

Procarcinogens: Polycyclic Aromatic Hydrocarbons and Heavy Metal Content in Some Locally Processed Foods in South Eastern Nigeria

C. O. Ujowundu^{1*}, K.L. Ihekweazu¹, C.S Alisi¹, F. N. Ujowundu¹ and C.U. Igwe¹

¹Department of Biochemistry, Federal University Technology Owerri, Nigeria

ABSTRACT

This study investigated the presence of polycyclic aromatic hydrocarbons (PAHs) and heavy metals in commonly consumed roasted meats and smoked fish in Owerri, Imo State, Nigeria. The processed foods were group as; freshly processed- 6 to 12 hours heat/flame/smoke exposure and long processed- 7 days heat/flame/smoke exposure. Freshly processed (FP) and long processed (LP) beef, fatty beef, chicken, fish and pork samples were purchased from road-side food vendors, wrapped in clean labelled paper foil and taken to the laboratory for analysis. Gas chromatography with flame ionization detector (GC-FID) was used for the evaluation of PAH and atomic absorption spectrophotometer (AAS) was used to determine heavy metals. Our result showed that the total concentration of PAHs in LP food samples were higher when compared to FP samples. Benzo(a)pyrene and other PAHs which are probable human carcinogen, were present in varying concentrations in the samples. Toxic heavy metals such as lead and cadmium were present at varying concentrations in the samples, while mercury was not detected in any of the samples. This study have added to the numerous evidences that processing of food by exposure to heat, flame and smoke encourages the generation of toxic compounds and the nature of the food chain and certain environmental activities can impact negatively on their nutritional content. This therefore places consumers at potential health risk.

Keywords: PAHs, Benzo(a)pyrene, Mutagens, Cancer, Toxicants, Metals, Smoke, Roasting

1. INTRODUCTION

Studies have shown cancer to be a major cause of human mortality among the numerous diseases afflicting mankind. Human diet and dietary habits are factored in the aetiology of cancer, making nutrition to account for one third of the total cause of cancer (1). Cancers most commonly associated with diet include those of esophagus, stomach, colon, liver and the prostate. Several industrial and daily human activities release toxic and harmful compounds into the environment such as polycyclic aromatic hydrocarbons (PAHs) and heavy metals. PAHs are fused aromatic rings (2), formed from incomplete combustion or pyrolysis of organic materials (such as; coal, oil, gas, wood, fossil fuels and biomass) by a series of complex chemical reactions (3,4).

Some PAHs are identified as mutagenic and carcinogenic. In mammalian cells PAHs undergo metabolic activation to diol epoxides that bind covalently to cellular macromolecules, such as DNA, leading to errors in DNA replication and mutations that can initiate carcinogenesis (5). Studies have shown that most food intake of PAHs comes from

* Tel.: +2348036683491

*Corresponding author: Email:Ujowundu@yahoo.com

vegetables and cooked meats (6). Exposure includes breathing in PAHs in tobacco smoke, auto emissions or industrial exhausts, consumption of charcoal broiled food and contaminated water. Human exposure to PAH is over 90 % linked to food and it can penetrate food via water and air (7,8). They can also be absorbed through the skin when in contact. The impacts of PAHs exposure are observed largely at the lungs, breast, oropharynx, genitourinary and gastrointestinal tracts (9). Several animal and human studies have implicated colon cancer and other forms of cancer to dietary exposure to PAH (10).

Heavy metals when released in the environment are toxic to humans and animals (11). However, some heavy metals are beneficial to the body. The largest man-made sources include combustion of fossil fuels and industrial processes. Exposure to heavy metals may occur through the diet, medications, the environment, or in the course of work or play. Chronic illness may be caused by heavy metal toxicity from the environment and food supply. Toxic heavy metals target sites which includes; membrane structural proteins, enzymes, or DNA molecules. Once at the target site, they can displace an important mineral from its binding site (12).

In South Eastern Nigeria, some foods are prepared by roasting and smoking using woods. Ashes from these woods have been shown to contain significant concentration of heavy metals, and they are also sources of PAH, which are strongly sorbed to the woods matrix (13,14). These foods are often consumed by several people including the upper, middle and lower classes, for their nutritional value and easy access. They can be purchased from food centres often sited at strategic locations, especially at road sides and street junctions. This research was carried out to determine the presence and concentration of PAHs and heavy metals in high protein containing food such as lean beef, fatty beef, fish, chicken and pork. The result may serve as pointer to potential health hazards to consumers of these foods and forms a basis for public health education.

2. MATERIALS AND METHOD

2.1 Preparation of Food Samples

The samples used were non fatty beef (this will be referred here as beef) and fatty beef (known as “Suya”), chicken, pork and mackerel fish. The locally processed food samples were grouped into fresh processed (FP) and long processed (LP). The fresh processed samples were exposed to 6 - 12 hours heat/flame/smoke generated by firewood and charcoal. The long processed samples were exposed initially (6-12 hours) to heat/flame/smoke from firewood and mild but consistent heating for 7 days. Fish samples were processed in a similar way but exposed to heat/smoke generated by firewood. Samples (1.0 kg each) were wrapped in clean labelled paper foil and taken to the laboratory for analysis. The foods were processed by food vendors under the supervision of the researchers. The food vendors were located along streets of Ihiagwa market and mammy market Obinze in Owerri West Local Government, Imo State. These areas witnessed heavy vehicular movement and road construction activities during (September – October 2012) the study period.

2.2 Determination of PAHs by Gas Chromatography (GC)

To start the cold extraction 2 g of each sample was weighed into a clean extraction container and 10 ml of dichloromethane was added, thoroughly mixed and allowed to settle. The mixture was carefully filtered into clean solvent and rinsed into extraction bottle, using filter paper fitted into Buchner funnel. The extract was concentrated to 2 ml and then transferred for cleanup and separation (This involved further purification of the extract prior to gas

chromatographic analysis). To achieve this, 1 cm of moderately packed glass wool was placed at the bottom of 10 mm ID × 250 mm long chromatographic column. Slurry of 2 g activated silica in 10 ml dichloromethane was prepared and placed into the chromatographic column. To the top of the column 0.5 cm of sodium sulfite was added.

The column was rinsed with additional 10 ml of dichloromethane. The column was pre-eluted with 20 ml of dichloromethane and this was allowed to flow through the column at a rate of about 2 minutes until the liquid in the column was just above the sulfite layer. Immediately, 1 ml of the extracted sample was transferred into the column. The extraction bottle was rinsed with 1 ml of dichloromethane and added to the column as well. The stop-cork of the column was open and the eluant was collected with a 10 ml graduated cylinder.

Prior to exposure of the sodium sulfite layer to air, dichloromethane was added to the column in 1-2 ml increments. Accurately measured 10 ml of the eluant was collected and labeled aliphatic. The concentrated aliphatic fractions were transferred into labeled glass vials with rubber crimps caps for GC analysis. 1 µL of the concentrated sample was injected by means of syringe through a rubber septum into the column. Separation occurs as the vapour constituents' partition between the gas and liquid phases. The sample components were automatically detected as they emerge from the column (at a constant flow rate) by the Flame Ionization Detection (FID) detector whose response was dependent upon the composition of the vapour.

2.3 Determination of Heavy Metal Content

A sample weight of 5 g was burnt to ash and dissolved in 5 ml of 10 % HCl. The concentration of lead (Pb), cadmium (Cd), mercury (Hg), zinc (Zn), and iron (Fe) were determined by atomic absorption spectrophotometer as described by James (15).

2.4 Statistical Analysis

The obtained data were expressed as mean ± standard deviation and the significant difference among the group was assessed using one way analysis of variance (ANOVA).

3. RESULTS

3.1 Concentration of Polycyclic Aromatic Hydrocarbons in Freshly Processed Samples

The content and concentration of different PAHs in fresh processed samples are shown in Table 1. The total PAH varied from 0.021 mg/kg in FP pork to 0.213 mg/kg in FP fish. The concentrations of 16 PAHs compounds were analysed in the freshly processed food samples. Acenaphthylene and acenaphthene were not detected in chicken. Also acenaphthene, fluorene and phenanthrene were not detected in fatty beef. Fluorene was not detected in beef while naphthalene was not detected in all the samples. The concentrations of benzo[a]pyrene were 7.88×10^{-4} mg/kg, 1.25×10^{-4} mg/kg, 6.48×10^{-5} mg/kg, 5.20×10^{-6} mg/kg and 1.76×10^{-3} mg/kg, in beef, fatty beef, fish, chicken and pork respectively. The concentrations of benz[a]anthracene were 4.59×10^{-5} mg/kg, 2.26×10^{-7} mg/kg, 1.73×10^{-4} mg/kg, 3.44×10^{-6} mg/kg and 6.10×10^{-6} mg/kg in beef, fatty beef, fish, chicken and pork respectively. Also the concentrations of dibenz[a,h]anthracene were 8.0×10^{-8} mg/kg, 3.24×10^{-5} mg/kg, 9.10×10^{-5} mg/kg, 3.46×10^{-5} mg/kg and 8.05×10^{-6} mg/kg in beef, fatty beef, fish, chicken and pork respectively.

3.2 Concentration of Polycyclic Aromatic Hydrocarbons in Long Processed Samples

* Tel.: +2348036683491

*Corresponding author: Email:Ujowundu@yahoo.com

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141 The concentration of various PAH compounds of long processed samples are presented in
 142 Table 2. The results showed that total PAHs ranged from 0.015 mg/kg in LP pork to 0.934
 143 mg/kg in LP fish. The concentrations of benzo[a]pyrene were 3.12×10^{-5} mg/kg, 5.01×10^{-5}
 144 mg/kg, 5.205×10^{-4} mg/kg, 1.258×10^{-5} mg/kg and 3.204×10^{-4} mg/kg in beef, fatty beef, fish,
 145 chicken and pork respectively. The concentrations of benz[a]anthracene were 3.2×10^{-5}
 146 mg/kg, 1.19×10^{-4} mg/kg, 7.5×10^{-4} mg/kg, 3.1105×10^{-5} mg/kg and 7.076×10^{-6} mg in beef, fatty
 147 beef, fish, chicken and pork respectively. Similarly, the concentrations of
 148 dibenz[a,h]anthracene were 8.66×10^{-5} mg/kg, 2.874×10^{-4} mg/kg and 1.59×10^{-5} mg/kg in
 149 beef, fish and chicken respectively. Dibenz[a,h]anthracene were not detected in fatty beef
 150 and pork

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152 **Table 1: Concentration (mg/kg) of Polycyclic Aromatic Hydrocarbons in Freshly**
 153 **Processed Samples**

Type of PAH	Beef	Fatty beef	Fish	Chicken	Pork
Naphthalene	ND	ND	ND	ND	ND
Acenaphthylene	2.45×10^{-5}	7.27×10^{-6}	5.47×10^{-4}	ND	1.12×10^{-4}
Acenaphthene	9.94×10^{-6}	ND	1.14×10^{-4}	ND	3.56×10^{-5}
Fluorene	ND	ND	1.42×10^{-4}	9.34×10^{-6}	5.32×10^{-6}
Anthracene	2.41×10^{-5}	2.6×10^{-8}	5.19×10^{-4}	1.83×10^{-5}	2.12×10^{-4}
Phenanthrene	8.49×10^{-6}	ND	8.21×10^{-4}	2.22×10^{-5}	1.553×10^{-5}
Fluoranthene	2.04×10^{-5}	4.64×10^{-6}	1.02×10^{-3}	2.86×10^{-5}	4.573×10^{-5}
Pyrene	82.0×10^{-5}	2.08×10^{-6}	3.75×10^{-4}	3.11×10^{-6}	4.323×10^{-5}
Benz(a)anthracene	4.59×10^{-5}	2.26×10^{-7}	1.73×10^{-4}	3.44×10^{-6}	6.10×10^{-6}
Chrysene	5.72×10^{-5}	3.61×10^{-6}	8.01×10^{-4}	2.60×10^{-6}	3.049×10^{-5}
Benzo(b)fluoranthene	3.83×10^{-2}	7.81×10^{-3}	1.84×10^{-2}	2.22×10^{-3}	3.14×10^{-3}
Benzo(k)fluoranthene	4.95×10^{-6}	2.67×10^{-6}	1.88×10^{-5}	9.0×10^{-8}	7.1×10^{-7}
Benzo(a) pyrene	7.88×10^{-4}	1.25×10^{-4}	6.48×10^{-5}	5.20×10^{-6}	1.76×10^{-3}
Indeno (1,2,3-ed)pyrene	1.34×10^{-3}	3.50×10^{-2}	1.93×10^{-1}	2.94×10^{-2}	1.53×10^{-2}
Dibenz(a,h)anthracene	8.0×10^{-8}	3.24×10^{-5}	9.10×10^{-5}	3.46×10^{-5}	8.05×10^{-6}
Benzo(g,h,i) perylene	9.32×10^{-4}	1.22×10^{-4}	2.37×10^{-4}	3.0323×10^{-4}	6.293×10^{-5}
Total					

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155 **ND → Not Detected**

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* Tel.: +2348036683491

*Corresponding author: Email: Ujowundu@yahoo.com

157 **TABLES 2: Concentration (mg/kg) of Polycyclic Aromatic Hydrocarbons in the in long**
 158 **processed Samples**

Type of PAH	Beef	Fatty beef	Fish	Chicken	Pork
Naphthalene	ND	ND	ND	ND	ND
Acenaphthylene	1.6×10^{-6}	1.247×10^{-4}	4.25×10^{-5}	4.79×10^{-5}	5.882×10^{-4}
Acenaphthene	1.04×10^{-5}	ND	1.843×10^{-4}	0.869×10^{-5}	2.48×10^{-5}
Fluorene	1.44×10^{-5}	ND	2.5×10^{-5}	1.198×10^{-5}	ND
Anthracene	0.162×10^{-5}	6.008×10^{-4}	1.85×10^{-4}	1.264×10^{-4}	ND
Phenanthracene	3.7×10^{-5}	ND	7.63×10^{-4}	0.527×10^{-5}	ND
Fluoranthene	1.08×10^{-4}	4.428×10^{-4}	3.09×10^{-2}	5.385×10^{-5}	3.077×10^{-5}
Pyrene	3.3×10^{-5}	2.619×10^{-5}	1.941×10^{-3}	5.188×10^{-5}	2.007×10^{-5}
Benz(a)anthracene	3.2×10^{-5}	1.19×10^{-4}	7.5×10^{-4}	3.1105×10^{-5}	7.076×10^{-6}
Chrysene	8.47×10^{-5}	1.654×10^{-4}	5.24×10^{-4}	4.7112×10^{-5}	4.87×10^{-6}
Benzo(b)fluoranthene	3.64×10^{-3}	3.02×10^{-2}	8.477×10^{-1}	1.6076×10^{-1}	8.92×10^{-3}
Benzo(k)fluoranthene	2.1×10^{-6}	1.96×10^{-4}	5.37×10^{-5}	6.35×10^{-6}	ND
Benzo(a) pyrene	3.12×10^{-5}	5.01×10^{-5}	5.205×10^{-4}	1.258×10^{-5}	3.204×10^{-4}
Indeno (1,2,3-cd)pyrene	6.6×10^{-2}	6.5×10^{-2}	4.954×10^{-2}	3.254×10^{-2}	ND
Dibenz(a,h)anthracene	8.66×10^{-5}	ND	2.874×10^{-4}	1.59×10^{-5}	ND
Benzo(g,h,i) perylene	1.796×10^{-5}	1.895×10^{-3}	2.654×10^{-5}	3.53×10^{-5}	2.698×10^{-5}

159 **ND → Not Detected**

160 **3.3 Heavy Metal Content of Fresh and Long Processed Food Samples**

162 **The concentrations of heavy metals in fresh and long processed samples are presented in**
 163 **Table 3.** The concentration of iron ranged from 14.92 ± 0.63 mg/kg in LP beef to 43.52 ± 0.41
 164 mg/kg in LP chicken. Mercury was less than 0.001 mg/kg in all the samples and was termed
 165 not detected. Zinc content of the various food samples were observed to be higher in
 166 concentration than other elements determined. The concentration of zinc varied from $20.80 \pm$
 167 0.80 mg/kg in FP chicken to 109.40 ± 0.70 mg/kg in FP beef. Appreciable amount of zinc was
 168 observed in LP beef (76.25 ± 0.35 mg/kg) and pork (85.00 ± 0.25 mg/kg) and in FP fatty beef
 169 (83.45 ± 0.70 mg/kg). Cadmium concentration ranged from 0.180 ± 0.011 mg/kg in FP fatty
 170 beef to 2.345 ± 0.35 mg/kg in LP beef. The concentration of lead varied from 0.885 ± 0.08
 171 mg/kg in FP pork to 9.910 ± 0.39 mg/kg in LP beef.
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* Tel.: +2348036683491

*Corresponding author: Email:Ujowundu@yahoo.com

In the beef samples, cadmium and Pb concentrations were higher ($P < 0.05$) in LP than in FP samples. Significantly higher concentration of Fe was observed in FP beef than in LP beef. Also concentrations of Zn in FP beef were higher ($P < 0.05$) than in LP beef samples. Iron concentration in fatty beef was significantly ($P < 0.05$) higher in LP than in FP. Zn and Pb concentrations in fatty beef were higher ($P < 0.05$) in FP than in LP fatty beef. Cd concentration in the LP fatty beef was significantly higher than in FP fatty beef.

Concentrations of iron and Zinc in LP fish were higher ($P < 0.05$) than the concentrations of iron and zinc in the FP fish. Cd concentration in the FP fish was significantly higher than in LP fish. The concentration of Pb in LP fish was higher ($P < 0.05$) than the concentration in FP roasted fish. Zn and Fe concentrations in LP chicken were significantly higher when compared to FP chicken. Concentration of cadmium in LP chicken varied non-significantly with FP chicken. Pb concentration in FP chicken was higher ($P < 0.05$) than the concentration in LP chicken. The higher Cd concentration in FP pork varied non-significantly when compared to the LP.

Table 3. Heavy metal content (mg/kg) of fresh processed and long processed sample

SAMPLE IDENTITY	IRON	MERCURY	ZINC	CADMIUM	LEAD
Fresh processed beef	41.69±0.84	<0.001	109.4±0.7	0.633±0.04	5.13±0.23
Long processed beef	14.93±0.63	<0.001	76.25±0.35	2.345±0.35	9.91±0.39
Fresh processed fatty beef	20.27±0.35	<0.001	83.45±0.7	0.18±0.01	2.245±0.07
Long processed fatty beef	43.50±0.40	<0.001	25.55±0.4	0.265±0.04	2.045±0.15
Fresh processed fish	26.20±0.40	<0.001	23.70±0.6	0.895±0.01	0.705±0.01
Long processed fish	40.85±0.62	<0.001	51.95±0.49	0.51±0.02	3.70±0.40
Fresh processed chicken	25.14±0.24	<0.001	20.80±0.8	0.415±0.3	0.705±0.01
Long processed chicken	43.52±0.41	<0.001	44.00±0.30	0.443±0.04	3.70±0.40
Fresh processed pork	23.85±0.39	<0.001	62.20±0.20	0.355±0.06	0.885±0.08
Long processed pork	17.57±0.44	<0.001	85.00±0.25	0.305±0.01	2.135±0.03

Values = mean ± SD of triplicate determinations

4. DISCUSSION

PAHs are a group of chemicals that result from incomplete burning of coal, oil, gas, wood, fossil fuels in general and biomass (9). Studies have shown that most intake of polycyclic aromatic hydrocarbons in food come from vegetables and cooked meats (6). PAHs have been identified as mutagenic and carcinogenic compounds and benzo(a)pyrene is among the most potent and best documented carcinogen (16,17). Studies in experimental animals have shown various toxicological effects, such as haematological effects, reproductive and developmental toxicity and immunotoxicity. The most important is the carcinogenic and

* Tel.: +2348036683491

*Corresponding author: Email:Ujowundu@yahoo.com

genotoxic (DNA-damaging) potential of these compounds. A number of PAHs have shown carcinogenicity in experimental animals and genotoxicity and mutagenicity in vitro and in vivo. The presence of benzo[a]pyrene classified as carcinogenic to humans (1A) and benz[a]anthracene and dibenz[a,h]anthracene classified as probably carcinogenic to humans (Group 2A) is very important. Some of the detected PAHs are possibly carcinogenic to humans (Group 2B) or not classifiable as to its carcinogenicity to humans (18).

The results obtained in this study showed that the total concentrations of PAHs in LP food samples were higher than the concentrations in the freshly processed. This could be attributed to longer duration of processing (19). Roasting very close to the heat source at very high temperature is an important factor in food preservation. This ensures proper drying for long time storage and spoilage prevention (20,21). The high amount of PAHs observed in fresh processed fish compared to other fresh processed samples could be due to the type of fuel used (22) and the exposure of the sample to smoke generated by the firewood. The local processing of fish allows smoke from incomplete wood burning to come into direct contact with the fish. This can lead to its considerable contamination with various PAHs because the process is poorly controlled. The least concentration of total PAHs obtained in fresh processed pork compared to other fresh processed samples indicates the effect of processing. Food vendors pre-cook the pork sample before roasting. This procedure may reduce both the fat content and time of roasting on open flame. The fresh roasting of the pork may be to impart flavours and colours (23). Higher concentration of the PAHs in long roasted fatty beef compared to the freshly roasted fatty beef may be as a result of higher fat content of meat (24), and pyrolysis resulting from increased amount of melted fat dropped on heat source (22). Also the lower amount of total PAHs in beef compared to fatty beef can be attributed to fat content as reported by Mottier *et al.* (25) who found significantly higher levels of carcinogenic PAHs in high fat containing lamb sausages. Also the content of PAH in the woods used (13) may have contributed to the PAH content of these locally processed foods. Similarly, the longer time of processing may enhance the release of the solidly bound PAH in the woods matrix (14)

A cursory look at the individual PAHs showed that naphthalene was not detected in any of the samples. This may be due to its volatile nature. Naphthalene is the lightest amongst the PAHs with 2-fused benzene rings and easily sublimates at room temperature (26). However, study of Houessou *et al.*, (27) on the formation of PAHs during the roasting process indicated a possible transformation of low molecular PAHs to high molecular PAHs as roasting temperature increased. This transformation may be implicated in the increased concentration of high molecular weight PAHs which are largely carcinogenic (i.e benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, dibenz[a,h]anthracene and indeno[1,2,3-cd]pyrene, benzo[g,h,i]perylene) in the long processed samples

The concentrations of benzo[a]pyrene, benz[a]anthracene and dibenz[a,h]anthracene which are classified as probable carcinogens to humans (Group 2A) are of great health concern to consumers. Benzo[a]pyrene is regarded as the most potent PAHs. Its metabolism in living system increases its toxicity (28). As the living system attempts to degrade Benzo[a]pyrene, it forms reactive metabolites (benzo[a]pyrene 7,8-dihydrodiol which is in part oxidized to 7,8-diol-9,10-epoxide) that may bind to DNA causing disruption to the genetic functioning of the affected cells inducing a genotoxic effect. (28,29,30). The highest concentrations of benzo[a]pyrene were obtained in freshly processed pork (1.757×10^{-3} mg/kg) and long processed fish (5.01×10^{-4} mg/kg). It was a surprise to find the highest amount of benzo[a]pyrene in FP pork, which total PAHs ranked among the least. Our results also indicated that dibenz[a,h]anthracene another probable carcinogen was not detected in the

LP samples, while the concentration of benz[a]anthracene reduced. Also in the LP pork 7 PAHs; naphthalene, fluorene, anthracene, phenanthracene, benzo[k]fluoranthene, dibenz[a,h]anthracene and indeno[1,2,3-cd]pyrene were lost after long processing. These variations can be attributed to the method of processing the pork, which setup differs from that of fish and beef. This finding calls for further studies. Indeno (1,2,3,-cd)pyrene and Benzo(k)fluoranthene at concentrations of 6.6×10^{-2} mg/kg and 3.64×10^{-3} mg/kg respectively were among the highest detected carcinogenic PAHs in long processed beef sample. Similar pattern was observed in all LP samples. These observations corroborates the assertion that roasting imparts carcinogenic compounds in food (31,32). The industries activities within the areas where these animal foods were breed could affect air quality which may impact negatively on the chemical constituents of food chain especially the plants (33,34) which constituents majority of these animal feed during free ranching as practiced in Nigeria. Studies by Rey-Salgueiro et al. (8) showed that PAH concentrations in plants were related to their surface exposed to air, indicating a significant contribution of environmental air quality to plant PAHs concentration.

Studies have shown some heavy metals to be toxic while some referred to as trace elements are beneficial to life in certain quantities. The results (Table 3) of this study showed the presence of lead, cadmium, zinc, and iron in FP and LP samples. Mercury was not detected. The concentration of lead varied from 0.71 ± 0.01 mg/kg in FP chicken to 9.91 ± 0.39 mg/kg in LP beef. Lead value of 5.13 ± 0.23 mg/kg in FP beef and 3.70 ± 0.4 mg/kg in LP fish were also observed. Lead is number 2 on the Agency for Toxic Substances and Disease Registry's (ATSDR) top 20 hazardous substances. Lead is an important paediatric heavy metal poison (35). It affects bones, brain, blood, kidneys, and thyroid gland on exposure (36,37).

Acute lead exposure can affect cardiac function, and chronic exposure may affect the electrical and mechanical activity of the heart via the alteration of vascular smooth muscle function as observed in experimental animals. Intracellular lead substitutes calcium in calcium-dependent signaling pathways by interacting with calmodulin and calcium-dependent potassium channels. Lead can affect the intercellular messenger protein kinase C and its role in smooth muscle contraction (38). Lead absorption is enhanced by deficiencies of iron, calcium, and zinc (39).

The concentration of cadmium ranged from 0.18 ± 0.01 mg/kg in FP beef to 0.895 ± 0.01 mg/kg in FP fish.

Cadmium is present in insecticides, fungicides, sludge, and fertilizers used in agriculture. About 50% of absorbed cadmium is through respiration and about 7% absorbed in the gastrointestinal system is taken up with food. Organs such as the liver, placenta, kidneys, lungs, brain, and bones can be affected by cadmium exposure (35,37). Cadmium and its compounds accumulation have a possible risk of irreversible effects on human health. A primary mechanism for cadmium toxicity is its effect on cells which has been ascribed to the oxidative stress promoting cadmium action, as observed *in vivo*, and most importantly, the depletion of glutathione and alteration of sulfhydryl homeostasis. Thus, cadmium indirectly increases oxidative stress and lipid peroxidation (38). Cadmium and lead contents in the samples may be due to metal bioaccumulation in food chain. The higher amount of these two important heavy metals in the LP samples may be attributed to the long duration of roasting. Since wood ashes contains heavy metals (13), the long period of roasting increases the amount of wood ashes generated and the possibility of its heavy metal content to volatilize and penetrate the foods. Also, long processing may increase the exposure period to industrial activities such as road construction and exposure to dust and fumes from vehicles. Also, heavy metal contamination of food samples may emanate from emissions from disposal and burning of hazardous wastes such as electronics, used vehicle tyres and batteries (40).

* Tel.: +2348036683491

*Corresponding author: Email:Ujowundu@yahoo.com

Iron and Zinc are nutritionally essential for a healthy life. The presence of iron and zinc may be as a result of its natural occurrence in food stuff. For example studies have shown low fat roasted beef as one of the top five foods rich in zinc (41). Iron and zinc are important for proper immune system function. Iron is a constituent of red blood cells and functions as primary carrier of oxygen throughout the body. Zinc supports normal growth and development, and is important for protein and DNA synthesis (41). Metals such as zinc, iron, copper and cobalt serve as catalyst of enzymatic reactions. Most enzymes require ions to either activate or stabilize them. For example, iron (a stabilizing ion) is a structural and functional component of the cytochrome P-450 enzyme system and zinc (an activating ion) forms a temporary bond with alkaline phosphatase (an enzyme needed for bone formation) (42). Generally, the presence of these heavy metals in elevated levels and PAH could be as a result of bioaccumulation over time. They could be picked up through diet and water (7) and transferred through the food chain even before they were processed (43).

4.1 Conclusion

This study has shown that polycyclic aromatic hydrocarbons and heavy metals are present in fresh and prolonged processed foods. Since the metabolites of PAHs target cellular macromolecules such as DNA and this may lead to mutations and carcinogenesis while toxic heavy metals target membrane structures, enzymes or DNA, exposure to these compounds can impact negatively on living system causing serious adverse health problems to living organisms

Considering the findings and observations of this study, we recommend the following measures: Increased awareness on the toxicity and risk of PAHs and heavy metals. This will encourage better processing methods of foods by individuals in order to reduce the health risk. If roasting must take place, it should be done in places free from heavy metal emissions, and food samples should not be placed too close to the heat source. PAHs and heavy metal tolerable limits and standard in food stuff should be developed by regulatory bodies

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COMPETING INTERESTS

Authors have declared that no competing interests exist

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between all authors. Authors COU, FNU and CSA, designed the study. Authors COU and CUI, performed the statistical analysis, authors KLI and COU wrote the protocol, and the first draft of the manuscript. Authors COU, KLI, FNU, CSA and CUI managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

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* Tel.: +2348036683491

*Corresponding author: Email:Ujowundu@yahoo.com

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* Tel.: +2348036683491

*Corresponding author: Email:Ujowundu@yahoo.com

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* Tel.: +2348036683491

*Corresponding author: Email: Ujowundu@yahoo.com