https://dx.doi.org/10.4314/ijs.v23i2.9

CHEMICAL AND MICROBIAL PROPERTIES OF KILN-SMOKED CATFISH IN SELECTED LOCATIONS IN ILORIN METROPOLIS, NIGERIA

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(Received: 23rd March, 2021; Accepted: 30th May, 2021)

ABSTRACT

The use of smoking kiln for drying catfish is on the increase in Nigeria due to its effectiveness in reducing moisture and contamination with toxic compounds during smoking. Chemical properties of kiln-smoked catfish in selected locations in Ilorin metropolis were determined in this study. Kiln-smoked catfish were obtained from four major locations (Oyun, Asa-Dam, Tanke and Agbo-Oba) in Ilorin, Nigeria. The samples were subjected to chemical and polycyclic hydrocarbon content analyses. Dried catfish from all the locations had low moisture and crude fibre contents. There were no significant differences (p>0.05) in the crude fibre contents of the kiln-smoked catfish. Protein contents ranging from 53.72-56.49% were obtained for the kiln-smoked catfish samples. Fat contents ranged from 9.92-11.77% while the carbohydrate contents ranged from 19.02-23.59%. Potassium was the most abundant mineral in the samples with no traces of lead and cadmium. Agbo-Oba samples contained the highest pyrene (2983.215 ng/μl) and total polycyclic hydrocarbon (PAHs) (3349.090 ng/μl). Data on steroid fractions indicated that 17β-estradiol was significantly greater in quantity than those recorded from other steroid fractions. Microbial analyses of the samples revealed the presence of the following pathogenic organisms: *Klebsiella spp, Salmonella spp, Shigella spp, Pseudomonas aeruginosa, Staphylococcus aureus, Bacillus cereus, Vibrio spp, Aspergillus niger, penicilium spp, Trichoderma spp* which are harmful to man. The use of smoking kiln method improved the nutrients and reduced PAHs in catfish.

Keywords: Smoking kiln, Catfish, Chemical properties, Polycyclic hydrocarbon, Mineral elements

INTRODUCTION

Fish and shellfish are important contributors to the intake of many nutrients worldwide, especially in coastal areas (FAO, 2016). Nogueira *et al.* (2013) reported fish as an essential food item with easy digestibility, high mineral content, vitamin, quality protein and an excellent dietary source of polyunsaturated fatty acids (PUFAs) which are essential constituents of human diets. Nurnadia *et al.* (2011) described fish and shellfish as food with low fat and carbohydrate contents but with an excellent source of protein. Fish is a perishable food item with high moisture contents ranging from 56.99–68.46% (Fapohunda and Ogunkoya, 2006; Akpambang, 2015) and this high amount of moisture could make fish highly susceptible to microbial attacks after harvesting. According to Burt (2003), spoilage in fish could be enzymatic, microbial and chemical in nature. Large percentages (30–50%) of post-harvest losses in fish after harvesting, due to poor handling techniques, have been reported by Nwaigwe (2017). However, Bate and Bendall (2010) were of the opinion that proper handling, processing and preservation techniques could minimize the losses.

Akinola *et al.* (2006) reported different types of preservative methods that could be applied to fish among which are drying, smoking, freezing, chilling, brining etc. Most common of all these processing techniques in Nigeria is smoke-drying (Gawi and Sogbesan, 2017). Palm *et al.* (2011) describe smoking of fish as one of the ancient technologies used for preserving fish. FAO (2017) defined fish smoking as a process of treating or exposing the fish to smoke from smoldering wood or plant materials. According to Goulas and Kontominas (2005), components such as aldehydes, ketones, alcohols, acids, hydrocarbons, esters, phenols, ethers, etc. are transferred to the surface of the smoked goods and there is subsequent penetration of the smoke into their flesh. Eves and Brown (1993) stated that processing of fish by smoking or drying enhances the nutritive value and promotes digestibility of protein. Roda *et al.* (1999) however, explained that direct exposure of fish to smoke caused higher concentrations of polycyclic aromatic hydrocarbons in the fish as compared to the indirect methods.

Therefore, the use of modern technology in smoking fish is necessary to reduce contamination with toxic substances such as polycyclic aromatic hydrocarbon. Bolaji (2005) suggested that the use of modern equipment such as solar dryers, kilns and ovens is an upgrade on the traditional fish processing technique. In Nigeria, the use of smoking kiln on fish is now common and adopted by fish farmers. Smoking kiln is a fabricated equipment with drying and heating chambers. It had been reported that smoking kiln is safe and the temperature of the chamber is uniformly distributed for effective drying (Adigio *et al.*, 2015). Smoking kiln prevent direct flame to the fish thereby, preventing formation of black soot on the product (Adigio *et al.*, 2015). According to Okereke *et al.* (2014), smoking kiln prevents poor quality fish product, smoke and heat loss, uneven smoking, accommodate larger volumes of fish and saves time.

Lots of fabricated kiln had been produced and used in Nigeria for bulk production of dried fish. The source of smoke and heating is from sawdust, rice bran, melon husk and charcoal respectively as reported by Olayemi *et al.* (2013) and Aremu *et al.* (2013). Apart from the proximate composition of the kiln-smoked fish that have been widely studied, there is limited information on other nutritional value of kiln-smoked fish. This study determined the chemical and microbial properties of kiln-smoked catfish in selected locations from Ilorin metropolis, Nigeria.

MATERIALS AND METHODS

Kiln-smoked catfish were sourced from the four geographical locations of Ilorin metropolis namely Oyun, Asa-Dam, Tanke and Agbo-Oba

Analyses

Proximate and Mineral Determination

AOAC (2005) methods were used to determine moisture (Method 925.10), fat (Method 2003.05), ash (Method 923.03), Fibre (Method 930.15) and protein (Method 960.52), while carbohydrate was calculated by difference. Mineral was carried out according to the method of Novozamsky *et al.* (1983).

Polycyclic Hydrocarbon Determination

Sample preparation was done according to Palm *et al.* (2011) and the instrument is Agilent Technologies 7890A gas chromatograph system equipped with a Flame Ionization Detector (GCFID) and operating in split less mode. The column used was HP5 (30m x 320um x 0.25um) with a non-polar stationary phase (HP-5MS, 5% phenyl methyl polysiloxane). The oven temperature was set initially at 60 °C and held for 1 min. The first ramp rate increased to 210 °C at 12 °C/min and second ramp rate increased to 320 °C at 8 °C/min and held for 5 min. Carrier gas was Helium: Nitrogen, while the ignition gases were Hydrogen and compressed air. Total run time was 32.25 min and detector temperature was 325 °C. The inlet temperature was held at 270 ºC with flow rate of 1.2 ml/min, while injections of 1 μl of sample each were performed in the split less mode. Identification of PAHs in the samples was based on comparison of the retention times with those in a standard solution, and quantification on the corresponding areas of the respective chromatograms.

Determination of Steroid using HPLC

The method of Murad *et al.* (2016) was used for sterol extraction and determination in catfish samples. HPLC analysis was carried out using Agilent 1200 series HPLC system with Agilent 1260 detector. The column used was BONDAPAK-C_{18} with dimension 1.7 μm x 2.1 mm x50 mm. The mobile phase was composed of 0.2% aqueous formic acid (A) and acetonitrile (B). A gradient time program was designed as follows: 0 min, 50% A; 0-3.0 min, 50%-10% A; 3.0-5.0 min, 10% -50% A. Injection volume was 10 μl. The detection wavelength of the detector was set at 254 nm and flow rate of 0.3 ml/min at 20 °C.

Microbial Analyses

Bacteria and fungi load, isolation and identification were done according to Fawole and Osho (2001), while the biochemical tests were performed according to Collins *et al.* (2002)

Statistical Analyses

Proximate, mineral and steroid contents were analyzed in triplicate, while polycyclic hydrocarbon was analyzed in duplicate. Data obtained were subjected to analysis of variance (ANOVA) to determine the mean, standard deviation and significant differences among the samples ($P < 0.05$) and ($P<0.0001$) for steroid . The means were separated using Tukey Test as packaged by SPSS (ver. 17).

RESULTS AND DISCUSSION

Effect of Location on the Proximate Composition of Smoked Catfish

Proximate composition of kiln-smoked catfish in selected location in Ilorin, Kwara State, Nigeria is shown in table 1. The results showed that location had significant ($P<0.05$) effect on the moisture, ash, fat, protein and carbohydrate contents of catfish. However, there were no significant differences ($P>0.05$) in locations with respect to crude fibre of catfish. The results also showed that, catfish obtained from Oyun location had the highest total ash, crude fat and protein than catfish obtained from other locations. Likewise, catfish obtained from Tanke location recorded the highest contents in moisture and carbohydrate than those from other locations.

Moisture contents observed in all the samples were lower than reported values for smoked dried fish. Flowra *et al.* (2012) reported moisture contents of 14.06-24.58% for dried fish while Adeyeye *et al.* (2015) reported moisture contents of 11.86-13.81% for smoked fish samples. The variation noticed in moisture contents of the catfish can be due to the size, temperature and duration of drying. This result therefore indicated that kiln drying is suitable to remove an appreciable amount of moisture from fish thereby prolonging the shelf-life of the product. Oyun sample had the highest ash content (6.04%) while Tanke sample had the lowest ash value (4.92%). Ash contents observed indicated that the catfish are good source of minerals. Sesugh *et al.* (2012) and Ikeme (1991) observed ash contents of between 5.4-15% for dried fish while Nnaji and Ngele (2016) reported lower ash contents ranging from 2.07-3.55% for dried catfish obtained in the market. Crude fibre contents of the catfish were low and depended on the diet, age and size of the fish. Oyun sample exhibited the highest fat contents while sample from Agbo-Oba had the lowest fat content. Fat contents obtained were within the values (1.91-17.76%) reported for marine fish (Flowra *et al.*, 2012). Higher fat contents ranging from 16.5-27.50% had been reported for smoked catfish (Sesugh *et al.,* 2012; Nnaji and Ngele, 2016). The high fat content in the cat fish could be attributed to the removal of moisture content. High fat contents observed in Oyun sample could lead to short shelf-life as a result of rancidity.

Table 1: Effect of Location on the Proximate Composition of Catfish

Parameter	Location			
(%)	Oyun	Asa-Dam	Tanke	Agbo-Oba
Moisture	6.30 ± 0.04^{c}	6.49 ± 0.02^{b}	7.06 ± 0.05^{a}	6.33 ± 0.01^{c}
Total ash	6.04 ± 0.02^{a}	5.39 ± 0.02^{b}	4.92 ± 0.01^{d}	5.15 ± 0.03^{c}
Crude fibre	0.38 ± 0.01^{a}	0.37 ± 0.02^{a}	0.34 ± 0.04^{a}	0.41 ± 0.01^{a}
Crude fat	11.77 ± 0.05^{a}	10.51 ± 0.03^{b}	10.37 ± 0.02^{a}	9.92 ± 0.04^{d}
Crude protein	56.49 ± 0.04^{a}	55.67 ± 0.05^{b}	53.72 ± 0.03^{c}	55.77 ± 0.05^{b}
Carbohydrate	19.02 ± 0.04^{d}	$21.57\pm0,14^{c}$	23.59 ± 0.06^{a}	22.42 ± 0.10^{b}

Value with the same superscript along the row are not significantly different ($p<0.05$) from each other

Oyun sample was significantly different ($p<0.05$) from other samples in protein content, while no significant differences ($p>0.05$) in the protein values observed for samples from Asa-Dam and Agbo-Oba. The protein values observed in this study were similar to the values (30.60-68.05%) reported by Fapohunda and Ogunkoya (2006); Sesugh *et al.* (2012); Okereke *et al.* (2014); Adeyeye *et al.* (2015); Mohammad and Yusuf (2016) and Nnaji and Ngele (2016). Protein content of the dried smoked catfish depends majorly on the types of feed given to the fish, time and frequency of feeding, maturation size, processing and handling methods. The catfish contain appreciable amount of carbohydrate which could be in form of glycogen. Nutritional composition of kiln-smoked catfish had been reported to depend on the source of heat, feeding habit, sex and seasonal variations (Akinneye *et al*., 2010; Aremu *et al*., 2013; Abraha *et al*., 2018). The variation in the proximate composition of the catfish may be due to the type of feed intake of the fish, size, location, maturity and the different processing methods employed.

Effect of Location on the Mineral Composition of Smoked Catfish

Predominant mineral elements in the samples were potassium and calcium. Other elements detected at low concentrations were iron, copper, zinc, nickel and manganese. Table 2 revealed that sample location had significant ($P<0.05$) effects on the mineral contents of catfish examined. The results indicated that catfish samples obtained from Agbo-Oba had the highest iron (0.030 mg/ml) content than the fish obtained from other locations and was significantly different ($p<0.05$) from other samples. On the other hand, there were no significant differences ($p>0.05$) in iron contents in catfish obtained from Oyun, Asa-Dam and Tanke. The differences in the mineral content could be attributed to the habitat, type of feeds used by the farmers in rearing the fish as well as the amount of time and temperature employed during fish smoking process. The absence of lead and cadmium showed that consumption of the fish cannot impose health hazard to the consumers. Castro-gonzález and Méndez-armenta (2008) and Palaniappan and Karthikeyan (2009) suggested that heavy metals determination in fish is very important in order to identify the level and maintain concentration under permissible level. According to the European Union (2006), the maximum tolerable limit (MTL) of lead in fish is 0.3 mg/kg, copper is 0.020 mg/kg and cadmium, 0.05-0.3 mg/kg wet weight basis respectively. The heavy metals were not detected in the kiln-smoked catfish in all the locations showing that they are safe for human consumption. The variations in the mineral values could be as a result of the environmental conditions, feed, ecological requirements, metabolism and other factors such as salinity, water pollution level, and sediment (Ashraf *et al*. 2012).

Table 2: Effect of Location on the Mineral Contents (mg/ml) of Catfish

Parameter	Location			
	Oyun	Asa-Dam	Tanke	Agbo-Oba
Fe	0.020 ± 0.000^{b}	0.025 ± 0.003^{b}	0.025 ± 0.002^{b}	0.030 ± 0.001^{a}
Cu	0.025 ± 0.003^{bc}	0.029 ± 0.004^{b}	0.040 ± 0.000^{a}	0.020 ± 0.000^{c}
Zn	0.030 ± 0.002^{a}	0.020 ± 0.004^{b}	0.020 ± 0.001^{b}	0.010 ± 0.000^{c}
Ni	0.010 ± 0.000^{c}	0.020 ± 0.002^{a}	0.010 ± 0.000^{b}	0.015 ± 0.007^{bc}
Mn	ND	ND	ND	ND
Pb	ND	ND	ND	ND
Cd	ND	ND	ND	ND
K	0.425 ± 0.007^{a}	0.295 ± 0.007^{c}	0.310 ± 0.004^{bc}	0.320 ± 0.009^{b}
Ca	0.250 ± 0.000^{a}	0.210 ± 0.014^{c}	0.225 ± 0.021^{b}	0.220 ± 0.014^{bc}

Value with the same superscript along the row are not significantly different ($p<0.05$) from each other. ND= Not detected

Effect of Location on the Polycyclic Aromatic Hydrocarbons of Smoked Catfish

Polycyclic aromatic hydrocarbon (PAHs) contents of catfish samples from selected locations in Ilorin metropolis is as shown in table 3. The PAHs identified in the catfish samples were Acenaphthne, Acenaphthylene, Anthracene, Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Fluoranthene, 2-Methylnaphthalene, Naphthalene, Phenanthrene, and Pyrene. Out of the 13 PAHs detected, five (5) were identified in Oyun, seven (7) in Asa-Dam, seven (7) in Tanke and nine (9) were identified in Agbo-Oba. Agbo-Oba sample had highest Pyrene (2983.215 ng/μl), Benzo(a)anthracene (182.891 ng/μl), Benzo(b)fluoranthene (61.012 ng/μl), Benz(k)fluoranthene (12.815 ng/μl), Chrysene (28.947 ng/μl), Anthracene (25.742 ng/μl) and Naphthalene (25.236 ng/μl). Agbo-Oba sample had the highest total PAHs (3349.090 ng/μl) followed by Tanke (1851.170 ng/μl), Oyun (891.130 ng/μl) and Asa-Dam (347.870 ng/μl) in decreasing order.

Table 3: Effect of Location on Polycyclic Hydrocarbon (ng/µl) of Catfish

PAH	Oyun	Asa-Dam	Tanke	Agbo-Oba
Acenaphtene	ND	0.860±0.06[a]	ND	ND
Acenaphthylene	ND	0.510±0.02[a]	0.601±0.03[a]	ND
Anthracene	15.766±1.10[b]	2.611±0.21[c]	15.977±0.33[b]	25.742±2.50[a]
Benz(a)anthracene	9.677±0.40[c]	ND	29.853±1.20[b]	182.891±1.00[a]
Benzo(b)fluoranthene	ND	ND	58.914±2.40[a]	61.012±2.01[a]
Benzo(k)fluoranthene	ND	5.386±1.50[c]	8.116±0.31[b]	12.815±0.30[a]
Chrysene	ND	ND	ND	28.947±0.52[a]
Dibenz(a,h)anthracene	ND	ND	56.383±0.30[a]	ND
Fluoranthene	606.441±2.52[a]	233.895±2.25[b]	ND	ND
2-Methylnaphthalene	ND	ND	ND	26.529±0.81[a]
Naphthalene	ND	ND	ND	25.236±0.40[a]
Phenanthrene	2.313±0.19[a]	1.128±0.30[b]	ND	2.700±0.61[b]
Pyrene	256.929±3.52[c]	103.479±1.20[d]	1681.330±2.70[b]	2983.215±4.90[a]
Total PAHs	891.130±2.62[c]	347.870±2.50[d]	1851.170±3.21[b]	3349.090±3.73[a]

Value with the same superscript along the row are not significantly different ($p<0.05$) from each other. ND-Not detected

PAHs have been identified as mutagenic and carcinogenic compounds. Benzo(a)pyrene is among the most potent and best documented carcinogen (Food Safety Authority of Ireland, 2015). Warshawsky (2000) listed the following PAHs such a Benzo(a)anthracenes, Benzofluoranthracenes, Benzo(a)pyrenes, Chrysenes, and Dibenz(a,h)anthracene as four to five ring PAHs belonging to carcinogenic compounds. Ndiaye et al. (2015) reported that the use of wood and charcoal to smoke fish increases the risk of contamination with byproducts of combustion such as PAHs and other contaminants. PAHs may be formed during processing and domestic food preparation such as barbecuing, smoking, drying, roasting, baking, frying or grilling. Direct fire-drying and heating processes used during the production of oils from plant origin, fish and meat caused pyrolysis of the dripping oil thereby generating PAHs that is deposited on the surface of the product (Food Safety Authority of Ireland, 2015; Lee et al., 2016; Lawal, 2017). Lee et al. (2016) further concluded that PAHs formation during grilling of meat and fish is dependent on fat contents, cooking duration and temperature used for cooking. According to Food Safety Authority of Ireland (2015) the maximum allowed PAHs (such as Benzo(a)pyrene, Benz(a)anthracene, Benzo(b)fluoranthene and Chrysene) in smoked fish is 30 µg/kg while maximum limit for Benzo(a)pyrene is 2.0 µg/kg, though Benzo(a)pyrene was not detected in all the catfish samples analyzed. Higher values of PAHs found in Agbo-Oba and Tanke may be due to the type of wood used as the source of fuel, temperature, duration and the conditions of the water used in rearing the fish. Temperature and time of smoking are major factors determining pyrolysis reaction taking place during smoking with the formation of polycyclic aromatic hydrocarbons which are deposited on food materials. According to Lawal (2017), higher PAHs in fish may also be attributed to residual PAHs found in rivers, lakes etc due to vehicle emission, coal and biomass combustions. Zenlinkova and Zendi (2015) in their review reported the presence of low molecular PAHs such as Naphthalene, Acenaphthene, Fluorene, and Phenanthrene in some fresh sea fish species. Therefore, location from where the catfishes were sourced had impact on the PAH of the kiln-smoked fish due to the nature of habitat, source of fuel available, processing and handling methods adopted.

Effect of Location on the Steroids of Kiln-Smoked Catfish

Steroids in Kiln-smoked catfish were significantly affected by location and steroids fractions (Table 4). Six types of steroids were identified in the catfish samples analyzed. Regardless of the steroid fractions, kiln-smoked catfish obtained from Agbo-Oba had significantly the highest amounts of steroids and followed in decreasing order of magnitude by those of Asa-Dam, Tanke and Oyun respectively. Data on steroid fractions indicated that 17β-estradiol was significantly greater in quantity than those recorded from other steroid fractions. The testosterone was next in quantity and was also statistically different from other steroid fractions. Significant difference ($P>0.0001$) was not recorded between estriol and progesterone but both were significantly higher than keto-testosterone and estrone. Estrone had the least value among the steroid fractions but was statistically similar to that of keto-testosterone.

Consumption of food with residual steroid could pose health problem to the consumer. Duarte *et al.* (2002) reported serious problem of premature sexual development and ovarian cysts in consumers of meat products with zeranol residue in Puerto Rico. Likewise, Bergman *et al.* (2013) reported endocrine disorder and cancer as the implication of eating steroids contaminated foods. Hormones are used to increase productivity in fish farming but the chemicals could contaminate the environment, promote endocrine system changes thereby causing environmental, biological and food safety problem (Hogaa *et al.*, 2018). The Joint FAO/WHO Expert Committee on Food Additives (JECFA) established an acceptable daily intake of 0–0.05 μg/kg per body weight intake for 17β-estradiol, 0–30 μg/kg per body weight for progesterone and 0–2 μg/kg per body weight for testosterone (JECFA, 2000). The steroid values identified in this study were low when compared to the daily limit established.

Table 4: Steroid (μg/100g) in Catfish at Selected Locations in Ilorin Metropolis

Results of variation	Factor	Steroids (μg/100g)
Location	Agbo-Oba	7.49×10^{-4a}
	Asa-Dam	5.45×10^{-4b}
	Oyun	5.13×10^{-4c}
	Tanke	5.38×10^{-4bc}
Steroid fractions	17β-Estradiol	19.4×10^{-4a}
	Estriol	1.74×10^{-4c}
	Estrone	0.87×10^{-4d}
	Ketotestosterone	1.12×10^{-4d}
	Progesterone	1.64×10^{-4c}
	Testosterone	5.26×10^{-4b}
P-value	Location (L)	<0.0001
	Steroid fractions (S)	<0.0001
	L *S	<0.0001

Values are presented as mean ± standard error. Values followed by same superscripts along a column are not significantly different at $p< 0.0001$). NB: *= interaction.

Effect of Location on the Microbial Properties of Kiln-Smoked Catfish

The result of characterization of bacteria isolates are shown in table 5. The probable bacteria isolates identified from various locations are as follows: Tanke (*Staphylococcus aureus, Pseudomonas aeruginosa* and *Serratia spp*), Agbo-Oba (*Klebsiella spp., Salmonella spp., Pseudomonas aeruginosa*) and *Vibrio spp*), Asa-Dam (*Klebsiella spp., Pseudomonas aeruginosa*, *Vibrio spp, Bacillus cereus* and *Staphylococcus aureus*) and Oyun (*Klebsiella spp., Pseudomonas aeruginosa, Salmonella spp* and *Shigella spp*.). Based on these results, it could be deduced that *Pseudomonas aeruginosa* is common among the fish samples obtained from various locations.

The presence of *Bacillus cereus* may arise from the food contact surfaces where the catfish had been exposed to. Wonang *et al*. (2001) stated that *Bacillus cereus* has been reported to cause food poisoning.

On the other hand, Mbachu *et al.* (2014) reported that toxins produced by *Bacillus* sp. are capable of causing some diseases such as pneumonia and bronchopneumonia. The presence of *Klebsiella* sp. is an indication of poor handling practices among handlers and sellers of kiln-smoked catfish, while the presence of *Pseudomonas* specie has also been implicated in food spoilage (Mbachu *et al.*, 2014). The results in table 5 show that kiln-smoked catfish in these locations were colonized by *Pseudomonas aeruginosa.* Their presence is of public health significance, because they are capable of causing infections such as food-borne intoxication (Edem *et al.,* 2017). According to Thi *et al.* (2020), *Pseudomonas aeruginosa* is a Gram negative opportunistic pathogenic organism causing acute and chronic infections when ingested which could compromise immune systems.

Staphylococcus aureus, Salmonella spp., Vibrio spp. and *Shigella spp.* were isolated from kiln-smoked catfish. This could be as a result of handling, transportation as well as exposure of the kiln-smoked catfish to the dirty environment. These organisms are of public health significance as they are considered the leading cause of food-borne disease outbreak worldwide (Karagozlu *et al.*, 2007). The presence of *Shigella* sp. had been reported to be detrimental to the health of consumers (Arlington, 2007). The FDA standard limit for *Salmonella spp* and *Vibrio spp* in food is 0.0 Cfu/ml (FDA, 2001). The presence of these organisms in kiln-smoked catfish is currently of public concern.

Kadariya *et al.* (2014) reported that toxin production strain of *Staphylococcus* is the leading cause of gastro enteritis following handling of food by the person who harbors the microorganism in the nose and on the skin. Figure 1 and table 6 showed the bacteria and fungi isolates. Predominant fungal was *Penicillium spp* while others include *Trichoderma spp, Geotricum albidum, Fusarium oxysporium, Aspergillus niger* and *Fusarium oxysporium.* The microbial loads of kiln-smoked catfish are presented in table 7. The bacteria counts ranged from 1.9 x 10^6 to 2.0 x 10^7cfu/g for Tanke location; 1.7 10^7 to 6.4 x 10^7cfu/g for Agbo-Oba location. The bacteria count recorded for Asa-Dam and Oyun were from 3.7 x 10^7 to 7.0 x $10^7$and 2.0 x 10^6 to 8.0 x 10^6cfu/g respectively.

The fungal count obtained in this study for Tanke location was between 2.5 x 10^3 and 2.2 x 10^4 cfu/g; Agbo-Oba location from 8.2 x 10^3 to 3.6 x 10^4 cfu/g; Asa-Dam location ranged from 1.0 x 10^3 to 1.4 x 10^3 cfu/g and Oyun location ranged from 0.0 x 10^2 to 2.0 x 10^3 cfu/g.

In order to prevent the occurrence of food-borne diseases, Elijah *et al.* (2020) posited the necessity to ensure that foods sold to consumers are hygienic and safe for human consumption. Therefore, the hygienic quality and the associated potential health hazards of food could be linked to the microbial load and the presence of pathogenic microorganisms in foods (Hoque *et al.*, 2015).

Table 5: Characteristics of Bacteria in Kiln-smoked Catfish in Selected Locations in Ilorin Metropolis

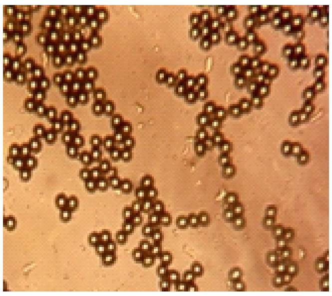
Samples	Gram reaction	Shape	Catalase Test	Oxidase test	Mannitol Test	Indole test	EMB Test	Triple sugar iron test	Presumptive identification
Tanke	-	Cocci single /clustered	+	-	-	-	-	Absence of carbohydrate fermentation	*Staphylococcus aureus*
	-	Rods chain single	+	-	-	+	-	Dextrose, Lactose, Sucrose (DLS)	*Pseudomonas aeruginosa*
	+	Rods single	+	-	-	+	-	DLS	*Serratia spp*
Agbo- Oba	-	Rods single	+	-	-	+	-	DLS and gas production	*Klebsiella spp*
	-	Rods single	+	-	-	-	-	DLS	*Salmonella spp*
	-	Rods single	+	+	+	-	-	DLS and gas production	*Pseudomonas aeruginosa*
	+	Rods single	+	+	+	-	-	DLS	*Klebsiella spp*
	-	Rods single	+	+	-	-	-	Absence of carbohydrate fermentation	*Pseudomonas aeruginosa*
	-	Rods single	+	+	-	-	-	Absence of carbohydrate fermentation and presence of H_2	*Pseudomonas aeruginosa*
	-	Rods single	+	+	+	+	-	Absence of carbohydrate fermentation	*Vibrio spp*
	-	Filamentus	+	-	-	-	-	-	*Pseudomonas aeruginosa*
Asa-Dam	+	Rods single	+	-	+	+	-	-	*Klebsiella spp*
	-	Rods single	+	+	+	+	-	DLS	*Vibrio spp*
	-	Rods single	+	+	+	-	-	Absence of carbohydrate fermentation and gas production	*Pseudomonas aeruginosa*
	+	Rods single	+	-	+	-	-	DLS and gas production	*Bacillus cereus*
	-	Cocci clustered	-	-	+	-	-	DLS and gas production	*Staphylococcus aureus*
Oyun	-	Rods single	+	+	+	-	-	DLS	*Pseudomonas aeruginosa*
	-	Rods single	+	-	-	-	-	DLS	*Salmonella spp*
		Rods single	-	-	+	+	-	DLS	*Klebsiella spp*
	+	Rods single	+	+	+	-	-	Absence of carbohydrate fermentation	*Klebsiella spp*
	-	Rods single	+	-	-	+	-	DLS and gas production	*Klebsiella spp*
	-	Rods single	-		+	+	-	DLS and gas production	*Shigella spp*

Table 6: Bacteria and Fungi Isolates from Dried Catfish obtained from different Locations in Ilorin Metropolis

Location	Bacterial Isolate	Fungi Isolate
Tanke	*Staphylococcus aureus, Pseudomonas aeruginosa, Serrataspp*	*Trichoderma spp, Geotricum albidum, Fusariumoxysporium*
Agbo-Oba	*Klebsiella spp, Salmonella spp, Vibrio spp, Pseudomonas aeruginosa*	*Aspergillus niger, Fusarium oxysporium, Penicillium spp*
Asa-Dam	*Klebsiella spp, Vibrio spp, Pseudomonas aeruginosa, Staphylococcus aureus, Bacillus cereus*	*Penicillium spp*
Oyun	*Klebsiella spp, Salmonella spp, Shigella spp, Pseudomonas aeruginosa*	*Penicillium spp, Trichoderma spp*

Table 7: Microbial Load of Kiln-Smoked Catfish from Selected Location in Ilorin Metropolis

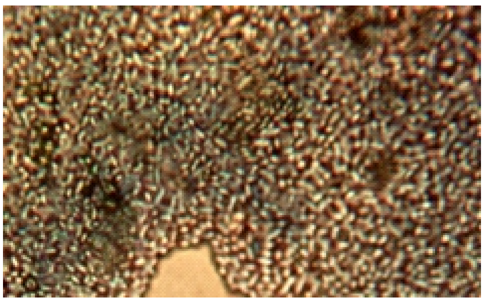
Location	Bacteria Count (cfu/g)		Fungi Count (cfu/g)	
	10^{-5}	10^{-6}	10^{-2}	10^{-3}
Tanke	1.9×10^{6}	2.0×10^{7}	2.5×10^{3}	2.2×10^{4}
Agbo-Oba	1.7×10^{7}	6.4×10^{7}	8.2×10^{3}	3.6×10^{4}
Asa-dam	3.7×10^{7}	7.0×10^{7}	1.4×10^{3}	1.0×10^{3}
Oyun	2.0×10^{6}	8.0×10^{6}	0.0×10^{2}	2.0×10^{3}



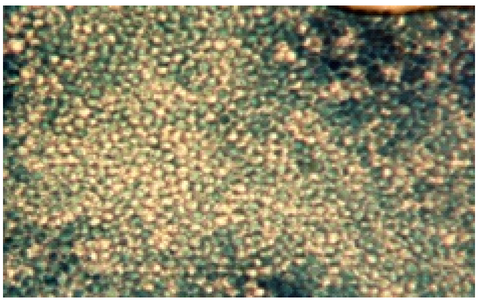
Trichoderma spp

Fusarium oxysporium

Pennicillium spp



Aspergillus niger



Geotricum albidum

Figure 1: Fungi Isolates from Kiln-smoked Fish

CONCLUSIONS

With this study, it could be deduced that the parameters analyzed varied according to location, and this may be due to the feed, fish size, maturity, source of fuel, exposure of habitat to pollutants, processing and handling techniques etc. Appreciable amount of protein were retained after smoking with low moisture contents. The use of smoking kiln did not totally eliminate the polycyclic aromatic hydrocarbon (PAH) contamination in the catfish during smoking but greatly reduced PAH when compared to the quantities recorded using traditional methods. Mineral contents of the kiln-smoked catfish depend majorly on the habitat, feed and location. Heavy metals were not detected in the catfish samples making the product safe for human consumption. Moreover, steroid contents of the catfish samples were low and could not impose any health risk on the consumers. The microbial isolates indicated that the kiln-smoked catfish samples were contaminated during handling and processing. Therefore, enlightenment and sensitization of fish processors on hygiene is very paramount in order to prevent outbreak of food borne diseases.

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