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Health Risk Assessment of Polycyclic Aromatic Hydrocarbons in Charbroiled Meat Commonly Consumed in Port Harcourt Metropolis

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Abstract: This study was designed to assess polycyclic aromatic hydrocarbons (PAHs) concentrations in four selected commonly consumed charbroiled meats (*Micropogonias undulatus*, *Gallus gallus domesticus*, *Sus scrofa domesticus*, *Bos Taurus)* and their potentialhealth risks associated with consumption. The charbroiled samples (croaker fish, chicken, pork and beef) respectively were analyzed with Gas Chromatograph GC (Agilent 6890N) coupled with mass detector (Agilent 5975) in accordance with standard analytical method for PAHs. The levels of PAHs in croaker fish, chicken, pork and beef collected from Mile 4 are significantly lower at $p<0.05$ in comparison to the concentrations of PAH in croaker fish, chicken, pork and beef collected from Choba. The highest mean individual concentration was recorded for Benzo (a) pyrene in croaker fish (0.733±0.015mg/kg) and pork (0.733±0.021mg/kg) from Choba and Mile 4 respectively and were above the maximum permissible limits as recommended by the USEPA. Low molecular weight PAHs (LMW-PAHs) were generally predominant compared to High molecular weight PAHs (HMW-PAHs). This suggests that the sources of these PAHs in the samples analyzed were mainly of pyrogenic and petrogenic originat the Choba and Mile 4 sites respectively. Estimated Daily Dose (EDD), Hazard Quotient (HQ), Hazard Index (HI) and Life Time Excess Carcinogenic Risk (LECR) showed that ingestion of charbroiled croaker fish and chicken across the study areas were above the set standard limits. Hence there is a potential risk of consumption. However, Hazard indexes < 1 described by the EPA across all samples analyzed indicated non-carcinogenic threat from the consumption of charbroiled meat.

Keywords: PAHs, Charbroiled, Health risk, Petrogenic origin, Port Harcourt Metropolis.

1. Introduction

Scientists and regulatory organisations throughout the world are struggling to find solutions to the widespread health problems that may be linked back to environmental toxins. This is an issue in both emerging and developed nations because of the use of smoking, curing, roasting, and grilling in the preservation of meat and fish products (Akpambang et al. 2009). Both the stability and flavour of the final product are enhanced by these procedures. Traditional methods of food preparation, however, lead to the introduction of hazardous substances like Polycyclic Aromatic Hydrocarbons

(PAHs) into the food supply, which can have harmful consequences on the health of consumers (EFSA 2008; Agodokpessi et al. 2011; Ledesma et al.2016).

Incomplete combustion results in the production of polycyclic aromatic hydrocarbons (PAHs), which are produced whenever solid fuels like wood, coal, or oil are burned. Environmental contamination and the different degrees of heat used during food preparation and processing are the primary routes of introduction of PAHs into food (Guillen 1994). Incomplete combustion of charcoal and pyrolysis of fats occur during cooking processes such smoking, grilling, boiling, and toasting due to the adsorption and deposition of particles (Guillen 1994). As a class of molecules, polycyclic aromatic hydrocarbons (PAHs) are a major cause for concern in the natural world. While PAHs can be produced by a number of natural processes, human activities are increasingly being recognised as a major contributor. It is generally agreed that petrogenic and pyrolytic sources are the most significant among anthropogenic sources. Among the more than one hundred PAHs that have been studied, the United States Environmental Protection Agency (USEPA) has prioritised the elimination of sixteen due to their high toxicity (USEPA 1993).

The increased concentration of PAHs in foods that have been browned or broiled poses a greater health risk to consumers, despite the fact that these items are increasingly popular at home and in restaurants due to their wonderful flavour (Harrison et al. 2016). Polycyclic aromatic hydrocarbons (PAHs) found in meals that have been charbroiled are known to be carcinogenic. The high levels of PAHs released into the air during broiling mean that it is not a safe way to prepare meat (Harrison et al.2016). When meat is cooked at a very high temperature, such as over an open flame or by frying in a pan, PAHs are released (Rose et al.2015). Exposure to PAHs from charbroiled food may be higher than that from the surrounding environment, which may increase the risk of developing cancer in humans. The purpose of this study was, therefore, to assess the potential human health risks associated with consuming four commonly consumed charbroiled meats (Micropogonias undulatus, Gallus gallus domesticus, Sus scrofa domesticus, Bos Taurus) from various roadside vendors in Port Harcourt, Rivers State, Nigeria.

2. Materials and Methods

Study Area

This map displays the stations used to collect data for the research. Obio-Akpor Local Government Area in the city of Port Harcourt contains the study areas of Mile 4 (N4º49′22.4112" and E6 º 58′52.6188") and Choba (at N4 º53′54.3588" and Line 4, E6 º54′22.8816"). The Local Government Area has a total area of 250 km^2 and a population of 464,789 as of the 2006 census. Rumuodomaya is the Headquarter of the Obio-Akpor LGA. The Ikwerre People are the area's original inhabitants.

To the south lies Port Harcourt (Local Government Area), to the east is Oyigbo and Eleme, to the north is Ikwerre and Etche, and to the west is Emohua. Obio-Akpor is a key economic hub in Port Harcourt.

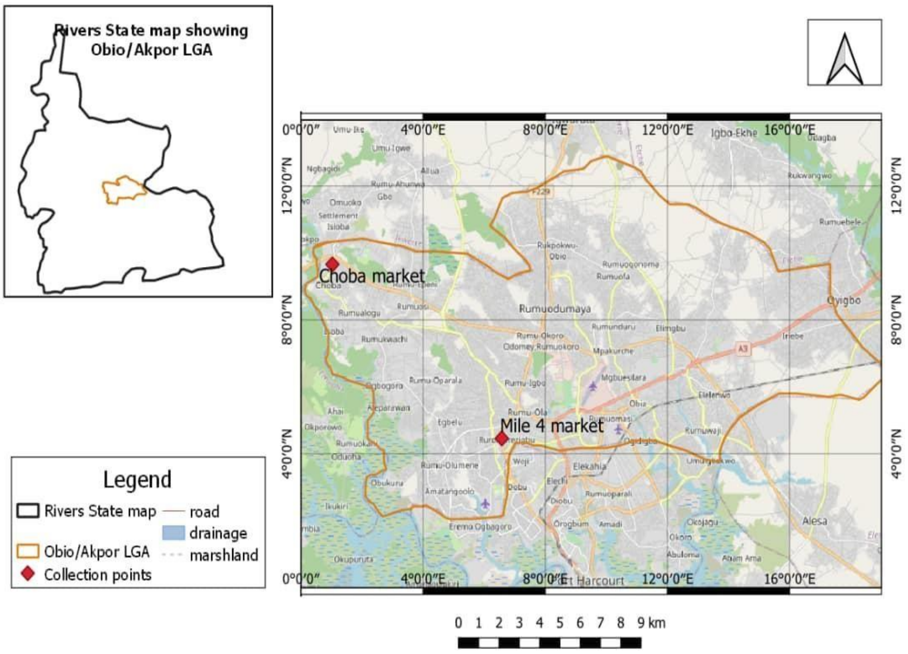

Figure 1. Showing map of Sampling Location

2.1. Sample Collection

We bought samples from various roadside barbeque stands in the research areas, covered them in aluminium foil, and carried them to the lab in a polyethylene bag to prevent cross-contamination. Purchasing four samples from each location, for a grand total of eight.

2.2. Sample Preparation/Extraction

The PAHs were extracted using a cold extraction technique. The samples were dried by adding anhydrous salt (Na2 SO4) to a beaker containing 5 grams of each sample and shaking the beaker for a few minutes to remove excess moisture. Once that was done, 30 ml of dichloromethane (the extraction solvent) was poured into the beaker. After aggressively shaking the sample mixture for 20 minutes, the organic layer was let an hour to settle. When the sample was extracted, it was filtered using filter paper containing 5 grams of sodium sulphate (Na2 SO4) to aid in moisture absorption, then transferred to a sample container for storage for 24 hours before being poured into a vial and subsequently injected into a GC for analysis.

2.3. Analysis of Polycyclic Aromatic Hydrocarbons (PAHs)

The samples were analysed for PAHs using a GC (Agilent 6890N) equipped with a mass detector (Agilent 5975), following the ASTM analytical procedure. Extractions were performed, and then samples were examined (where sample extract is thickly concentrated).

2.4. Health Risk Assessment

Toxic Equivalency Factor

Risks of cancer and mutation from eating charbroiled meat were calculated using the US Environmental Protection Agency's (EPA) suggested guidelines for PAHs in food (Nisbet and Lagoy.1992). In order to express the relative potency of various PAHs in comparison to B(a)P, the toxic equivalency factors (TEF) have been established. All of the PAH component concentrations are converted to B(a)p equivalent concentrations TEQ (BaP) by multiplying by the respective TEFs provided in (table 1). (AFSSA.2003). Studies monitoring smoked and fresh fish as well as other, more comprehensive monitoring projects have benefited from this approach (Law et al.2002).

$$\mathrm{TEQBAP} = (\mathrm{TEFi\ X\ Ci}) \qquad (1)$$

Where Ci is the measured individual PAH concentrations for the compound with the assigned TEFi.

Table 1. Benzo (a) pyrene Equivalent Factor for Carcinogenicity (TEF).

PAH compound	TEF (Nisbet and Lagoy.1992)
Naphthalene	0.001
Acenaphthylene	0.001
Acenaphthene	0.001
Fluorene	0.001
Phenanthrene	0.001
Anthracene	0.01
Fluoranthene	0.001
Pyrene	0.001
Benzo (a)anthracene	0.01
Chrysene	0.001
Benzo (b)fluoranthene	0.1
Benzo (k)fluoranthene	0.01
Benzo (a) pyrene	1.0
Dibenzo (a,h)anthracene	1.0
Indeno (1,2, 3- C, d) pyrene	0.1
Benzo (g,h,i) perylene	0.01

Table 2. Toxicity Values for PAHs Contaminants

PAHS	RFD (mg/kg/d) (EPA)		CSF (USEPA)(mg/kg/d)
Naphthalene	2.00 x 10^{-02}	Chrysene	7.30 x 10^{-3}
Acenaphthylene	2.00 x 10^{-02}	Benzo(a)anthracene	7.30 x 10^{-1}
Acenaphthene	6.0 0 x 10^{-02}	Benzo(a)anthracene	7.30 x 10^{-1}
Fluorene	4.0 0 x 10^{-02}	Benzo(b)fluoranthene	7.30 x 10^{-1}
Phenanthrene		Benzo(k)fluoranthene	7.30 x 10^{-2}
Anthracene	3.0 0 x 10^{-01}	Benzo (a) pyrene	7.30
Fluoranthene	4.0 0 x 10^{-02}	Dibenzo (a,h)anthracene	7.30
Pyrene	3.00 x 10^{-02}	Indeno (1,2, 3-c,d)pyrene	7.30 x 10^{-1}
Benzo (g,h,i) perylene	4.0 0 x 10-02		

Dietary Exposure to PAHs

Dietary PAH exposure dosage estimates for humans over a lifetime were calculated. Using the following equation, we determined the carcinogenic potential of PAH combinations based on the B(a)P equivalent dose received once daily.

The typical daily intake of carcinogenic PAHs is

$$\frac{\text{TEQ x IR x}}{\text{CF BW}} \qquad (2)$$

These exposure assumptions were set so that they would be in line with EPA recommendations for the default assumption of acceptable maximum exposure (USEPA.1991), where IR is the intake rate or amount of a carcinogenic substance consumed.

From the annual per capita fish consumption of 25kg for Nigeria (FAO. 2008), PAHs were calculated using a fish consumption rate of 68.5kgday-1 per person. The formula uses CF (0.001mg/g) and BW (70kg) as the conversion factor and weight, respectively.

Non – cancer Hazard, Carcinogenic Risk Assessment

The hazard quotient method was used to quantify the risk associated with ingesting non-carcinogenic PAHs. The exposure dose for each PAH divided by an oral chronic reference dose represents the hazard quotient (HQ) approach (RFD).

$$\text{RFD} \qquad (3)$$

The RFD values (mg/kg/day) in table 2 and the individual HQ results in Hazard index (HI).

$$HI = \Sigma (HQ1 + HQ2 + HQ3 + HQ4 + HQn) \quad (4)$$

Here, we estimate the carcinogenic risk associated with eating smoked Fish over the course of a 70-year lifespan using the TEQBAPs we calculated for the seven USEPA-classified carcinogens (USEPA.2000). Use the slope factor for benzo (a) pyrene in table 2 to calculate the overall risk for dosage exposure to a mixture of carcinogenic exposure dose (mg/kg/ bw/day).

Risk (carcinogenic) = Average daily dose x slope factor

$$(SF) \quad (5)$$

2.5. Statistical Analysis

IBM SPSS was used to examine the data (version 23). The significant level ($p<0.05$) was determined using one-way analysis of variance (ANOVA). Further statistical work and computations were done in Microsoft Excel.

3. Results

The concentrations ($mgkg^{-1)}$) of individual PAH (Benzo [a] anthracene, Benzo [b] flouranthene, Benzo [k] flouranthene, Benzo [a] pyrene, Dibenzo [ah] anthracene,Chrysene, Indeno [1,2,3-cd] pyrene, Naphthalene, Acenaphthylene, Acenaphthene, Flourene, Phenanthrene, Anthracene Flouranthene, Pyrene, Benzo [ghi] perylene) in the charbroiled meat samples (*Micropogonias undulatus*, *Gallus gallus domesticus*, *Sus scrofa domesticus*, *Bos Taurus)* from Choba and Mile 4 in Port Harcourt, Nigeria are presented in Table 3 and Table 4 respectively.

Table 3. PAHs Concentration ($mgkg^{-1)}$) for Charbroiled Fish, Chicken, Pork and Beef (Suya) Collected from Study Area 1 (Choba).

PAHs (CHOBA)	Suya	Croaker fish	Chicken	Pork
Naphthalene	BDL	0.033 ± 0.006^b	BDL	BDL
Acenaphthylene	BDL	0.073 ± 0.006^b	BDL	BDL
Acenaphthene	BDL	0.053 ± 0.006^b	BDL	0.053 ± 0.006^b
Flourene	0.150 ± 0.010^b	0.053 ± 0.005^a	0.043 ± 0.006^a	0.047 ± 0.005^a
Anthracene	0.227 ± 0.029^c	0.023 ± 0.006^a	0.163 ± 0.006^b	0.047 ± 0.005^a
Phenanthrene	0.140 ± 0.010^d	0.033 ± 0.006^a	0.087 ± 0.005^c	0.067 ± 0.012^b
Flouranthene	BDL	0.087 ± 0.006^c	0.073 ± 0.006^b	BDL
Pyrene	BDL	0.180 ± 0.010^c	0.090 ± 0.006^b	BDL
Benzo [a] anthracene	BDL	BDL	BDL	BDL
Chrysene	BDL	BDL	BDL	BDL
Benzo [b] flouranthene	BDL	BDL	BDL	BDL
Benzo [k] flouranthene	BDL	BDL	BDL	BDL
Benzo [a] pyrene	0.002 ± 0.001^a	0.733 ± 0.015^c	0.333 ± 0.153^b	0.019 ± 0.001^a

Dibenzo [a,h] Anthracene	BDL	BDL	BDL	BDL
Indeno [1,2,3-cd] pyrene	BDL	BDL	BDL	BDL
Benzo [ghi] perylene	BDL	BDL	BDL	BDL
Total PAHs	0.519	1.268	0.789	0.233
Carcinogenic PAHs	0.002	0.733	0 333	0.733
Non-carcinogenic PAHs	0.517	0’482	0.517	0.545

*Means in rows with the same letters are not significantly different at p<0.05*BDL- Below detectable limit

Values are presented as mean ±SD of quadruplet determination (N=4) .Carcinogenic P AHs - Benzo [a] anthracene, Benzo [b] flouranthene, Benzo [k] flouranthene, Benzo [a] pyrene, Dibenzo [ah] anthracene,Chrysene, Indeno [1,2,3-cd] pyrene.Non-carcinogenic PAHs – Naphthalene, Acenaphthylene, Acenaphthene, Flourene, Phenanthrene, Anthracene Flouranthene, Pyrene, Benzo [ghi] perylene.

Table 4. PAHs concentration ($mgkg^{-1)}$) for charbroiled fish, chicken, pork and beef (suya) collected from study Area 2 (Mile 4).

PAHs (MILE 4)	Suya	Croaker fish	Chicken	Pork
Naphthalene	BDL	BDL	BDL	BDL
Acenaphthylene	BDL	0.053 ± 0.006^{b}	BDL	BDL
Acenaphthene	BDL	0.043 ± 0.006^{b}	BDL	BDL
Flourene	0.077 ± 0.006^{d}	0.063 ± 0.006^{c}	BDL	0.027 ± 0.006^{b}
Anthracene	0.073 ± 0.006^{c}	0.033 ± 0.006^{b}	BDL	0.073 ± 0.006^{c}
Phenanthrene	0.133 ± 0.021^{c}	0.037 ± 0.012^{b}	BDL	0.047 ± 0.006^{b}
Flouranthene	0.847 ± 0.015^{c}	0.073 ± 0.006^{b}	BDL	BDL
Pyrene	0.520 ± 0.015^{d}	0.213 ± 0.006^{b}	0.043 ± 0.006^{a}	0.260 ± 0.010^{c}
Benzo [a] anthracene	BDL	BDL	BDL	BDL
Chrysene	BDL	BDL	BDL	BDL
Benzo [b] flouranthene	BDL	BDL	BDL	BDL
Benzo [k] flouranthene	BDL	BDL	BDL	BDL
Benzo [a] pyrene	0.013 ± 0.006^{a}	0.720 ± 0.010^{c}	0.367 ± 0.115^{b}	0.733 ± 0.021^{c}
Dibenzo [a,h] anthracene	BDL	BDL	BDL	BDL
Indeno [1,2,3-cd] pyrene	BDL	BDL	BDL	BDL
Benzo [ghi] perylene	BDL	BDL	BDL	BDL
Total PAHs	1.663	1.235	0.41	1.14
Carcinogenic PAHs	0.013	0.720	0.367	0.733
Non-carcinogenic	1.65	0.515	0.043	0.407

*Means in rows with the same letters are not significantly different at p<0.05*BDL- Below detectable limit

Values are presented as mean ±SD of quadruplet determination (N=4). Carcinogenic P AHs - Benzo [a] anthracene, Benzo [b] flouranthene, Benzo [k] flouranthene, Benzo [a] pyrene, Dibenzo [ah] anthracene, Chrysene, Indeno [1,2,3-cd] pyrene.Non-carcinogenic PAHs – Naphthalene, Acenaphthylene, Acenaphthene, Flourene, Phenanthrene, Anthracene Flouranthene, Pyrene, Benzo [ghi] perylene.

Cancer Risk Assessment of PAHs in Charbroiled Meats

The carcinogenic risk from eating smoked fish was evaluated by determining the carcinogenic toxicity (TEQBaP) in comparison to B(a)P. (Tables 5 and Table 6). Although TEQBaP has been linked to carcinogenicity (Essumang et al., 2013), it also has the potential to cause a variety of other serious health problems, including those related to the lungs, the reproductive system, libido, and IQ. According to a study (Essumang et al., 2013) Toxic Exposure Quotient (TEQ) values for the seven USEPA priority carcinogens are displayed in (Tables 5 and Table 6). Daily EQBaP intake and lifetime carcinogenic risk from eating smoked fish items over 70 years were also presented for adults (Tables 5 and Table 6).

The Carcinogenic toxicity (TEQBAP) related to B(a)P from Choba in the following samples for adults is presented in Table 5 . Results show that the total (ΣTEQBAP) were 0.002,0.733,0.333 and 0.019. Their corresponding BaPEQ daily dose mgkg^{-1}day^{-1} and carcinogenic risk for an adult involved in life time of 70 years ingestion of the smoked fish products were 1.96x 10^{-06},7.17 x 10^{-4}, 3.26 x 10^{-4} and 1.86 x 10^{-05} and 1.46x10-2,5.3509,2.431 and 1.39x10-1 respectively. The Carcinogenic toxicity (TEQBAP) related to B(a)P from Mile 4 in the following samples for adults is presented in Table 6.Results show that the total (Σ TEQBAP) were 0.013,0.72,0.367,0.733. Their corresponding BaPEQ daily dose mgkg^{-1}day^{-1} 0.013,0.72,0.367,0.733 risk of cancer from eating smoked fish over the course of 70 years as an adult 1.27x10^{-5},7.05x10^{-4},3.6x10^{-4},7.2x10^{-4} and 9.29x10^{-5},5.14x10^{-3},2.62x10^{-3} and5.24x10^{-3} respectively.

Table 5. Risk Assessment Based on Carcinogenic Equivalency, Average Daily Dose and Risks for Charbroiled Meat in Study Area 1(Choba)

Carcinogenicequivalency	Suya	Croaker Fish	Chicken	Pork
Benzo [a] anthracene	BDL	BDL	BDL	BDL
Benzo [b] flouranthene	BDL	BDL	BDL	BDL
Benzo [k] flouranthene	BDL	BDL	BDL	BDL
Benzo [a]pyrene	0.002	0.733	0.033	0.019
Dibenzo [ah]anthracene	BDL	BDL	BDL	BDL
Chrysene	BDL	BDL	BDL	BDL
Indeno [1,2,3-cd] pyrene	BDL	BDL	BDL	BDL
∑BaP-TEQ	0.002	0.733	0.333	0.019
BaPEQ daily dose mgkg^{-1}day^{-1}	1.96 x 10-6	7.17x 10-4	3.26x10-4	1.86x10-5
LECR	1.46x10-2	5.3509	2.431	1.39x10-1

Table 6. Risk Assessment Based on Carcinogenic Equivalency, Average Daily Dose and Risks for Charbroiled Meat in Study Area 1 (Mile 4)

Carcinogenicequivalency	Suya	Croaker fish	Chicken	Pork
Benzo [a] anthracene	BDL	BDL	BDL	BDL
Benzo [b] flouranthene	BDL	BDL	BDL	BDL
Benzo [k] flouranthene	BDL	BDL	BDL	BDL
Benzo [a] pyrene	0.013	0.72	0.367	0.733
Dibenzo [ah]anthracene	BDL	BDL	BDL	BDL
Chrysene	BDL	BDL	BDL	BDL
Indeno [1,2,3-cd]pyrene	BDL	BDL	BDL	BDL
∑BaP-TEQ	0.013	0.72	0.367	0.733
BaPEQ daily dosemgkg^{-1}day^{-1}	1.27x10^{-5}	7.05x10^{-4}	3.6x10^{-4}	7.2x10^{-4}
LECR	9.29x10^{-5}	5.14x10^{-3}	2.62x10^{-3}	5.24x10^{-3}

Non-cancer Risk Assessment of PAHs, Average Daily Doses and Hazard Index (Mean±SD) for Charbroiled Meats

The Non –carcinogenic risk assessment toxicity (TEQBAP) related to B(a)P from Choba in the following samples for adults is presented in Table 7. Results show that the total (Σ TEQBAP) were 0.0026,0.000742,0.000456 and 0.000637.Their corresponding BaPEQ daily dose mgkg^{-1}day^{-1} 2.51X10^{-6},7.26X10^{-7},1.89X10^{-6} and 6.23X10^{-7} and targeted hazard indexes were 1.11X10^{-5},1.61X10^{-5},1.11X10^{-5} and 3.55X10^{-6} respectively. Table 8 shows result obtained from non –carcinogenic risk assessment toxicity (TEQBAP) related to B(a)P from Mile 4 in the following samples for adults .Results show that the total (Σ TEQBAP) were 0.0023,0.00081,0.000043 and 0.0011.Their corresponding BaPEQ daily dose mgkg^{-1}day^{-1} and 7.86X10^{-4},5.04X10^{-4},4.21X10^{-5} and1.44X10^{-4} targeted hazard indexes were 3.98X1 0^{2},1.37X10-^{2,}1.40X10^{-3}and 9.34X10^{-3}respectively.

Table 7. Risk Assessment Based on Non-carcinogenic Equivalency, Average Daily Dosesand Hazard Index for Charbroiled Meats in Study Area 1 (Choba)

Non-Carcinogeneic Equivalency (CHOBA)	Suya	Croaker fish	Chicken	Pork
Napthalene	BDL	0.000033	BDL	BDL
Acenaphthylene	BDL	0.000073	BDL	BDL
Acenaphthene	BDL	0.000053	BDL	0.000053
Flourene	0.00015	0.000053	0.000043	0.000047
Phenanthrene	0.00014	0.000033	0.000087	0.000067
Anthracene	0.00227	0.00023	0.000163	0.00047
Flouranthene	BDL	0.000087	0.000073	BDL
Pyrene	BDL	0.00018	0.00009	BDL
Benzo [ghi] perylene	BDL	BDL	BDL	BDL

∑BaP-TEQ	0.0026	0.000742	0.000456	0.000637
BaPEQ daily dose $mgkg^{-1}day^{-1}$	$2.51X10^{-6}$	$7.26X10^{-7}$	$1.89X10^{-6}$	$6.23X10^{-7}$
Hazard Index	$1.11X10^{-5}$	$1.61X10^{-5}$	$1.11X10^{-5}$	$3.55X10^{-6}$

Table 8. Risk Assessment Based on Non-Carcinogenic Equivalency, Average Daily Dosesand Hazard Index (mean±SD) for Charbroiled Meats in Study Area 2 (Mile 4).

Non-Carcinogeneic equivalency (MILE 4)	Suya	Croaker fish	Chicken	Pork
Napthalene	BDL	BDL	BDL	BDL
Acenaphthylene	BDL	0.000053	BDL	BDL
Acenaphthene	BDL	0.000043	BDL	BDL
Flourene	0.000077	0.000063	BDL	0.000027
Phenanthrene	0.000133	0.000037	BDL	0.000047
Anthracene	0.00073	0.00033	BDL	0.00073
Flouranthene	0.000847	0.000073	BDL	BDL
Pyrene	0.00052	0.000213	0.000043	0.00026
Benzo [ghi] perylene	BDL	BDL	BDL	BDL
∑BaP-TEQ	0.0023	0.00081	0.000043	0.0011
BaPEQ daily dosemgkg^{-1}day^{-1}	$7.86X10^{-4}$	$5.04X10^{-4}$	$4.21X10^{-5}$	$1.44X10^{-4}$
Hazard Index	$3.98X10^{-2}$	$1.37X10^{-2}$	$1.40X10^{-3}$	$9.34X10^{-3}$

4. Discussion

Results in Table 3 and 4 shows the mean values of PAHs concentrations in Charbroiled meat samples from the both sites, Choba and Mile 4. The average PAH concentrations (Mean±SD.mg/kg) and total mean PAH concentrations (mg/kg) in the various charbroiled meat samples are shown in Table 3 and Table 4. Sixteen (16) PAHs were detected in the samples with average concentration ranging from below detection limit of 0. 1mg/kg (0.0001μg/kg) to 0.733±0.015 and 0.847±0.015 for Choba and Mile 4 respectively. The average PAH concentration (mean±S.D, mg/kg) and total mean PAH concentration in *Bos Taurus* (Charbroiled Beef) are shown in Table 3. Average concentrations of these PAHs ranged from 0.227±0.0029 and 0.847 ±0.015mg/kg recorded for Anthracene and Flouranthene from Choba and Mile 4 respectively. Napthalene, Acenaphthylene, Acenaphthene, Flouranthene, pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)Fluoranthene, Pyrene,Benzo(a)anthracene, chrysene, Benzo(b)flourantene, Benzo{k)flouranthene, Dibenzo(a,h) anthracene, Indeno(1,2,3-cd)pyrene, and Benzo{g,h,i}perylene were below detection limit(BDL) from Choba and Mile 4 respectively.

The total PAH concentrations in *micropogonias undulates* (Croaker fish) from Choba site were significantly higher ($p<0.05$) than their respective concentration in the Mile 4 *micropogonias undulates* (Croaker fish) while Benzo(a) pyrene levels were significantly higher and above the European Union(EU) limit of 2.0μg/kg(0.0002mg/kg .This result is in line with the study by Nakamura et al.,(2008)who found the high levels of PAHs in smoked fish could be attributed tothe fat content . The total average PAH concentration in *Gallus gallus domesticus* (chicken) in Mile 4 was markedly lower compared to the ratio found in Choba sites respectively. The concentration of benzo (a) pyrene analysed in *Gallus gallus domesticus* (chicken) from Mile 4 and Choba were 0.367±0.115 and 0.333±0.153 respectively. The concentration of the *Gallus gallus domesticus* (chicken) were below the USEPA limit of 5.0µg/kg (0.0005mg/kg) and exceeded the EU limit of 2.0µg/kg (0.0002mg/kg) .The total concentration of PAHs in the *Sus scrofa domesticus* (pork) ranges from 0.019 ±0.001 to 0.067±0.012 and 0.026 ±0.010 to 0.733±0.021 from Choba and Mile 4 respectively .The total PAH concentration in the *Sus scrofa domesticus* (pork) from Choba was markedly lower than the Mile 4 site. In this charbroiled pork, the PAH average concentrations of 0.019±0.001 and 0.733±0.021 were recorded for Benzo (a) pyrene from both sites.

This pattern resembles that seen in Gallus gallus domesticus (chicken). Mile 4's PAH content was higher than the USEPA's permitted limit of 5.0 g/kg (0.0005 mg/kg), which posed a concern to human health. For the carcinogenic risk related to eating the smoked fish, the carcinogenic toxicity (TEQBaP relative to B (a) P were determined. TEQBaP is directly linked to carcinogenicity (Essumang et al. 2013) and may have implications for other unfavourable health outcomes that are not malignant, such as lung conditions, birth deformities, impotence, low IQ, etc (Essumang et al.2013). According to Tables 5 and 6, the TEQ for the seven USEPA priority carcinogens in suya (beef), croaker fish, chicken, and pig, respectively, was 0.002, 0.733, 0.333, and 0.019 for Choba and 0.013, 0.72, 0.367, 0.733 for Mile 4. The corresponding QBaP daily dose and carcinogenic risk for an adult involved in life-long consumption of smoked fish products were also calculated to be 1.96 x 10-6, 7.17 x 10-4, 3.26 x 10-4, and 1.86 x 10-5 cancer risk from Choba across all samples. These values were also calculated to be 1.46 x 10-2, 5.3509, 2.431, and 1.39 x 10-1.

According to these risk values, 1 in 1000 persons who consume beef that has been charbroiled is likely to develop cancer at some point in their lifetime, 7 out of 1000,3 out of 1000 and 1 out of 10000 in site 1(Choba) while for Mile 4, 1 out 100,5 and 2 persons Table 4.3) and $1.27x10^{-5}$,$7.05x10^{-3}$.$6x10^{-4}$ and $7.2x10^{-4}$ and cancer $9.29x10^{-5}$ $5.14x10^{-3}$,$2.62x10^{-3}$ and $5.24x10^{-3}$ risk from Mile 4 (Table 6) . According to these numbers, 1 in 100,000, 7 in 1,000, 6 in 1,000, and 7 in 10,000 persons, respectively, have a lifetime risk of developing cancer from eating charbroiled meat. According to this study, the daily doses of charbroiled beef (suya), pork from Choba, and croaker fish from Mile 4 had Bap-TEQ values that were lower than the USEPA's 1993 carcinogenic unit risk of 1 x 10-5, indicating no probable cancer risk. All of the croaker fish and chicken that was charbroiled throughout the locations exceeded the regulatory standards set by the USEPA and posed a risk to human health. Hazard indices (PAH16 HQs) for exposure to non-carcinogenic PAHs were 1.11X10-5, 1.61X10-5, 1.11X10-5, 3.55X10-6, 3.98X10-2, 1.37X10-2, 1.40X10-3, and 9.34X10-3 at the two sites, respectively (Tables 7 and 8). The hazard indices of the non-carcinogenic PAHs were less than 1.

These outcomes support those of (Yusuf et al.2015). Nonetheless, risk indexes greater than 1 are likely to have a negative impact on human health. a concentration of these dangerous PAHs from smoked salmon in their meals that is usually considered to have no meaningful risk for the development of non-cancer health problems, according to the EPA. The greatest hazard to human health is posed by risks related to carcinogenesis when they are combined.

5. Conclusions

The results of this study show that the low molecular weight PAHs from the EPA list are the most prevalent PAHs in the samples that were analysed (particularly those of two or three benzene rings). This suggests that the sources of these PAHs in the samples analysed are mainly of pyrogenic and petrogenic origin at Choba and Mile 4 sites respectively. The present study provides insight of the current concentration of polycyclic aromatic hydrocarbons in commonly consumed charbroiled meat (; *Micropogonias undulatus*, *Gallus gallus domesticus*, *Sus scrofa domesticus*, *Bos Taurus* and their potential health risks associated with consumption). Data from this study highlighted that there was a potential high molecular weight-PAH health concern for the indigenes of Choba and Mile 4 as the estimated daily intake of PAHs in four commonly consumed charbroiled meats exceeded the tolerable daily intake level. Moreso, the Hazard Indexes across the study areas were less than 1 suggesting that no potential adverse health risk may exist while the carcinogenic potency equivalency relating to benzo(a) pyrene B(a)P of charbroiled meats at both study sites exceeded the critical allowable limit for carcinogenic PAHs thus suggesting potential adverse health effect for population at Choba and Mile 4. These health risk estimates in the present study strongly suggest that subsequent dietary intake of the commonly consumed meats around industrial areas or close to the main roads should be discouraged. Furthermore, the low molecular weight compounds among the 16 EPA PAHs are mainly present in food. It must be emphasised, nonetheless, that these substances have a lower toxicity profile than the high-molecular-weight EPA list members.

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Data Availability

The corresponding author can provide you with the information needed to access the data that support this study's conclusions.

Conflict of Interest

The authors affirm that they have no known financial or interpersonal conflicts that would have appeared to have an impact on the research described in this publication.

Consent for Publication

All authors have read the work and given their consent for publication.

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