

# THE SIGNIFICANCE OF PROCESSING TECHNIQUES ON THE QUALITY OF SMOKED AFRICAN CAT FISH (*Clarias gariepinus*) USING DIFFERENT ENERGY SOURCES

## ABSTRACT

There is unavoidable need for fish smoking as a preservative technique to reduce rampant post harvest losses in the tropical Africa. However the imperative of healthier and quality smoked products through improved processing method were however investigated. Organoleptic and chemical assessment of African catfish collected from a reputable fish farm in Ogbomoso, Oyo state Nigeria was carried out. Eviscerated and non-eviscerated fish samples were smoked using four different smoke sources: Gmelina (*Gmelina arborea*), Parkia (*Parkia biglobosa*), Neem (*Azadirachita indica*) and charcoal. Overall acceptability was based on 5-point Hedonic scale (excellent (5) - poor (1). Chemical test was on Polycyclic Aromatic Hydrocarbon contents (benzo(a)pyrene, Fluoranthene, Naphthalene, Acenaphthalene, Chrysene and Benzo(ghi) perylene). Data were subjected to one way Analysis of Variance (ANOVA) using general linear mode (GLM) of Factorial Experimental Design and means were separated by Duncan's multiple range tests ( $P < 0.05$ ). Non- eviscerated smoked African catfish samples had lower scores for colour than eviscerated smoked samples for energy sources used. Eviscerated samples had mean scores of 4.64, 3.91, 3.36 and 2.82 for charcoal, Gmelina, Neem and Parkia smoked samples respectively, much better than scores of 4.36, 2.46, 2.36 and 2.27 obtained for non-eviscerated samples. Total concentrations of polycyclic aromatic hydrocarbons (PAH) were highest in samples produced using Gmelina as smoke source and Neem for eviscerated (15.25  $\mu\text{g}/\text{kg}$ ) and non-eviscerated (29.43  $\mu\text{g}/\text{kg}$ ) samples respectively. Evisceration of fish prior to smoking enhances its sensory characteristics however; concentrations of PAHs for both eviscerated and non-eviscerated fish samples were within the recommended international standard limit.

**Keywords:** Catfish, smoked fish, smoke sources, organoleptic properties

## 1. INTRODUCTION

Fish is a very important source of animal protein, whose importance has been recognized by man from the distant past [1]. The nutritional benefits of fish are linked to high quality protein and the presence of certain vitamins and minerals [2]. In addition, the fish contain polyunsaturated fatty acids that play an important role in human health [3]. Fish consumption is not forbidden within religious groups, unlike eating beef, dog, and pork, which is forbidden in some religions [4]. The drying effects during smoking, together with the antioxidant and bacteriostatic effects of the smoke, allow smoked products to have extended shelf life [5]. In Nigeria, processing of fish either through smoking or drying is widely used in fish preservation. In the process, moisture content present in the fish is extracted through heating, thus inhibiting the action of micro-organisms and prolongs shelf life [6, 7, 8]. Storage life extension of smoked fish can result from a combination of lowered water activity and the uptake by the product of bactericidal and antioxidant components of wood smoke [9, 10]. Smoking is one of the fish preservation methods that combine drying and decomposition of wood during combustion that lead to component such as phenol, formaldehyde, organic acids, and polycyclic aromatic hydrocarbons [11]. Smoking is mainly applied because it improves the organoleptic profile such as, colour, texture, and flavour of the fish [12]. On the other hand, it provides undesirable effects of amount which, the most important is the contamination of food by toxic and carcinogenic compounds such as PAHs, N-nitrosamines, aromatic amines, and  $\beta$ -carbolines [13]. Smoke is the product of incomplete combustion of wood and consists of numerous individual components, namely, aldehydes, ketones, alcohols, acids, hydrocarbons, esters, phenols, ethers, etc. These components are transferred to the smoked goods by deposition on their surface and subsequent penetration into their flesh [14]. For this reason, the exportation of smoked fish is becoming increasingly stringent due to the emergence of food safety and agricultural health standard, along with the fact that buyers keep changing their requirements, offer new parameters for food safety [15].

This experiment was undertaken to determine the variation in the level of Polycyclic Aromatic Hydrocarbons present in eviscerated and non-eviscerated smoked African catfish (*Clarias gariepinus*)

samples and also to examine the organoleptic characteristics using different smoke sources (Gmelina, Parkia, Neem and charcoal) with the aim of predicting their suitability for human consumption.

## 2. MATERIALS AND METHODS

A total of hundred (100) smoking size African catfish (*C. gariepinus*) were obtained from a reputable fish farm in Ogbomoso. The modern smoking process (using charcoal oven) experiment was carried out at the fishery unit, Ladoko Akintola University of Technology (LAUTECH) Teaching and Research Farm, Ogbomoso. African catfish samples were eviscerated, washed with clean water and smoked using four different fuel sources Gmelina (*Gmelina arborea*), African locust bean (*Parkia biglobosa*), Neem (*Azadirachita indica*) and charcoal. Fifty (50) fresh fish samples were eviscerated while the remaining fifty were not eviscerated. The fish were then scrubbed with potassium aluminum sulfate and later rinsed with clean water. They were all placed inside the charcoal oven for drying. The fish samples were turned every 2 hours to prevent the fish from burning. The drying lasted for 36 hours after which the fish were removed from the smoking chamber. The samples were kept at room temperature after complete dryness and about 5g samples for each treatment were transported to the laboratory for analysis.

### 2.1 Organoleptic Assessment

The smoked fish samples assessment was based on scoring system which involved measurement of certain parameters on a 5-point hedonic scale (excellent (5), very good (4), good (3), fair (2) and poor (1) for colour, texture, taste, flavour and overall acceptability. [16]

### 2.2 Chemical Analysis

Smoked fish were analyzed for the following Polycyclic Aromatic Hydrocarbon contents: (Benzo(a)pyrene, Fluoranthene, Naphthalene, Acanaphthalene, Benzo(ghi)perylene), Chrysene, Pyrene and Phenanthrene. This was carried out according to the method recommended by Moret and Conte (2002) [17] at the Animal science laboratory, University of Ibadan, Oyo state.

### 2.3. Statistical Analysis

Data collected were subjected to one way Analysis of Variance (ANOVA) using general linear Model (GLM) of Factorial Experimental Design and means were separated by Duncan's multiple range test ( $P = .05$ ).

## 3. RESULTS AND DISCUSSION

### 3.1 Sensory Evaluation

The mean sensory score for colour in eviscerated African catfish as shown in Table 1 are 4.64, 3.91, 3.36 and 2.82 respectively for charcoal, Gmelina, Neem and Parkia, much better than scores of 4.36, 2.46, 2.36 and 2.27 obtained for non-eviscerated fish samples (Table 2) smoked with charcoal, Parkia, Neem and Gmelina respectively. Eviscerated samples also produced better scores of texture, taste and acceptability for all treatments. Non eviscerated fish samples only had better score for flavour than eviscerated in all treatments except Parkia smoked sample. The samples were all generally acceptable to the taste panel.

### 3.2 Polycyclic Aromatic Hydrocarbons Concentration

Generally, smoke sources employed had a significant effect ( $P = .05$ ) on concentrations of all PAHs. As shown in Table 4, smoked eviscerated African catfish produced using Gmelina had highest concentration of Acenaphthalene ( $0.74\mu\text{g}/\text{kg}$ ), Pyrene ( $1.92\mu\text{g}/\text{kg}$ ) and Naphthalene ( $2.89\mu\text{g}/\text{kg}$ ) while charcoal smoked samples had lowest concentration in all PAHs except Benzo(ghi)perylene ( $0.67\mu\text{g}/\text{kg}$ ). In non-eviscerated African catfish samples, charcoal smoked samples record highest concentration (Table 5) in chrysene ( $2.75\mu\text{g}/\text{kg}$ ), Benzo(a)pyrene ( $2.95\mu\text{g}/\text{kg}$ ) and Naphthalene ( $3.76\mu\text{g}/\text{kg}$ ). However, total concentration of PAHs in eviscerated fish sample was highest in Gmelina smoked samples ( $15.25\mu\text{g}/\text{kg}$ ) and the lowest was in charcoal ( $2.19\mu\text{g}/\text{kg}$ ) while the highest total PAHs in non-eviscerated was in Neem smoked fish ( $29.43\mu\text{g}/\text{kg}$ ) and the least was recorded in Gmelina ( $15.25\mu\text{g}/\text{kg}$ ).

**Table 1: Sensory scores for Eviscerated African Catfish (*C. gariepinus*) smoked under different energy sources**

<b>Parameter</b>	<b>GSE</b>	<b>Judgement</b>	<b>PSE</b>	<b>Judgement</b>	<b>NSE</b>	<b>Judgement</b>	<b>CSE</b>	<b>Judgement</b>
<b>Colour</b>	3.91	Light	3.36	Intermediate	2.82	Intermediate	4.64	Very light
<b>Flavour</b>	2.61	Medium	2.55	Medium	2.52	Medium	2.67	Slightly mild
<b>Texture</b>	2.55	Medium firm	3.55	Firm	3.27	Medium firm	2.27	Delicate
<b>Taste</b>	3.27	Fair	3.55	Good	4.09	Good	3.01	Fair
<b>Acceptability</b>	2.88	Acceptable	3.25	Acceptable	3.25	Acceptable	3.07	Acceptable

*GSE: Gmelina smoked eviscerated PSE: Parkia smoked eviscerated NSE: Neem smoked eviscerated CSE: Charcoal smoked eviscerated*

**Table 2: Mean sensory scores for Non-eviscerated African catfish (*C. gariepinus*) smoked under different energy sources**

	<b>GSNe</b>	<b>Judgement</b>	<b>PSNe</b>	<b>Judgement</b>	<b>NSNe</b>	<b>Judgement</b>	<b>CSNe</b>	<b>Judgement</b>
<b>Colour</b>	2.57	Dark	2.46	Dark	2.36	Dark	4.36	Light
<b>Flavour</b>	2.82	Medium	2.72	Medium	2.64	Medium	2.64	Medium
<b>Texture</b>	2.18	Delicate	2.82	Medium firm	3.09	Medium firm	2.27	Delicate
<b>Taste</b>	2.46	Bad	3.18	Fair	3.18	Fair	3.82	Good
<b>Acceptability</b>	2.43	Moderately acceptable	2.80	Acceptable	2.82	Acceptable	3.27	Acceptable

*GSNe: Gmelina smoked non-eviscerated PSNe: Parkia smoked non-eviscerated NSNe: Neem smoked non-eviscerated*

*CSNe: Charcoal smoked non-eviscerated*

**Table 3: Mean Sensory score for Eviscerated and Non-eviscerated African Catfish (*C. gariepinus*).**

Parameters	Treatments							
	GSE	GSNe	PSE	PSNe	NSE	NSNe	CSE	CSNe
<b>Colour</b>	3.91	2.27	3.36	2.46	2.82	2.36	4.64	4.36
<b>Flavour</b>	2.61	2.82	2.55	2.72	2.82	2.64	2.27	2.64
<b>Texture</b>	2.55	2.18	3.55	2.82	3.27	3.09	2.27	2.27
<b>Taste</b>	3.27	2.46	3.55	3.18	4.09	3.18	3.01	3.82
<b>Acceptability</b>	2.88	2.43	3.25	2.80	3.25	2.82	3.07	3.27

*GSE: Gmelina smoked eviscerated, GSNe: Gmelina smoked non-eviscerated, PSE: Parkia smoked eviscerated, PSNe: Parkia smoked non-eviscerated, NSE: Neem smoked eviscerated, NSNe: Neem smoked non-eviscerated, CSE: Charcoal smoked eviscerated, CSNe: Charcoal smoked non-eviscerated.*

**Table 4: Concentration of Polycyclic Aromatic Hydrocarbons present in Smoked Eviscerated African catfish (*C. gariepinus*) using different energy sources**

Parameters	Treatments				
	GSE	PSE	NSE	CSE	SEM
<b>Benzo (ghi)perylene (µg/kg)</b>	0.76 <sup>a</sup>	0.69 <sup>a</sup>	0.12 <sup>b</sup>	0.67 <sup>b</sup>	0.16
<b>Acenaphthrene (µg/kg)</b>	0.74 <sup>a</sup>	0.68 <sup>a</sup>	0.73 <sup>a</sup>	0.31 <sup>a</sup>	0.11
<b>Phenanthrene (µg/kg)</b>	1.24 <sup>a</sup>	1.72 <sup>a</sup>	0.17 <sup>b</sup>	0.05 <sup>b</sup>	0.19
<b>Chrysene (µg/kg)</b>	2.70 <sup>b</sup>	2.71 <sup>b</sup>	0.72 <sup>a</sup>	0.31 <sup>a</sup>	0.24
<b>Pyrene (µg/kg)</b>	1.92 <sup>b</sup>	1.86 <sup>b</sup>	0.23 <sup>a</sup>	0.18 <sup>a</sup>	0.40
<b>Benzo (a)pyrene(µg/kg)</b>	2.74 <sup>a</sup>	2.75 <sup>a</sup>	0.73 <sup>a</sup>	0.32 <sup>b</sup>	0.26
<b>Fluoranthene (µg/kg)</b>	2.04 <sup>a</sup>	2.19 <sup>b</sup>	0.25 <sup>b</sup>	0.19 <sup>b</sup>	0.24
<b>Naphthalene (µg/kg)</b>	2.89 <sup>a</sup>	3.83 <sup>a</sup>	0.83 <sup>b</sup>	0.79 <sup>b</sup>	0.37
<b>ΣPAHs (µg/kg)</b>	15.25 <sup>c</sup>	11.91 <sup>b</sup>	2.27 <sup>a</sup>	2.19 <sup>a</sup>	3.17

Mean with same superscript are not significantly different according to Duncan Multiple range test (DMRT) at p=0.05.

GSE: Gmelina smoked eviscerated PSE: Parkia smoked eviscerated NSE: Neem smoked eviscerated CSE: Charcoal smoked eviscerated

**Table 5: Concentration of Polycyclic Aromatic Hydrocarbons present in Smoked Non-Eviscerated African catfish (*C. gariepinus*) using different energy sources**

Parameters	Treatments				SEM
	GSNe	PSNe	NSNe	CSNe	
<b>Benzo (ghi)perylene (µg/kg)</b>	0.80 <sup>b</sup>	1.08 <sup>a</sup>	1.23 <sup>a</sup>	0.29 <sup>b</sup>	0.11
<b>Acenaphthrene (µg/kg)</b>	0.77 <sup>a</sup>	1.16 <sup>a</sup>	0.77 <sup>a</sup>	0.29 <sup>b</sup>	0.08
<b>Phenanthrene (µg/kg)</b>	0.03 <sup>c</sup>	1.03 <sup>b</sup>	1.77 <sup>a</sup>	1.16 <sup>b</sup>	0.18
<b>Chrysene (µg/kg)</b>	0.77 <sup>b</sup>	2.29 <sup>a</sup>	2.39 <sup>a</sup>	2.75 <sup>a</sup>	0.34
<b>Pyrene (µg/kg)</b>	0.31 <sup>d</sup>	3.09 <sup>b</sup>	3.66 <sup>a</sup>	1.76 <sup>c</sup>	0.26
<b>Benzo (a)pyrene(µg/kg)</b>	0.79 <sup>c</sup>	2.24 <sup>b</sup>	2.65 <sup>ab</sup>	2.95 <sup>a</sup>	0.34
<b>Fluoranthene (µg/kg)</b>	0.68 <sup>c</sup>	0.21 <sup>b</sup>	2.79 <sup>a</sup>	2.23 <sup>b</sup>	0.33
<b>Naphthalene (µg/kg)</b>	0.90 <sup>b</sup>	3.64 <sup>a</sup>	3.70 <sup>a</sup>	3.76 <sup>a</sup>	0.46
<b>ΣPAHs (µg/kg)</b>	4.00 <sup>d</sup>	11.91 <sup>b</sup>	29.43 <sup>a</sup>	13.85 <sup>c</sup>	1.75

**Mean with same superscript are not significantly different according to Duncan Multiple range test (DMRT) at p=0.05.**

GSE: *Gmelina* smoked eviscerated, GSNe: *Gmelina* smoked non-eviscerated, PSE: *Parkia* smoked eviscerated, PSNe: *Parkia* smoked non-eviscerated, NSE: *Neem* smoked eviscerated, NSNe: *Neem* smoked non-eviscerated, CSE: *Charcoal* smoked eviscerated, CSNe: *Charcoal* smoked non-eviscerated.

**Table 6: Concentration of Polycyclic Aromatic Hydrocarbons present in Smoked African Catfish using different energy sources**

Parameters	Treatments								
	GSE	GSNe	PSE	PSNe	NSE	NSNe	CSE	CSNe	SME
<b>Benzo (ghi)perylene (µg/kg)</b>	0.76 <sup>bc</sup>	0.80 <sup>b</sup>	0.69 <sup>c</sup>	1.08 <sup>ab</sup>	0.12 <sup>a</sup>	1.23 <sup>a</sup>	0.67 <sup>d</sup>	0.29 <sup>d</sup>	0.10
<b>Acenaphthrene (µg/kg)</b>	0.74 <sup>abc</sup>	0.77 <sup>ab</sup>	0.68 <sup>bcd</sup>	1.16 <sup>a</sup>	0.73 <sup>abc</sup>	0.77 <sup>ab</sup>	0.31 <sup>cd</sup>	0.29 <sup>b</sup>	0.07
<b>Phenanthrene (µg/kg)</b>	1.24 <sup>b</sup>	0.03 <sup>c</sup>	1.27 <sup>b</sup>	1.03 <sup>b</sup>	0.17 <sup>c</sup>	1.77 <sup>a</sup>	0.05 <sup>c</sup>	1.16 <sup>b</sup>	0.13
<b>Chrysene (µg/kg)</b>	2.70 <sup>a</sup>	0.77 <sup>b</sup>	2.71 <sup>a</sup>	2.29 <sup>a</sup>	0.72 <sup>b</sup>	2.39 <sup>a</sup>	0.31 <sup>b</sup>	2.75 <sup>a</sup>	0.21
<b>Pyrene (µg/kg)</b>	1.92 <sup>c</sup>	0.31 <sup>d</sup>	1.86 <sup>c</sup>	3.09 <sup>b</sup>	0.23 <sup>b</sup>	3.66 <sup>a</sup>	0.18 <sup>b</sup>	1.76 <sup>c</sup>	0.26
<b>Benzo (a)pyrene(µg/kg)</b>	2.74 <sup>a</sup>	0.79 <sup>c</sup>	2.75 <sup>a</sup>	2.24 <sup>b</sup>	0.73 <sup>cd</sup>	2.65 <sup>ab</sup>	0.31 <sup>d</sup>	2.95 <sup>a</sup>	0.22
<b>Fluoranthene (µg/kg)</b>	2.04 <sup>a</sup>	0.68 <sup>b</sup>	2.19 <sup>a</sup>	0.21 <sup>a</sup>	0.25 <sup>b</sup>	2.79 <sup>a</sup>	0.19 <sup>b</sup>	2.23 <sup>a</sup>	0.22
<b>Naphthalene (µg/kg)</b>	2.89 <sup>a</sup>	0.90 <sup>b</sup>	3.83 <sup>a</sup>	3.64 <sup>a</sup>	0.83 <sup>b</sup>	3.70 <sup>a</sup>	0.79 <sup>b</sup>	3.76 <sup>a</sup>	0.30
<b>ΣPAHs (µg/kg)</b>	15.25 <sup>c</sup>	4.00 <sup>f</sup>	11.91 <sup>e</sup>	27.98 <sup>b</sup>	2.27 <sup>g</sup>	29.43 <sup>a</sup>	2.18 <sup>g</sup>	13.85 <sup>d</sup>	2.10

*Mean with same superscript are not significantly different according to Duncan Multiple range test (DMRT) at p=0.05.*

*GSE: Gmelina smoked eviscerated, GSNe: Gmelina smoked non-eviscerated, PSE: Parkia smoked eviscerated, PSNe: Parkia smoked non-eviscerated, NSE: Neem smoked eviscerated, NSNe: Neem smoked non-eviscerated, CSE: Charcoal smoked eviscerated, CSNe: Charcoal smoked non-eviscerated.*

### **3.3 Discussion**

African catfish produced using charcoal for both eviscerated and non-eviscerated had a lucid brownish colour and had the highest score for colour. The sensory score shows that colour of the products is important and thus has influence on the general preference of the consumer. This is consistent with other findings which states that consumer preference for smoked fish was primarily based on the colour and the best appearance of smoked fish is characterized by its surface colour [18].

Non-eviscerated fish samples produced dark and dull appearance compared to eviscerated samples. This due to the prompt degradation of hemoglobin present in the visceral organs thereby changing from red to dark coloration.

Organoleptic properties of the smoked fish samples vary with the smoke sources used and this also conforms to the findings which explained that sensory qualities of smoked products are decisively influenced by composition of the smoke and nature of wood involved [18]. This is also in agreement with Eyo (2001) [5] who posited that better flavoured smoked fish are obtained by smoking with hardwoods than softwoods due to higher content of some phenolic compounds particularly guaiacol and syringol in the hardwood.

The PAHs concentration recorded in the smoked African catfish produced using Neem and Parkia for eviscerated and non-eviscerated was relatively high compared to other treatments. This is result was similar to the recent work by Rinto et al. [19] who posited that the use of fuel from coconut trunk, drift wood, coconut husk and sawdust in the process of smoking fish has a variation of time and different effect of smoking. The variation in concentration of PAHs in all treatments was also in agreement with [20] who states that the actual levels of PAHs in smoked foods depend on several variables in the smoking process, including type of smoke generator, combustion temperature, and degree of smoking. The duration of smoking non-eviscerated fish samples was longer than eviscerated samples due to differences in mass as a result of the visceral organs.

### **4. Conclusion**

This study revealed that smoked non-eviscerated African catfish and eviscerated African catfish produced using Charcoal and Gmelina as smoke sources had higher overall acceptability. However, in all the smoked fish samples examined, the 5 µg/kg acceptable limits of Benzo(a)pyrene which is the marker of the carcinogenic PAHs as recommended by the European Commission was not exceeded [21]. Also, evisceration of African catfish samples prior to smoking enhances its sensory characteristics.

## REFERENCES

1. Ayuba LO, Jackson BA, Onah OR, Adamade CA, Ozumba IC. Effects of smoking process and conditions on the proximate composition of catfish (*Clarias gariepinus*). *Annals. Food Science and Technology*, 2019. 2019, V.20, n.2, p. 183-190.
2. Özpolat E, Patir B. Determination of shelf life for sausages produced from some freshwater fish using two different smoking methods. *Journal of Food Safety*, 2016.v.36, pp. 69-76, doi: 10.1111/jfs.12214..
3. Boran G, Boran M, Karacam H. Seasonal changes in proximate composition of anchovy and storage of anchovy oil. *J. Food Qual.* 31. 2008. pp. 503–513.
4. Agbelege OO, Ipinjolu JK. An assessment of the exploitation and management techniques of the fisheries resources in the Nigeria portion of the Lake Chad. *Journal of Arid Zone Fisheries*, 2001. 89– 98.
5. Eyo, AA. *Fish Processing Technology in the Tropics*. National Institute for Freshwater, Fisheries Research (NIFFR), New Bussa, 2001. 37-39:
6. Clucas IJ, Ward AR. *Post-Harvest Fisheries Development: A Guide to Handling Preservation, Processing and Quality*, Chatham Maritime, Kent, 1996.
7. Oyeleye, O. “Export potentials of smoked fish trade in Nigeria”, *The Guardian*, Newspaper Publication, Lagos, 2003, Vol. 19 No. 8916, p. 27.
8. Amoo, IA, Akinneye JO, Arannilewa ST. “Effect of drying methods on *Sardinella* sp. and *Heterotis niloticus*”, *International Journal of Fisheries*, 2007. Vol. 2, pp. 99 -103.
9. Singh RP, Heldman DR. *Introduction to Food Engineering*, 5th ed., Academic Press, 2013.
10. Pigott GM. *Fish Processing*, A Book by Singh, R.P. *Encyclopaedia Britannica*, Last Updated 1-2-2015, Retrieved 14 January, 2016.
11. Ekomy AS, Bruneau D, Mbega DJ, Aregba W. Nouveau concept de séchage et de fumage artisanal des aliments: Application en milieu de pêche artisanale au Gabon. *Afrique Science*, 2013. 9(3), 45–55.
12. Hitzel A, Pöhlmann M, Schwägele F, Speer K, Jira W. Polycyclic Aromatic Hydrocarbons (PAH) and phenolic substances in cold smoked sausages depending on smoking conditions using smoldering smoke. *Journal of Food Research*, 2012, 14–19.
13. Ledesma E, Rendueles M, Díaz, M. Smoked food. *Current Developments in Biotechnology and Bioengineering*. 2017, 201–243.
14. Goulas AE, Kontominas MG. Effects of Salting and Smoking method on the keeping quality of Chub Mackerel (*Scomber japonicus*). *Food Science*. 2005. *Elsevier*.
15. Gbolagunte DG, Salvador AF, Enoghase JS. Evaluation of the microbial load on smoked fish from some markets in Ogun state, Nigeria. *African Journal of Microbiology Research*. 2012, Vol. 6 (7). Pp 1376-1379.
16. Emokpae, A.O. “Organoleptic assessment of the quality of fresh fish”, *Nigerian Institute of Oceanography and Marine Research (NIOMR) Occasional Paper No 12*. 1979.pp. 1-4.

17. Moret S and Conte L. A rapid method for polycyclic aromatic hydrocarbon determination in vegetable oils. *Journal of separation science*. 25(1-2):96-100. 2002.
18. Oduor-Odote PM, Obiero M, Odoli C. *African Journal of Food Agriculture Nutrition and Development*. 2010, Vol. 10 No. 6.
19. Rinto MN, Iswandi W, Juwita K and Ningsi S. the effect of the use of type of wood in the appearance and flavour of smoked skipjack. *East Asian Journal of Multidisciplinary Research*. 2003. 167-176Vol. 2(1)
20. Moret S, Purcaro G, Conte LS. Polycyclic aromatic hydrocarbons in vegetable oils from canned foods. *European Journal Lipid Science Technology*, 2005. 107, 488-496. <http://dx.doi.org/10.1002/ejlt.200501060> .
21. European Commission. European Union Commission Regulation. Setting maximum levels for certain contaminants in food stuffs No 188 1/2006 - Dec 2006.