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**Omoruyi K**
Department of Aquaculture and Fisheries Management, Faculty of Agriculture, University of Benin, Benin City, Edo State, Nigeria

**Odigie G**
Department of Aquaculture and Fisheries Management, Faculty of Agriculture, University of Benin, Benin City, Edo State, Nigeria

**Oyamendan BE**
Department of Aquaculture and Fisheries Management, Faculty of Agriculture, University of Benin, Benin City, Edo State, Nigeria

**Corresponding Author:**
**Odigie G**
Department of Aquaculture and Fisheries Management, Faculty of Agriculture, University of Benin, Benin City, Edo State, Nigeria

# Assessment of the polycyclic aromatic hydrocarbon profile in African catfish (*Clarias gariepinus*) smoke-dried with selected wood energy sources

**Omoruyi K, Odigie G and Oyamendan BE**

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**Abstract**
This study was carried out to determine the polycyclic aromatic hydrocarbon profile in *Clarias gariepinus* smoke-dried with selected wood energy sources. This was investigated using four different woods; *Gmelina arborea*, *Hevea brasiliensis*, *Lophira alata* and *Pentaclethra macrophylla* and their charcoal derivatives. The fish were smoke-dried using the Magbon-Alade smoking kiln and the African traditional smoking method. Fish samples were homogenized and pure extracts from the samples were subjected to gas chromatography. The results showed that the polycyclic aromatic hydrocarbons concentrations in fresh fish (control) and fish smoke-dried with charcoals were below the detection limit but they were detected in fish smoked-dried with wood using the African traditional method. The study revealed that the fish smoke-dried with charcoal using the mechanical kiln were safe to consume. It also revealed that *Lophira alata* had the lowest concentration detected compared to other fuel woods.

**Keywords:** Polycyclic aromatic hydrocarbon, charcoal, wood, smoke-drying, *Clarias gariepinus*

## Introduction
Fish, if not sold or consumed fresh, proper preservation methods and techniques should be carried out to extend its shelf life [1]. Preservation methods such as smoking, frying, drying, salting, freezing, chilling, marinating, canning and a combination of these have been applied to conserve fish resources and retain fish quality [2]. During smoking, the smoke from the burning wood/charcoal containing several compounds impede bacteria growth while the heat from the fire causes drying. However, when the temperature is high enough the flesh will be cooked, preventing bacteria, fungal and enzymatic activity [3]. Food consumption has been identified as an important pathway of human exposure to contaminants, including PAHs. Polycyclic aromatic hydrocarbons (PAHs) are lipophilic compounds and usually accumulate in the fatty tissues of organisms and as such are known to be produced from the fatty tissues of fish during smoking through pyrolysis of fat at temperatures above 200 °C [4]. Traditional smoking techniques which involve treating pre-salted, whole or filleted fish directly with wood smoke from incomplete burning of wood can lead to its contamination with polycyclic aromatic hydrocarbons if the process is not adequately controlled or if very intense smoking procedures are employed [5]. Many factors contribute to the amounts of PAHs in food such as composition of the smoke, technology used in smoking, combustion temperature and type of wood used [6]. Processing fresh fish by subjecting them to heat treatment like drying, smoking, roasting, baking and frying has reportedly impacted and also increased the level of polycyclic aromatic hydrocarbons in them [7, 8]. The flames used in the drying process contain PAHs that adhere to the surface of the dried fish product [9]. It has been reported that wood smoke contains at least 100 PAHs and their alkylated derivatives and many of them are carcinogenic [10]. It has been reported that potential health hazards associated with smoked foods may be caused by carcinogenic components of wood smoke and could be responsible for the higher incidence of primary liver and stomach cancer in Nigeria compared with that in Europe and the USA [10, 11]. In 2017, PAHs were reported found in smoked fish obtained from major markets in Southern Nigeria [12]. In another study, varying levels of PAHs were also found in smoke-dried fishes [13]. However, there is a scarcity of information on the influence of wood and their charcoal derivatives used for smoking the fish on the presence and levels of carcinogenic PAHs in the smoked fish.

The objectives of the study were to identify and ascertain the concentrations of PAHs in African catfish (*C. gariepinus*) smoke-dried with selected wood energy sources and their charcoal derivatives as well as to ascertain if the concentrations of PAHs found in the samples are within the standard acceptable limit.

## 2. Materials and Methods

### 2.1 Collection of Fish Samples

A total of 90 freshly harvested African catfish (*C. gariepinus*) samples of about equal size, weight as well as the same stock were obtained from a reputable farm in Benin City, Edo state, Nigeria. The fish samples for the study were collected using a plastic bowl with clean tap water sealed with clean jute bags to prevent contamination.

### 2.2 Preparation of the Smoking Kiln

The Magbon-Alade smoking kiln in the demonstration farm of the Department of Aquaculture and Fisheries Management, University of Benin was used in smoking the fish samples. The coal chamber and smoking trays of the smoking kiln were thoroughly washed and cleaned; and allowed to dry in open air. The coal chambers were loaded with the same quantity of hardwood charcoal as fuel.

### 2.3 Type of Fuel Material

The type of fuel materials used were four kinds of wood and their charcoal derivatives. These include; *Gmelina arborea* (locally known as Meliana), *Hevea brasiliensis* (locally known as Rubber wood), *Lophira alata* (locally known as Ekki) and *Pentaclethra macrophylla* (locally known as Okpagha). These woods are commonly used for the production of charcoal for smoke-drying in the study area. The Charcoal used was obtained from the incomplete combustion of these fuel woods.

### 2.4 Processing Procedures

#### 2.4.1 Preparation of the fish sample

Before the smoking of the fish, the live fish were killed and dressed. No additive (spices or salt) was added to prevent alteration of results. The fish was divided into nine (9) batches; A, B, C, D, E, F, G, H, and I with each batch containing a total of ten (10) fish samples.

Batch A was the fresh fish which served as the control; Batch B was *C. gariepinus* smoke-dried with charcoal from *G. arborea*; Batch C was *C. gariepinus* smoke-dried with charcoal from *H. brasiliensis*; Batch D was *C. gariepinus* smoke-dried with charcoal from *L. alata*; Batch E was *C. gariepinus* smoke-dried with charcoal from *P. macrophylla*; Batch F was *C. gariepinus* smoke-dried with *H. brasiliensis* (Rubber wood); Batch G was *C. gariepinus* smoke-dried with *P. macrophylla*; Batch H was *C. gariepinus* smoke-dried with *G. arborea* and Batch I was *C. gariepinus* smoke-dried with *L. alata.*

#### 2.4.2 The smoking process

Sample B, C, D and E were carefully arranged in the Magbon-Alade smoking kiln while sample F, G, H and I were placed on four different wire gauze above four drums used for the local smoking of fish. The smoking process for sample B, C, D and E was carried out at 160-180°C until a constant weight was achieved. While sample F, G, H and I were smoke-dried for about 6h until the fish was completely dried. Periodically, during smoking, the fish samples were turned to allow even distribution of heat. Overheating was avoided to prevent charring. After smoking, the fish samples were allowed to cool at room temperature, they were then weighed, recorded and taken to the laboratory immediately for PAH analysis.

### 2.5 PAH Analysis

Samples of dried fish from each treatment were homogenized using the porcelain mortar and pestle and then packaged in labelled air-tight containers before extraction. The fresh and treated samples of smoke-dried *C. gariepinus* were extracted before carrying out the analysis. Extraction of PAHs was carried out according to the method described by Pena *et al.* [14] 10g each of the homogenized fish samples were thoroughly mixed with anhydrous $Na_2SO_4$ to dehydrate the sample. 20ml of the extraction solvent (di-chloromethane) was added to the samples. Samples were covered with aluminium foil to prevent evaporation and sonicated to separate the extracts. Extracts were cleaned up using a chromatographic column, moderately packed at the bottom with 1cm glass wool. 2g of silica gel and 1ml of anhydrous $Na_2SO_4$ was added to the column while the column was pre-eluted with 20 ml dichloromethane. Extracts were concentrated using an evaporator and collected in 2ml vials and the cleaned-up extracts were analysed for polycyclic aromatic hydrocarbons. Corresponding results were obtained using gas chromatography and a mass spectrometer.

### 2.6 Experimental Design

**The experimental design was made up of two main factors, namely**

- Animal source (*C. gariepinus*).
- Eight energy sources comprising of four woods (*G. arborea, H. brasiliensis, L. alata* and *P. macrophylla*) and their charcoal derivatives.
- Control.

The experimental design was a factorial laid down in a complete randomized design (CRD). Comprising of an animal source (*C. gariepinus*) × 8 energy sources (*G. arborea, H. brasiliensis, L. alata, P. macrophylla, G. arborea* charcoal, *H. brasiliensis* charcoal, *L. alata* charcoal and *P. macrophylla* charcoal). Experimental trials were conducted in triplicate.

### 2.7 Statistical analysis

Analysis of variance table (ANOVA) was used to ascertain the difference between the mean of samples. Data analysis was done using the GenStat software version 12.1. All analyses were carried out in triplicate. Duncan Multiple Range Test was used to study the difference between means. (DMRT) at $p<0.05$.

## 3. Results

### 3.1 Analysis of fish samples

Table 1, 2 and 3 show the summary of the results of PAH analysis of the control and *C. gariepinus* smoke-dried with various energy sources.

#### 3.1.1 PAH analysis of Control (Fresh fish)

The results of the chromatography analysis of the fresh *C. gariepinus* (Sample A) as shown in Table 1 indicated that the PAHs present in the sample were below the level of detection.

**Table 1:** Polycyclic aromatic hydrocarbons levels of fresh *C. gariepinus* control

| Parameters | Control |
|---|---|
| Acenaphthene | < 0.001 |
| Benzo(k)fluroranthene | < 0.001 |
| Acenaphthylene | < 0.001 |
| Anthracence | < 0.001 |
| Benz(a)anthracene | < 0.001 |
| Benzo(b)fluoranthene | < 0.001 |
| Benzo(g,h,i)perylene | < 0.001 |
| Benzo(a)pyrene | < 0.001 |
| Chrysene | < 0.001 |
| Dibenzo(a,h)anthracene | < 0.001 |
| Fluoranthene | < 0.001 |
| Fluorene | < 0.001 |
| Indeno(1,2,3-cd) | < 0.001 |
| Phenanthrene | < 0.001 |
| Pyrene | < 0.001 |
| Perylene | < 0.001 |

< 0.001: Not detected

### 3.1.2 PAH analysis of *C. gariepinus* smoke-dried with various wood charcoal

Table 2 shows the result of the chromatography analysis of *C. gariepinus* smoke-dried with four different wood charcoal using the mechanical smoking kiln. All PAHs present in the sample were below the level of detection (<0.001).

**Table 2:** PAHs Levels of *C. gariepinus* smoke-dried with different wood charcoal

| | Treatments | | | |
|---|---|---|---|---|
| **Parameters** | **B (Meliana)** | **C (Rubber)** | **D (Ekki)** | **E (Okpagha)** |
| Acenaphthene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Benzo(k)fluroranthene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Acenaphthylene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Anthracence | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Benz(a)anthracene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Benzo(b)fluoranthene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Benzo(g,h,i)perylene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Benzo(a)pyrene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Chrysene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Dibenzo(a,h)anthracene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Fluoranthene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Fluorene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Indeno(1,2,3-cd) | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Phenanthrene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Pyrene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Perylene | < 0.001 | < 0.001 | < 0.001 | < 0.001 |

< 0.001: Not detected

### 3.1.3 PAH analysis of *C. gariepinus* Smoke-dried with various wood types

Table 3 shows the PAH levels of *C. gariepinus* smoke-dried with various wood types. The highest (710.4) level of Acenaphthene was obtained in sample I (*L. alata*) and the lowest (343.7) in sample H (*G. arborea*). The highest (286.6) level of Anthracene was observed in sample G (*P. macrophylla*) while the lowest level (14.4) was observed in sample I (*L. alata*). The highest (58.83) level of Benzo (a) anthracene was observed in sample G (*P. macrophylla*) while the lowest (14.70) was observed in sample I (*L. alata*). The highest (41.20) level of Benzo (a) pyrene was observed in sample I (*L. alata*) while the lowest (0.70) was observed in sample G (*P. macrophylla*). The highest (15.20) level of Benzo (b) fluoranthene was observed in sample F *(H. brasiliensis)* while the lowest (0.01) was observed in sample I (*L. alata*). The highest (55.61) level of Benzo (g, h, i) pyrelene was observed in sample F (*H. brasiliensis*) while the lowest (0.59) was observed in sample I (*L. alata*). The highest (18.84) level of Benzo (k) fluoranthene was observed in sample G (*P. macrophylla*) while the lowest (0.01) was found in sample F (*H. brasiliensis*). The highest (13.78) level of Dibenz (a, h) anthracene was found in sample F (H. brasiliensis) while the lowest (0.01) was observed in sample G (*P. macrophylla*). The highest (82.29) level of Fluorene was observed in sample G (*P. macrophylla*) while the least (0.01) was found in sample I (*L. alata*). The highest (47.53) level of Indeno (1, 2, 3-cd) pyrene was observed in sample F (H. brasiliensis) while the lowest (0.01) was observed in sample G (*P. macrophylla).* The highest (94.22) level of Phenanthrene was observed in sample G (*P. macrophylla*) while the lowest level (22.36) was observed in sample I (*L. alata*). The highest (39.85) level of Pyrene was observed in sample H (*G. arborea*) while the lowest (2.52) was observed in sample I (*L. alata*). The highest (3996) level of Acenaphthylene was observed in sample G (*P. macrophylla*) while the lowest (146) was observed in sample I (*L. alata*).

The highest (42.68) level of Chrysene was observed in sample G (*P. macrophylla*) while the least (2.36) was observed in sample I (*L. alata*). The highest (647.3) level of Fluoranthene was observed in sample G (*P. macrophylla*) while the lowest (60.5) was observed in sample I (*L. alata).*

**Table 3:** PAHs Levels of *C. gariepinus* smoke-dried with different wood types

| Treatments | | | | | |
|---|---|---|---|---|---|
| **Parameters** | **F (Rubber)** | **G (Okphaga)** | **H (Meliana)** | **I (Ekki)** | **SED** |
| Naphthalene | $0.01^{A}$ | $0.01^{A}$ | $0.01^{A}$ | $0.01^{A}$ | 0.000943 |
| Acenaphthene | $559.5^{B}$ | $427.5^{C}$ | $343.7^{D}$ | $710.4^{A}$ | 0.0429 |
| Anthracene | $218.2^{B}$ | $286.6^{A}$ | $53.5^{C}$ | $14.4^{D}$ | 0.00943 |
| Benzo(a)anthracene | $25.73^{C}$ | $58.83^{A}$ | $41.73^{B}$ | $5.70^{D}$ | 0.0402 |
| Benzo(a)pyrene | $21.16^{B}$ | $0.70^{D}$ | $5.53^{C}$ | $41.20^{A}$ | 0.0402 |
| Benzo(b)fluoranthene | $15.20^{A}$ | $1.02^{C}$ | $2.43^{B}$ | $0.01^{D}$ | 0.0381 |
| Benzo(g,h,i)perylene | $55.61^{A}$ | $6.00^{C}$ | $10.48^{B}$ | $0.59^{D}$ | 0.0429 |
| Benzo(k)fluoranthene | $0.01^{D}$ | $18.84^{A}$ | $14.66^{B}$ | $4.85^{C}$ | 0.00776 |
| Dibenz(a,h)anthracene | $13.78^{A}$ | $0.01^{D}$ | $4.47^{B}$ | $3.67^{C}$ | 0.00449 |
| Fluorene | $26.81^{C}$ | $82.29^{A}$ | $35.98^{B}$ | $0.01^{D}$ | 0.00790 |
| Indeno(1,2,3-cd)pyrene | $47.53^{A}$ | $0.01^{D}$ | $0.99^{C}$ | $8.93^{B}$ | 0.00790 |
| Phenanthrene | $55.32^{C}$ | $94.22^{A}$ | $79.91^{B}$ | $20.36^{D}$ | 0.00943 |
| Pyrene | $30.02^{C}$ | $38.64^{B}$ | $39.85^{A}$ | $2.52^{D}$ | 0.00816 |
| Acenaphthylene | $3666^{C}$ | $3996^{D}$ | $3584^{B}$ | $146^{A}$ | 4.09 |
| Chrysene | $18.06^{B}$ | $42.68^{D}$ | $31.38^{C}$ | $2.36^{A}$ | 0.471 |
| Fluoranthene | $559.5^{B}$ | $647.3^{D}$ | $595.3^{C}$ | $60.5^{A}$ | 8.16 |
| Acenaphthene | $559.5^{B}$ | $427.5^{C}$ | $343.7^{D}$ | $710.4^{A}$ | 0.0429 |
| Anthracene | $218.2^{B}$ | $286.6^{A}$ | $53.5^{C}$ | $14.4^{D}$ | 0.00943 |
| Benzo(a)anthracene | $25.73^{C}$ | $58.83^{A}$ | $41.73^{B}$ | $5.70^{D}$ | 0.0402 |
| Benzo(a)pyrene | $21.16^{B}$ | $0.70^{D}$ | $5.53^{C}$ | $41.20^{A}$ | 0.0402 |
| Benzo(b)fluoranthene | $15.20^{A}$ | $1.02^{C}$ | $2.43^{B}$ | $0.01^{D}$ | 0.0381 |
| Benzo(g,h,i)perylene | $55.61^{A}$ | $6.00^{C}$ | $10.48^{B}$ | $0.59^{D}$ | 0.0429 |
| Benzo(k)fluoranthene | $0.01^{D}$ | $18.84^{A}$ | $14.66^{B}$ | $4.85^{C}$ | 0.00776 |
| Dibenz(a,h)anthracene | $13.78^{A}$ | $0.01^{D}$ | $4.47^{B}$ | $3.67^{C}$ | 0.00449 |
| Fluorene | $26.81^{C}$ | $82.29^{A}$ | $35.98^{B}$ | $0.01^{D}$ | 0.00790 |
| Indeno(1,2,3-cd)pyrene | $47.53^{A}$ | $0.01^{D}$ | $0.99^{C}$ | $8.93^{B}$ | 0.00790 |
| Phenanthrene | $55.32^{C}$ | $94.22^{A}$ | $79.91^{B}$ | $20.36^{D}$ | 0.00943 |
| Pyrene | $30.02^{C}$ | $38.64^{B}$ | $39.85^{A}$ | $2.52^{D}$ | 0.00816 |
| Acenaphthylene | $3666^{C}$ | $3996^{D}$ | $3584^{B}$ | $146^{A}$ | 4.09 |
| Chrysene | $18.06^{B}$ | $42.68^{D}$ | $31.38^{C}$ | $2.36^{A}$ | 0.471 |
| Fluoranthene | $559.5^{B}$ | $647.3^{D}$ | $595.3^{C}$ | $60.5^{A}$ | 8.16 |

Means with the same superscripts were not significantly different at 5% level of significance

## 4. Discussion

The results of the PAH analysis of fresh *C. gariepinus* was under the limit for safe consumption, this is similar to the report of Bomfeh *et al.* [15] where no PAHs were detected in the fresh fish sample (control). This indicates that the water in which the catfish were cultured was free of pollution by substances that are sources of PAHs. This is in agreement with observations made by Stolyhwo and Sikorski, [15] that fish and marine invertebrates may naturally contain minute or undetectable amounts of different PAHs absorbed from the environment. The study revealed that there was a significant difference ($p$<0.05) among the PAHs in the treatments with wood, except Naphthalene which showed similar results for all treatments. This indicates that different fuel woods contain varying concentrations of PAHs. Most PAHs detected were within tolerable levels in relation to the United States Environmental Protection Agency (USEPA) [16] maximum permissible limit for human health except for Acenaphthene, Anthracene, Acenaphthylene and Fluoranthene which recorded very high levels above the tolerable limit for human health. The reason could be a result of the direct exposure of smoke from the incomplete combustion of the fuel woods with various constituents of PAHs to the flesh of the fish during the smoke-drying process. This agrees with the finding of Osineye *et al.* [17] who concluded that direct use of fuel woods shows higher levels of PAHs compared to charcoal. The analysis of the PAHs of *C. gariepinus* smoke-dried with charcoal shows that all the parameters were below the detection limit. This is similar to the result reported by Silva *et al.*[13] who discovered more PAHs were detected in fish smoke-dried with other fuel sources when compared with those smoke-dried with charcoal, This indicates that the pyrolysis of hardwood into charcoal results in low PAH contents in the charcoal, leaving almost insignificant residual PAH levels, thereby minimizing the contamination of fish samples during smoking [17]. The results obtained in this research agree with Osineye *et al.* [17] who reported that no PAHs were detected in samples smoke-dried with a mechanical kiln. This could be attributed to the fact that a mechanical smoking kiln has a screen that shields the fish from smoke directly emanating from the fuel chamber of the kiln and has an opening which removes the excess smoke from the kiln [17]. This helps to shield the fish from being contaminated by the PAH content of the smoke. This result reaffirms the efficiency of the mechanical kiln design in screening PAHs contained in the different fuel sources from entering the fish being smoked [17]. In addition, Osineye *et al.* [17] also observed that traditional smoking methods expose fish to higher levels of PAHs when compared to mechanical kilns (Magbon-Alade smoking kiln) which completely screen them off.

Under the revised PAH indicator lists of the Codex Alimentarius Commission, seven PAHs have been listed as carcinogenic PAHs to be aware of [18, 19]. These include; benzo(a)pyrene, (benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a, h)anthracene, and indeno(1,2,3-cd) pyrene with the permissible limit of 10 mg/kg. The recommended oral exposure limit for Benzo[a] pyrene is set at 0.0003 µg/g/day. The study revealed that all *C. gariepinus* smoke-dried with various wood had

Benzo[a]pyrene in levels that significantly exceeded the recommended limit. The National Institute for Occupational Safety and Health Administration established a recommended exposure limit of 0.1 mg/kg for Benzo[b]fluoranthene [20]. However, this limit was significantly exceeded in all the *C. gariepinus* smoke-dried with the different kinds of wood. Benzo[k]fluoranthene is known to be a carcinogenic and respiratory disorder-causing substance [21]. The range of 0.00776 to 18.84 of Benzo[k]fluoranthene from this study is considered to be lethal to the body when consumed. The dibenz [a, h] anthracene levels from this study were within the tolerable range (<50ug/g) and similar to results reported by Ezike *et al.* [22] who discovered a range of 4.13 to 21.67 µg/g.
C. gariepinus smoke-dried with *P. macrophylla* had lower values for indeno (1, 2, 3-cd) pyrene (0.01), benzo(a)pyrene (0.70) and dibenzo(ah)anthracene (0.01) while benz(a) anthracene and chrysene had higher values of 58.83 and 42.68 respectively which exceeded the acceptable limit. C. gariepinus smoke-dried with *H. brasiliensis* showed high values of PAHs except for Benzo (k) fluoranthene (0.01). C. gariepinus smoke-dried with *L. alata* showed concentrations of PAHs below the permissible limit. The PAHs detected in *C. gariepinus* smoke-dried with *G. arborea* fell under tolerable limits.

## 5. Conclusion

This study revealed that the fish samples treated with charcoal had no PAH present in them or if present, were below detection level. Thus, fish samples smoke-dried by this method do not constitute a health risk, as the PAH contents were undetected and hence, below the maximum levels acceptable by the European Commission. The use of the Magbon-alade smoking kiln fueled with charcoal possibly contributed to the minimal level of PAHs that infiltrate the fish during the smoking process since the fuel source has already been stripped of most of its PAH contents as much lower quantities of PAHs are found in charcoal than in wood due to wood pyrolysis. Therefore, it could be concluded that irrespective of the variety of wood charcoal used coupled with the Magbon-alade smoking kiln and the uncontaminated fish, the final product (smoke-dried catfish) was free from PAH contamination and safe for consumption and posed no health effect (cancer or any deadly disease) on the consumers. This study also showed that *C. gariepinus* smoke-dried with *L. alata* (Ekki), a hardwood, gave the least concentration of most PAHs detected compared to other fuel woods used. This makes it the best of all the studied wood sources for smoking catfish using a traditional smoking kiln in agreement with Abiola [23] who concluded that *L. alata* is safe to be used as fuelwood in smoke-drying catfish as it produces no significant high level of carcinogenic PAH and produces fish samples that have good taste, retain their minerals and proximate components and have long shelf life. This study suggests that it is not advisable to use *H. brasiliensis* in smoking fish due to its high PAHs contents. *C. gariepinus* smoke-dried with *P. macrophylla* (Okpagha), a medium-textured leguminous woody plant, had the highest concentration of most PAHs detected. Therefore, *P. macrophylla* (Okpagha) poses a serious health hazard due to increased chemical carcinogens when used as direct fuel wood in the traditional smoking of catfish [24]. It was also observed that PAHs detected were above minimum permissible limits for all samples smoke-dried using the traditional method when compared with *C. gariepinus* smoke-dried with charcoal using the mechanical kiln. This could be due to the direct exposure of smoke from the fuel wood indicating that the traditional smoking method (Half drum) used in this study resulted in the increase of the PAH levels and concentrations in smoke-dried catfish.

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