2.52, 1.12-1.54 and 9.53-16.25 respectively. In this study, the PV, FFA, TBA, TVB-N and TMA values of smoked fish samples (Table 2) were in the range of 8.96 - 9.18 meq., peroxide/kg, 1.13-1.62, 1.04-1.16 (mg Mol/kg), 17.29-19.36 mgN/kg and 2.15-2.68 mgN/kg respectively. The concentrations of sixteen (16) PAHs compounds analysed in the smoked fish samples revealed as follows (Table 3). For smoked fish samples, the concentrations (μg /kg) of naphthalene, acenaphthylene, 1,2-Benzanthracene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz (α) anthracene, chrysene, benzo (β) fluoranthene, benzo(α) pyrene, benzo(g,h,i) perylene , indeno (1,2,3-ed)pyren and dibenz[a,h]anthracene were 4.53, 5.78, 5.52, 3.39, 5.61, 5.82, 5.89, 4.32, 3.67, 5.13, 4.56, 5.51, 5.94, 5.86, 4.45 and 5.79 respectively.

The results of the concentrations of Hg, Pb, Cd, and Cr in the smoked fish samples are presented in Table 4. The concentrations (μg/g) of Hg, Pb, Cd, and Cr in the smoked fish samples were 0.0011-0.0013, 0.0010-0.0017, 0.0014-0.0021, and 0.0912-0.0972 respectively.

The results of the microbiological study are presented in Table 5. It was also found that TVC of smoked fish samples were in the range of 1.0 x 10^3-6.0 x 10^4 cfu/g. *Staphylococcal* count of smoked fish samples were in the range of 11.0 x 10^2-570 x 10^4 cfu/g. *S. paratyphi* and *E. coli* were not detected in the smoked fish samples.

4 Discussion
The smoked fish samples have high amount of protein. This can help in reducing the problem of protein energy deficiency in the diets of Nigerians especially the children.

The peroxide values of the smoked fish were below the recommended value of between 20 and 40 mgeq./peroxide/kg for rancid taste to begin (da Silva et al., 2008)). The FFA values obtained were very low and this suggests that the level of fat decomposition in the fried and smoked fish samples is low. The values for FFA obtained are below the threshold for rancidity detection in smoked fish. The 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 (da Silva, 2002). The TBA values of smoked fish samples were also low. The TBA values of (1.03 – 1.11 mg TBA/kg) obtained for smoked fish is within the range specified by USFDA for smoked fish (da Silva et al., 2008). TVB-N is related to protein breakdown and is an index of fish spoilage (da Silva, 2002). The legislative standard for TVB-N include: 20mgN/100g for fresh fish, 30 mgN/100g for fish and 40 mgN/100g for fish that is unfit for human consumption but can be used for animal feed (FAO, 1992; da Silva, 2002). In this study, TVB-N of smoked fish samples is within the range of legislative standard for TVB-N which is 20mgN/100g for fresh fish. This suggests that the level of protein decomposition or breakdown in all the samples is low. The TMA of 1.82 – 2.95mgN/kg for smoked fish samples is within the range of < 3mgN/100g for fresh fish, >8mgN/100g for spoiled fish and ≥ 5mgN/100g for doubtful quality specified (da Silva et al., 2008).

Although the result of PAH analysis revealed the presence of sixteen (16) PAHs compounds analysed in the smoked fish samples. Ten of the sixteen (16) PAHs compounds in smoked fish samples have
concentrations above the 5.0μg /kg B(α)P maximum permissible levels stipulated by EU Regulation 1881/2006 (Amos-Tautua et al., 2013). This may pose danger to the consumer of these products.

The four heavy metals investigated in all the smoked fish samples showed that quantities detected are generally below the maximum permissible levels set by World Health Organization for fried and smoked fish products (Brain and Allen, 1993) for Pb (0.3 ppm); Cd (0.2 ppm), Hg (0.2ppm) and Cr (0.5ppm) and hence
Table 1 Proximate composition of smoked West African Ilisha samples from major markets in Ibadan, Oyo State, Nigeria

| Major markets | Moisture% | Protein% | Fat% | Crude fibre% | Ash% | Carbohydrate% |
|---------------|-----------|----------|------|--------------|------|--------------|
| Academy       | 12.56c    | 58.63f   | 14.16d | 1.87a        | 1.12a | 11.66c       |
| Apata         | 14.15c    | 56.42a   | 12.82b | 2.30b        | 1.41b | 12.90d       |
| Bodija        | 11.89b    | 52.13c   | 16.13f | 2.13c        | 1.54d | 16.18f       |
| Challenge     | 11.35b    | 55.63c   | 11.56a | 2.52d        | 1.33a | 17.61d       |
| Dugbe         | 13.62a    | 58.32f   | 14.89d | 2.47d        | 1.17a | 9.53b        |
| Gate          | 13.41d    | 53.86b   | 15.73c | 1.74a        | 1.23a | 14.03b       |
| Oja - Oba     | 15.18f    | 60.15b   | 13.62c | 1.81a        | 1.54d | 7.70a        |
| Oje           | 14.12c    | 57.38a   | 15.13e | 2.27c        | 1.45a | 9.65a        |
| Ojoo          | 12.59c    | 60.22a   | 14.18d | 1.94b        | 1.31a | 9.76a        |
| Sango         | 13.32d    | 54.24b   | 14.16d | 2.10a        | 1.42a | 16.25f       |

Data are means of 3 replicates
Data with the same subscript in the same column are not significantly different at p<0.05
Key: Fried = Fried fish
Smoked = Smoked fish

Table 2 Quality indices of smoked West African Ilisha samples from major markets in Ibadan, Oyo State, Nigeria

| Major markets | 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) |
|---------------|--------------------------------------|------------------------|--------------------------------------|---------------------------------------------|----------------------------------|
| Academy       | 9.18b                                | 1.34a                  | 1.03a                                | 18.11b                                      | 2.38a                            |
| Apata         | 9.12b                                | 1.40a                  | 1.10a                                | 18.32b                                      | 2.15a                            |
| Bodija        | 9.20b                                | 1.53a                  | 1.15a                                | 19.36c                                      | 2.43a                            |
| Challenge     | 9.15b                                | 1.62a                  | 1.13a                                | 17.29a                                      | 2.57a                            |
| Dugbe         | 9.04b                                | 1.39a                  | 1.07a                                | 17.43a                                      | 2.48a                            |
| Gate          | 8.96c                                | 1.57a                  | 1.08a                                | 18.27b                                      | 2.36a                            |
| Oja - Oba     | 9.03b                                | 1.29a                  | 1.16a                                | 17.71a                                      | 2.29a                            |
| Oje           | 8.99a                                | 1.26a                  | 1.04a                                | 18.86b                                      | 2.68a                            |
| Ojoo          | 9.11b                                | 1.13a                  | 1.09a                                | 18.03a                                      | 2.43a                            |
| Sango         | 9.07b                                | 1.17a                  | 1.11a                                | 17.81a                                      | 2.12a                            |

Data are means of 3 replicates
Data with the same subscript in the same column are not significantly different at p<0.05
Key: Fried = Fried fish
Smoked = Smoked fish
Table 3 Concentration (μg/kg) of polycyclic aromatic hydrocarbons in smoked West African Ilisha samples from major markets in Ibadan, Oyo State, Nigeria

| Type of PAH                  | Smoked fish |
|-----------------------------|-------------|
| Naphthalene                 | 4.53        |
| Acenaphthylene              | 5.78        |
| 1,2-Benzanthracene          | 5.52        |
| Acenaphthene                | 3.39        |
| Fluorene                    | 5.61        |
| Phenanthrene                | 5.82        |
| Anthracene                  | 5.89        |
| Fluoranthene                | 4.32        |
| Pyrene                      | 3.67        |
| Benzo(a)anthracene          | 5.13        |
| Chrysene                    | 4.56        |
| Benzo(b)fluoranthene        | 5.51        |
| Benzo(a)pyrene              | 5.94        |
| benzo [ghi] perylene         | 5.86        |
| Indeno(1,2,3-cd)pyrene      | 5.45        |
| Dibenzo(a,h)anthracene      | 5.79        |

Table 4 Heavy metals profile (Concentration (μg/g) of smoked West African Ilisha samples from major markets in Ibadan, Oyo State, Nigeria

| Major markets | Pb   | Cd   | Hg   | Cr      |
|---------------|------|------|------|---------|
| Academy       | 0.0011a | 0.0010a | 0.0020a | 0.0953b |
| Apati         | 0.0013a | 0.0011a | 0.0014a | 0.0972b |
| Bodija        | 0.0011a | 0.0016a | 0.0021a | 0.0912a |
| Challenge     | 0.0011a | 0.0013a | 0.0018a | 0.0926ab |
| Dugbe         | 0.0012a | 0.0017a | 0.0017a | 0.0949b |
| Gate          | 0.0013a | 0.0011a | 0.0014a | 0.0972b |
| Oja - Oba     | 0.0011a | 0.0016a | 0.0021a | 0.0912a |
| Oje           | 0.0011a | 0.0013a | 0.0018a | 0.0926ab |
| Ojoo          | 0.0012a | 0.0017a | 0.0017a | 0.0949b |
| Sango         | 0.0011a | 0.0016a | 0.0018a | 0.0928a |

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

Key: Fried = Fried fish  Smoked = Smoked fish

pose no risk to consumers (Amos-Tautua et al., 2013). The TVC values obtained for the smoked fish samples were within the range of specified microbiological limits recommended by ICMSF (1986) for fish and fishery products, the maximum recommended bacterial counts for good quality products (m) is 5 x 10^5 (5.7 log10 CFU/g). The *Staphylococcus* count values obtained for the smoked fish samples were below the specified recommended value for all fish samples. *S. aureus* was isolated from smoked fish samples and this can be attributed to post processing contamination. The *S. aureus* isolated from smoked fish samples was within the safety level which is equal to or greater than 10^5/g recommended by FDA, (2001). *S. paratyphi* was not detected in smoked fish samples and this conforms with the specified microbiological limits recommended by ICMSF (1986) for *S. paratyphi* count for fish and fishery products which is the presence of the organism, that is zero tolerance. In all cases, the absence of *S. paratyphi* and *E. coli* suggests Good Manufacturing Practices (GMP) and non faecal contamination of the products.

5 Conclusion

Based on this study smoked fish has high protein
content. The rancidity indices were also below the rancidity threshold. However, the presence of certain polycyclic aromatic hydrocarbons above the maximum recommended permissible level as well as the presence of S. aureus in some of the smoked samples may subject smoked fish consumers to chemical and microbiological risks if care is not taken.

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References

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

Adebayo-Tayo, B.C., Onilude, A.A., and Patrick, U.G., 2008, Mycoflora of Smoke-dried Fishes Sold in Uyo, Eastern Nigeria. World J. Agric Sci, p.23

Adeeyeey S.A.O., Oywewe O.B., Obadina A.O., Omemtu A.M., Adeniran O.E., Oyedele H.A. and Abayomi S.O., 2015, Quality and Safety Assessment of Traditional Smoked fish from Lagos State, Nigeria., International Journal of Aquaculture, 5(15): 1-9 (doi: 10.5376/ija.2015.05.0015)

Amos-Tautua B.M.W, Inengite, A.K.I, Abasi, C.Y and Amirize, GC 2013. Evaluation of polycyclic aromatic hydrocarbons and some heavy metals in roasted food snacks in Amassoma, Niger Delta, Nigeria. African Journal of Environmental Science and Technology 7(10): 961-966. DOI: 10.5897/AJEST2013.1545

Amusan E, Oramadike C.E, Abraham-Olukayode A.O., and Adejowo O.A., 2010, Bacteriological Quality of Street Vended Smoked Blue Whiting (Micromesistius poutassou). Internet Journal of Food Safety, 12: 122-126

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

da Silva, L. V. A., 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, L.V.A., Prinyawiwatkul, W, King, J.M., No, H.K., Bankston, J.D.Jr, and 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 http://dx.doi.org/10.1016/j.fm.2008.07.001

Doe, P.E., 1998, Fish Drying and Smoking Production and Quality, Lancaster, PA; Technomic Publishing Co., Inc., pp.89–115

European Commission, 2002, Opinion of the Scientific Committee on Food on the risk to human health of polycyclic aromatic hydrocarbons in food. SCF/CS/ CNTM/PAH/29/Final

European Commission, 2005a, Regulation (EC) No 208/2005 of 4 February 2005 amending Regulation (EC) No 466/2001 as regards polycyclic aromatic hydrocarbons. Official Journal of the European Community L 34, 3

European Commission, 2005b, Directive 2005/10/EC of 4 February 2005 laying down sampling methods and the methods of analysis for the official control of the levels of benz[a]pyrene in foodstuffs. Official

| Major markets | Salmonella paratyphi+ | Staphylococcal count | Escherichia coli count | Total viable count |
|---------------|----------------------|----------------------|-----------------------|--------------------|
| Academy       | 21.1 x 10^7          | -                    | 5.4 x 10^7            |
| Apara         | 19.3 x 10^7          | -                    | 3.3 x 10^7            |
| Bodija        | 32.0 x 10^7          | -                    | 1.0 x 10^7            |
| Challenge     | 57.0 x 10^7          | -                    | 4.1 x 10^7            |
| Dugbe         | 30.4 x 10^7          | -                    | 1.8 x 10^7            |
| Gate          | 29.0 x 10^7          | -                    | 2.5 x 10^7            |
| Oja - Oba     | 18.4 x 10^7          | -                    | 6.0 x 10^7            |
| Oje           | 15.2 x 10^7          | -                    | 2.2 x 10^7            |
| Ojoo          | 11.0 x 10^7          | -                    | 4.3 x 10^7            |
| Sango         | 24.3 x 10^7          | -                    | 6.2 x 10^7            |

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

Key: Fried = Fried fish Smoked = Smoked fish
Journal of the European Community L 34, 15
European Commission, 2007, Regulation (EC) No 333/2007 of 28 March 2007 laying down the methods of sampling and analysis for the official control of the levels of lead, cadmium, mercury, inorganic tin, 3-MCPD and benz(a)pyrene in food stuffs. Official Journal of the European Community L88, 29

Food and Agriculture Organisation of the United Nations, 1994, Review of the State of the World Fishery Resources; Marine Fisheries. FAO Fishery circular No 920. Rome

Fafioye, O. O, Efuntoye, M. O, Osho, A., 2002, Studies on the infestation of five traditionally smoked-dried fresh-water fish in Ago-Iwoye, Nigeria. Mycopathologia, 154: 177-179

FDA, Department of Health and Human Services, 2001, Pathogen Growth & Toxin Formation as a Result of inadequate Drying. In Fish & Fisheries Products Hazards & Controls Guidance: Third Ed. Chapter 14, p.191

ICMSF (International Commission on Microbiological Specifications for Foods), 1986, Microorganisms in Foods 2, Sampling for Microbiological Analysis. Principles and Specifications, 2nd edn. Oxford: Blackwell Science.

Odu N.N and Imaku L.N., 2013, Assessment of the Microbiological Quality of Street-vended Ready-To-Eat Bole (roasted plantain) Fish (*Trachurus Trachurus*) in Port Harcourt Metropolis, Nigeria. Researcher, 5(3): 9-18 (ISSN: 1553-9865)

Olatunde, A.A., 1998, Approach to the study of fisheries biology in Nigerian inland water. Proceedings of the International Conference of two decades of research in lake Kainji, pp.338-541

Simko, P., 2002, Determination of polycyclic aromatic hydrocarbons in smoked meat products and smoke flavouring food additives. B: Analytical Technologies in the Biomedical and Life Sciences, J. Chromatogra., 770: 3-18

Smirjakova S, Ondrassovicova O, Kaskova A, and Lakticova, K., 2005, The Effect of Cadmium and Lead Pollution on Human and Animal Health. Fol. Veter. 49: 31-32

Woyewoda, A.D., Shaw, S.J., Ke, P.J., and Burns, B.G., 1986, Quality indices-lipid related. In Recommended Laboratory Methods for Assessment of Fish Quality. Canadian technical report of fisheries and aquatic science, Canada

Zedec, M.S., 1980, Polycyclic aromatic hydrocarbons: a review. J. Envr. Pathol. Toxicol. 3: 537–567

Zeleznik, J., 1994, Occurrence of Heavy Metals in Smoked Meat Products (In Slovak). Atestation Thesis, Institute for Education of Veterinary Surgeons Kovice. p.46

Ziegler, R. G., 2000, Persons at high risks of cancer. Wall Str. J. 14: 10-12