ASSESSMENT OF POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) LEVELS IN SELECTED ROASTED AND SMOKED FOOD SAMPLES

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ABSTRACT

The study investigated the levels of polycyclic aromatic hydrocarbons (PAHs) in selected food samples which include roasted and smoked fishes, meats, corn, yam and ripe plantain using Gas Chromatography/Mass Spectrophotometer. The result revealed the presence of PAHs in the different food samples at varying concentrations of which more were observed in the smoked and roasted fish and meat samples than in the roasted yam, ripe plantain and corn. Benzo[a]pyrene were not observed in the roasted yam, ripe plantain and corn samples. Chrysene was most commonly found in the food samples that were negative for benzo(a)pyrene with higher concentration levels. Chrysene contributed most on the total PAH of the samples with a value 16.5933 mg/kg in mackerel fish while benzo[b]fluoranthene contributed in higher amount with a concentration value of 67.7566 mg/kg to total mean concentration of PAH in whole sample of catfish (Malashya type). The study revealed different concentrations of the PAHs in the food samples which have been noted to exhibit both non-cancer and cancer risks on and humans. The study therefore complements monitoring information on the levels of polycyclic aromatic hydrocarbons (PAHs) occurrence in the different food samples studied.

Keywords: Contamination, food sample, monitoring and polycyclic aromatic hydrocarbons.

INTRODUCTION

The importance of food to the human body cannot be overemphasized as they have their different major functions in the body. There are different methods of cooking and preservation of food substances depending on the need. However, each method of cooking or preservation has its peculiarity which may have positive or negative impact on the quality and nutritive composition of the food. Foods associated with burning, roasting and overheating have been observed to contain increased levels of polycyclic aromatic hydrocarbons (PAHs).

The presence of polycyclic aromatic hydrocarbons (PAHs) in the food samples poses risk to the health of people depending on them as source of food. Contaminated food constituents have increasingly turned out as major environmental issue that has continued to attract widespread attention. Foods have been noted to be the major route of exposure in consumption of PAHs. Food can be contaminated from environmental sources (natural and mostly anthropogenic), from industrial food processing, and from some domestic cooking practices (Zuzana and Thomas, 2015; European Food Safety Authority (EFSA), 2008; Scientific Committee on Food (SCF), 2002). Food burning, roasting and overheating has been associated with increased levels of polycyclic aromatic hydrocarbons. These chemicals which have been found to be toxic and carcinogenic have invariably become of great global concern with regards to their injurious implications to human health as well as the environment.

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Food processing (drying, smoking) and cooking of food at high temperatures (grilling, frying, roasting, baking) are commonly considered to be the major sources of PAHs contamination in foods (Mottier *et. al.* 2000; Dav´ıdek, 1995; Fretheim, 1983). Seeds and raw products use for oil production may be contaminated with PAHs through artificial drying and heating if precautionary measures are not taken (by using indirect drying and adequate temperature control). Drying of some food materilas is thought to be one of the sources of contamination by PAHs (Moreda, *et. al.*, 2001). Also, some preservation techniques such as industrial smoking some food products under inappropriate conditions could lead to contamination with PAHs (Simko, 2002).

Most of the staple foods enjoyed by the populace are prepared by either roasting or smoking methods. Roasting is a cooking method that uses dry heat, which may be an open flame, oven, or other heat source for roasting. The food material may be placed on a rack or in a roasting pan. Meats and most root and bulb vegetables can be roasted. The health risks associated with the use of this method in food preparation especially meat prepared at high temperatures is that it can generate carcinogenic chemicals. The two processes that are thought to be responsible are the formation of Heterocyclic amines (HCAs) which are formed when amino acids, sugars, and creatine (a protein) react at high temperatures and polycyclic aromatic hydrocarbons (PAHs) which are formed when fat and juices from meat grilled directly over an open fire drip onto the fire which then causes flames. The flames contain PAHs that then adhere to the surface of the meat. PAHs can also be formed during other food preparation processes, such as smoking of meats (Cathy, 2007). Studies have shown that cooking beef, pork, poultry, and fish at high temperatures can lead to the formation of heterocyclic amines, benzopyrenes, and polycyclic aromatic hydrocarbons, which are carcinogens (Sugimura *et al.*, 2004).

Polycyclic aromatic hydrocarbons (PAHs) also known as polyaromatic hydrocarbons or poly nuclear aromatic hydrocarbons are a class of organic chemicals consisting of two or more fused aromatic rings (Fetzer, 2000). They belong to the group of persistent organic pollutants (POPs) that are resistant to degradation which make them remain in environment for a long period and have the potential to cause adverse environmental effects. However, some of which some have been identified to be carcinogenic (Ogbuagu *et al.*, 2011), mutagenic and teratogenic compounds. Polycyclic aromatic hydrocarbons usually occur naturally, but some of the anthropogenic sources include road traffic and combustion of fossil fuels product. PAHs also occur in crude oil, coal, and tar deposits, and are produced as by-product of fuel burning in automobile exhaust fumes (Masih *et al.*, 2008, Staffan, 2003 and Fetzer, 2000). Natural crude oil and coal deposits contain significant amounts of PAHs, arising from chemical conversion of natural products molecules such as steroids to aromatic hydrocarbons. They are also found in processed fossil fuel (Gevao *et al.*, 1998).

The toxicity, persistence and prevalence of PAHs compounds have been reported (Howsam and Jones, 1998, Delistraty, 1997). Ogbuagu and Ayoade (2012) reported the PAHs in staple food of Nigeria**.** It has also been reported that PAHs require metabolic activation and conversion to display their genetoxic and carcinogenic effects (Pickering, 1999). The metabolic activation of Benzo[*a*]pyrene as one of the major PAHs of most carcinogenic compound of concern has been shown to be by a multifunctional cytochrome P-450. Cytochrome P-450 is the primary isoenzyme that biologically activates benzo[a]pyrene and may also be induced by other substances to form a variety of epoxides products by addition of oxygen across double bond as well as further conversion to compounds that could cause mutations and possibly cancer (Staffan, 2003; Pickering, 1999 and IARC, 1983).

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Benzo[*a*]pyrene toxicity results from the bioactivation of benzo[*a*]pyrene yielding the ultimate toxic carcinogenic compound, benzo[*a*]pyrene -7,8-dihydrodiol-9,10-epoxide as a result of its biological accumulation in large concentrations. PAHs also may interact in other steps of carcinogenic processes to promote cellular proliferations and some may be environmentally transformed which then may directly react with DNA to cause mutation and possible cancer without being metabolically activated. Furthermore, benz[a]anthrancene is fairly weak carcinogen but 7, 12-dimethyl benz[a]anthrancene is a very potent carcinogen (Delistrary, 1997).

The recommended the monitoring of 15 PAHs in 2002, including 8 high molecular weight PAHs that are also part of the U.S. EPA list which concluded that 15 out of 33 assessed PAHs, namely benz[a]anthracene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k] fluoranthene, benzo[ghi]perylene, benzo[a]pyrene, chrysene, cyclopenta[cd] pyrene, dibenzo[a,h]anthracene, dibenzo[a,e]pyrene, dibenzo[a,h]pyrene, dibenzo[a,i]pyrene, dibenzo[a,l]pyrene, indeno[1,2,3-cd]pyrene, and 5 methylchrysene show clear evidence of mutagenicity/genotoxicity and, with exception of benzo[ghi]perylene, have also shown clear carcinogenic effects in various types of bioassays in experimental animals (Scientific Committee on Food (SCF), 2002). However, the study of PAHs compounds has often been limited to sixteen (16) PAHs that had been designated by Environmental Protection Agency (US-EPA) as priority environmental pollutants (Staffan, 2003).

This research work therefore identified and evaluated the concentration levels of PAHs present in some selected roasted and smoked food stuffs which are commonly consumable food on most highways, major roads and streets as well as other related dry meats found in the markets. These foods samples were carefully and adequately selected such that a wide range of smoked and roasted foods commonly consumed were covered.

Materials and Methods

The samples used for this research were purchased or sourced from the markets and directly from the food vendors. The samples were collected were stored in labeled polyethylene bags and then taken to the laboratory. Also, fresh meat and ice fish were obtained and dried in an enclosed heat source.

These were then subjected to standard laboratory analysis used for extracting and analyzing the PAHs in food materials. The samples were homogenised and 10 g sample was put into a clean 250 ml extraction bottle or 100 ml conical flask. The 30 ml of extraction solvent (dichloromethane) was added to the sample in the 250 ml bottle or 100 ml conical flask and was covered properly with aluminium foil paper. It was agitated/swirled for 2mins while releasing cover to control pressure that built up and allowed extract to settle in a space of 3 - 15 mins, The extracted mixture was passed through a filter paper containing 1 - 3g of sodium sulphate together with activated silica gel and the volume of the extract obtained was recorded for further calculations. Finally an aliquot of the extract was transferred into vial, ready for injection. The extracted samples were then subjected to Gas Chromatography/Mass Spectrometer (GC/MS) for identification and concentration levels of PAHs in the various samples.

The analysis of samples for the presence of PAHs were limited to those as listed by the EFSA (2008) and United State Environmental Protection Agency (USEPA) which are the major ones of concern. These include Naphthalene (Na), Acenaphthylene (Acy), Acenaphthene (Ace), Fluorene (FL), Phenathrene (Phe), Fluoranthene (Flu), Pyrene (Pry), Chrysene (Chry), Benz[a]anthrancene (B[a]A), benzo[b]flouranthene (B[b]F), Benzo[k]fluoranthene (B[k]F), Benzo[a] pyrene (B[b]P), Anthrancene (An), Indeno[1,2,3,-cd] pyrene (IP), Be nzo[g,h,i] Perylene (B[g,h,i] P.

RESULTS AND DISCUSSIONS

The mean concentration (mg/kg) of each of the PAHs in the different selected smoked and roasted food samples are shown in Tables 1 – 6. The mean concentration (mg/kg) values of polycyclic Aromatic Hydrocarbons (PAHs) present in roasted yam, ripe plantain and corn is shown in Table 1, the result shows that of the sixteen (16) PAHs studied, six (6) which include acenaphthene, flourene, phenanthrene, anthrcene, flouranthene and benzo[a]pyrene were not observed in the yam, ripe plantain and corn samples. The highest mean concentration of 3.8724 mg/kg was recorded for pyrene in corn which also contributed highest value to the total PAH in the sample followed by chrysene with a value 2.7155 mg/kg in the same sample while the least value of 0.0057 mg/k was recorded for acenaphthylene. The highest total concentration of PAH (Fig. 1) occurred in corn with a value of 6.8073 mg//kg and the least value of 0.0158 mg/kg in the inside yam sample.

Table 1: Mean Concentration (mg/kg) values of Polycyclic Aromatic Hydrocarbons (PAHs) present in roasted yam, ripe plantain and corn

S/N	**PAHs**	Blank	Yam		Ripe plantain		Corn
			Inside	Whole	Inside	Whole	Whole seed
1	Naphthalene	-	0.0168	0.0145	0.06125	0.0128	0.0094
2	Acenaphthylene	-	0.0057	-	-	-	0.004
3	Acenaphthene	-	-	-	-	-	-
4	Flourene	-	-	-	-	-	-
5	Phenanthrene	-	-	-	-	-	-
6	Anthrcene	-	-	-	-	-	-
7	Flouranthene	-	-	-	-	-	-
8	Pyrene	-	-	0.0488	-	-	3.8724
9	Benz[a]anthracene	-	-	-	-	-	0.0199
10	Chrysene	-	-	-	-	0.1966	2.7155
11	Benzo[b]fluoranthene	-	-	-	-	-	0.0700
12	benzo[k]flouranthene	-	-	-	-	-	0.0747
13	Benzo[a]pyrene	-	-	-	-	-	-
14	Benzo [g,h,i] perlene	-	-	-	-	-	0.0285
15	Diabenz [a,h] anthracene	-	0.0082	0.0145	-	-	0.1197
16	Indeno [1,2,3-cd] pyrene	-	-	0.2086	-	0.099	0.0087
	TOTAL (PAH)	**0.0000**	**0.0158**	**0.0377**	**0.0408**	**0.0801**	**6.8073**

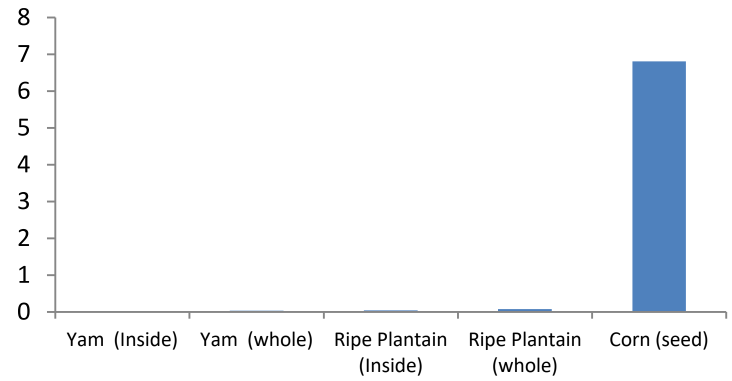

Fig. 1: Total concentration of polycyclic aromatic hydrocarbon in yam, ripe plantain and corn samples

The result of the mean Concentration (mg/kg) values of Polycyclic Aromatic Hydrocarbons (PAHs) present in different selected smoked ice fishes is shown in Table 2 and it revealed that acenaphthene and flourene were not present in mackerel ice fish while all other PAHs were present in the ice fishes in varying concentrations.

Chrysene contributed most on the total PAH with a value 16.5933 mg/kg in mackerel fish purchased from the market while indeno [1,2,3-cd] pyrene contributed most in that of mackerel fish prepared in an enclosure with a value of 8.8683 mg/kg. The least total PAH was recorded for the inside part of the mackerel fish prepared in an enclosure with a value of 6.0363 mg/kg.

Table 2: Mean Concentration (mg/kg) values of Polycyclic Aromatic Hydrocarbons (PAHs) present in different selected smoked ice fishes

S/N	**PAHs**	Blank	Mackerel fish				Scumbia fish	
			Inside (enclosed)	Whole (enclosed)	Inside	Whole	Inside	Whole
1	Naphthalene	-	0.0585	0.0182	0.0181	0.0988	0.0467	0.0722
2	Acenaphthylene	-	0.0359	0.0131	0.0128	0.0947	0.0283	0.0604
3	Acenaphthene	-	-	-	-	-	0.0191	0.0233
4	Flourene	-	-	-	-	-	-	0.0061
5	Phenanthrene	-	0.0200	-	0.0230	0.0989	0.9691	0.6927
6	Anthrcene	-	0.0142	-	0.2645	4.1909	0.6830	0.0480
7	Flouranthene	-	-	0.1244	0.1166	0.8659	0.0910	0.0321
8	Pyrene	-	0.5762	4.5169	3.3021	0.7123	4.5409	2.2154
9	Benz[a]anthracene	-	0.1909	0.0358	0.1294	1.3603	0.1278	0.0235
10	Chrysene	-	0.0105	3.3099	0.9928	16.5933	4.3799	1.7257
11	Benzo[b]fluoranthene	-	-	0.1228	0.254	3.8097	0.1458	0.1584
12	benzo[k]flouranthene	-	-	-	0.0832	2.6994	0.5364	0.3447
13	Benzo[a]pyrene	-	-	0.0547	0.3237	6.9535	0.4373	0.2276
14	Benzo [g,h,i] perlene	-	0.2416	0.8613	-	2.0976	0.4857	0.0692
15	Diabenz [a,h] anthracene	-	1.8708	0.4265	0.3192	0.3584	0.2341	0.4182
16	Indeno [1,2,3-cd] pyrene	-	3.0179	8.8683	3.8312	4.0465	1.6008	3.8448
	TOTAL (PAH)	**0.0000**	**6.0363**	**18.1244**	**9.5150**	**24.4972**	**14.046**	**9.7401**

The results of the PAHs observed in different fish samples are shown in Tables 3 and 4 while Fig. 2 shows the graph of total PAHs in the samples. In Table 3 and 4, all the sixteen PAHs studied were all observed in varying concentrations in different fish samples except for flourene which was not observed in mangala, sungu, balaa, prawn and crayfish at all. Also acenaphthene was not observed in sungu. Benzo[b]fluoranthene contributed in higher amount with a concentration value of 67.7566 mg/kg to total mean concentration of PAH in whole sample of catfish (Malashya).

Table 3: Mean Concentration (mg/kg) values of Polycyclic Aromatic Hydrocarbons (PAHs) present in different other selected smoked/ fishes.

S/N	PAHs		Catfish (Malashya type)		*Mangala*		*Arira*	
		Blank	Inside	Whole	Inside	Whole	Inside	Whole
1	Naphthalene	-	0.0868	0.0617	0.0059	0.0046	0.0775	0.0232
2	Acenaphthylene	-	0.0708	0.0495	0.0075	0.0063	0.0331	0.0163
3	Acenaphthene	-	0.0263	0.0433	-	0.0053	0.0753	0.1432
4	Flourene	-	0.0038	-	-	-	0.0034	-
5	Phenanthrene	-	0.0260	0.044	0.001	0.0089	0.0879	0.0130
6	Anthrcene	-	0.1929	0.0225	1.4736	1.9401	0.8020	0.8782
7	Flouranthene	-	0.2105	0.0438	1.3224	0.0935	0.3476	0.2608
8	Pyrene	-	0.7785	1.2719	-	0.0459	0.2331	2.8596
9	Benz[a]anthracene	-	0.4987	67.7566	1.9618	0.6759	0.3693	0.2941
10	Chrysene	-	6.7081	0.53945	35.7656	0.0213	0.0890	7.4640
11	Benzo[b]fluoranthene	-	1.7310	63.3166	3.3664	0.0346	0.6167	0.6994
12	benzo[k]flouranthene	-	0.8360	0.1919	1.7069	1.0037	6.1700	1.6493
13	Benzo[a]pyrene	-	2.2317	0.1143	0.3508	0.0195	1.0176	0.0385
14	Benzo [g,h,i] perlene	-	0.2776	0.5379	0.0004	0.0178	0.1800	0.1106
15	Diabenz [a,h] anthracene	-	0.1221	0.1679	0.1353	0.0194	0.1300	0.0882
16	Indeno [1,2,3-cd] pyrene	-	0.8557	2.7329	2.2069	0.9139	1.1452	2.1418
	TOTAL (PAH) (mg/kg)	**0.0000**	**11.8211**	**92.6579**	**30.7438**	**4.76865**	**6.7940**	**18.4104**

In Table 4, indeno [1,2,3-cd] pyrene contributed higher to the total PAH concentrations in bonga fish, sungu fish, baala fish, prawn and crayfish with values of 6.0566 for whole bonga fish ; 3.51965, 4.4615 (inside and whole sungu); 6.8386, 4.2833 (inside and whole baala); 15.3059 and 7.8939 mg/kg respectively while Chrysene contributed higher to that of inside of bonga fish with a value of 6.3379 mg/kg.

Table 5 shows the result of PAHs in beef, canda and beef suya meat while the Total PAH is shown in Fig 3. Flourene, flouranthene, benz[a]anthracene, benzo[k]flouranthene and benzo [g,h,i] perlene were not observed in beef samples prepared in an enclosure. Acenaphthene, flourene, phenanthrene, anthrcene, flouranthene and benzo [g,h,i] perlene were not observed in the bagged canda samples while Flourene, and Phenanthrene were not observed in bagged beef meat. As was observed in most of the fish samples indeno [1,2,3-cd] pyrene contributed higher to the total PAH concentrations in beef samples prepared in an enclosure, bagged beef not washed and that of lightly spiced suya meat with a values of mean concentrations of 3.0973, 2.2405 and 1.1171 mg/kg respectively. Anthrcene contributed more to the total concentration value of PAH in washed bagged beef with a value of 4.2720 mg/kg and Chrysene contributed more to that of heavily spiced suya with a value of 5.1226 mg/kg

Table 4: Mean Concentration (mg/kg) values of Polycyclic Aromatic Hydrocarbons (PAHs) present in different other related smoked fishes

S/N	**PAHs**	Blank	*Bonga fish*		*Sungu*		*Baala*		Prawm (*Oporo*)	Crayfish
			Inside	Whole	Inside	Whole	Inside	Whole	Whole	whole
1	Naphthalene	-	0.0281	0.0582	0.6628	0.0474	0.0466	0.0852	0.0261	0.1085
2	Acenaphthylene	-	0.0239	0.058	0.0352	0.1422	0.0862	0.1108	0.0165	0.0965
3	Acenaphthene	-	0.1398	0.0331	-	-	0.0795	0.0364	-	0.0419
4	Flourene	-	-	0.0035	-	-	-	-	-	-
5	Phenanthrene	-	0.6533	0.04573	-	0.0055	0.0557	0.0945	0.0042	0.0059
6	Anthrcene	-	1.1833	0.9817	0.0136	0.0137	0.0321	0.0238	0.0035	0.0949
7	Flouranthene	-	0.1211	0.1274	-	0.0262	0.0326	0.0247	0.0331	0.0397
8	Pyrene	-	0.6623	0.6004	0.0431	0.2204	1.6670	0.2676	0.9447	0.0948
9	Benz[a]anthracene	-	0.3496	0.1907	0.3757	0.0207	0.0191	0.0033	0.0192	0.0124
10	Chrysene	-	6.3379	0.3825	0.2813	0.2504	0.7855	0.1709	0.5424	0.2341
11	Benzo[b]fluoranthene	-	0.4621	1.0035	0.0661	0.0424	0.1742	0.0108	0.2416	0.1023
12	benzo[k]flouranthene	-	1.0505	0.6264	-	0.0102	0.1368	-	0.0235	0.0544
13	Benzo[a]pyrene	-	1.0141	0.2542	0.1005	-	0.0320	-	0.072	0.0813
14	Benzo [g,h,i] perlene	-	1.2182	0.1890	-	0.0117	0.0087	-	0.0379	0.0326
15	Diabenz [a,h] anthracene	-	0.1737	0.2139	0.10217	0.0809	0.0426	0.0770	0.0038	0.0125
16	Indeno [1,2,3-cd] pyrene	-	2.9665	6.0566	3.51965	4.4615	6.8386	4.2833	15.3059	7.8939
	TOTAL (PAH)	**0.0000**	**11.8984**	**9.8785**	**4.0599**	**5.1571**	**9.8284**	**5.0020**	**17.2744**	**8.8629**

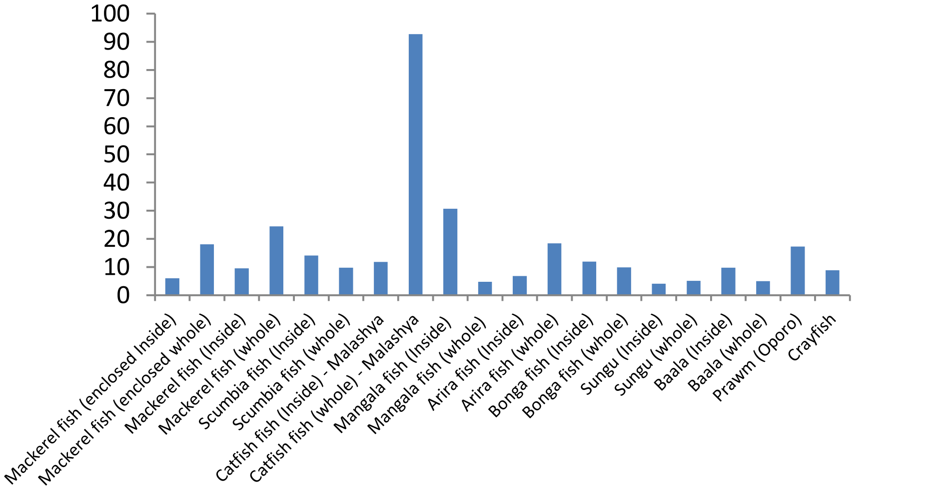

Fig. 2: Total concentration of polycyclic aromatic hydrocarbon in different fish samples

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Table 5: Mean Concentration (mg/kg) values of Polycyclic Aromatic Hydrocarbons (PAHs) present in the dried bagged beef meat and *canda* as well as suya beef meat

S/N	PAHs	Blank	Enclosed dried Beef	Bagged Dry Beef		Bagged Dry Beef skin (*Canda*)		*Suya* (beef meat)	
			Whole	washed	Not washed	scrape	Not scrape	Lightly spiced	Heavily spiced
1	Naphthalene	-	0.0806.	0.0133	0.0261	-	0.0064	0.0590	0.0268
2	Acenaphthylene	-	0.0567	0.0346	0.0463	0.0042	0.0047	0.0401	0.0158
3	Acenaphthene	-	0.0251	-	0.0926	-	-	-	0.0538
4	Flourene	-	-	-	-	-	-	-	-
5	Phenanthrene	-	0.0774	-	-	-	-	0.0668	
6	Anthrcene	-	0.0381	4.2720	0.2201	-	-	0.0219	0.0280
7	Flouranthene	-	-	0.3106		-	-	-	-
8	Pyrene	-	0.0415	2.1445	0.4681	0.4035	0.1324	0.0386	1.1547
9	Benz[a]anthracene	-	-	0.3383	0.0151	0.021	-	-	0.0131
10	Chrysene	-	0.0313	3.8217	0.5458	1.0013	0.0695	0.1590	5.1226
11	Benzo[b]fluoranthene	-	0.0091	0.0807	0.0039	0.0332	-	0.0075	0.0618
12	Benzo[k]flouranthene	-	-	0.3166	0.0192	0.0160	-	0.0213	0.0200
13	Benzo[a]pyrene	-	0.0096	0.0154	0.0251	0.0151	0.0063	-	-
14	Benzo [g,h,i] perlene	-	-	0.0101	0.0048	-	-	0.0288	0.0054
15	Diabenz [a,h] anthracene	-	0.2960	0.2478	0.2557	0.0127	0.0158	0.4187	0.1933
16	Indeno [1,2,3-cd] pyrene	-	3.0973	2.8723	2.2405	0.364	0.5359	1.1171	1.2031
	TOTAL (PAH) (mg/kg)	**0.0000**	**3.7629**	**10.4858**	**3.6475**	**4.8414**	**3.7673**	**1.9605**	**7.7627**

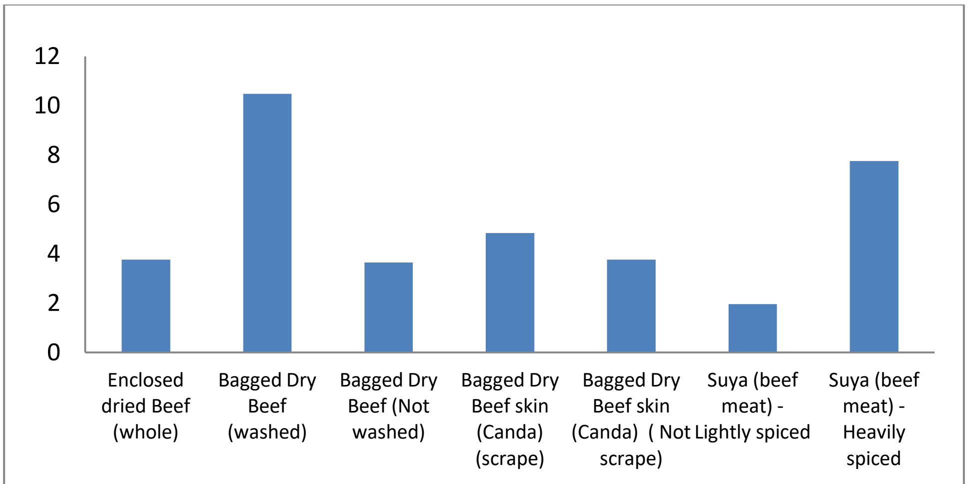

Fig. 3: Total concentration of polycyclic aromatic hydrocarbon in different meat samples

There could also be the possibility changes of PAHs in solutions as was observed the case of Chrysene with a value of 35.7656 mg/kg in the whole sample which was not observed for the inside part of the fish sample.

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The higher concentrations of these hydrocarbons in roasted fishes and meat than roasted yam, ripe plantain and corn could be due to the longer roasting duration, higher fat content of fish and meat, and pyrolysis resulting from melted fat and oil from fish and meat that drops onto the heat source (SCF, 2002; Knize *et al.*, 1999; Nawrot *et al.*, 1999). Also, the higher total concentrations of combined PAHs recorded in roasted corn than in yam and plantain though not a fatty/oily food substance could be due to the distance to the source of the heat (Phillips, 1999) and the higher temperature required for roasting (WHO, 1998) that may result in burning and charring.

Benzo[a]pyrene were not observed in the roasted yam, ripe plantain and corn while it was observed in other samples with higher concentration observed in catfish (Malashya), The maximum levels of benzo[a]pyrene for smoked meat and smoked meat products were 5. 0 and 2.0 µg/kg (equivalent to 0.005 and 0.002 mg/kg) and that for the sum of benzo[a]pyrene, benz[a]anthracene, benzo[b]fluoranthene and chrysene were 30. 0 and 12.0 µg/kg (equivalent to 0.030 and 0.012 mg/kg) (EU, 2006; 2011). This is also applied to smoked fish and some smoked fishery products as well as for smoked crustaceans. Following the maximum allowable limit for PAHs concentrations in the foods sample, the current study therefore reveals much higher concentrations of the PAHs in most of the samples. This therefore places the several consumers at potential health risk. In some samples, this study also reveals that the levels of chrysene contributed much in some of the samples. Chrysene was most commonly found in food samples that were negative for benzo(a)pyrene with higher concentration levels. The U.S. Department of Health and Human Services (HHS) has classified benz(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, dibenz(a,h)anthracene, and indeno(1,2,3-c,d)pyrene as known animal carcinogens. Also, benz(a)anthracene and benzo(a)pyrene have been classified by International Agency for Research on Cancer (IARC) as probably carcinogenic to humans. U.S. Environmental Protection Agency (EPA) classified benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, enzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-c,d)pyrene.as probable human carcinogens (Agency for Toxic Substances and Disease Registry (ATSDR), 2012) The agency has noted that PAHs generally have a low degree of acute toxicity to humans but has cancer as the most significant endpoint of their toxicity.

CONCLUSION

The result of this research work revealled the presence and concentration levels of polycyclic aromatic hydrocarbons in the food samples selected. Polycyclic aromatic hydrocarbons can have adverse effect on humans since some have been listed to be probable carcinogens to both animals and humans. Therefore this study complements monitoring information on the levels of polycyclic aromatic hydrocarbons (PAHs) occurrence in different food samples.

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REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) (2012) Case Studies in Environmental Medicine Toxicity of Polycyclic Aromatic Hydrocarbons (PAHs) https://www.atsdr.cdc.gov/csem/csem.asp

Cathy W. (2007). 5 Ways to Reduce Carcinogens in Well-Done Meat. http://altmedicine.about.com/od/healthykitchenrecipes/a/meatcarcinogens.htm

Dav´ıdek, J. (2001). Natural Toxic Compounds of Foods. Formation and Change during Processing and Storage. (Boca Raton, FL: CRC Press, Inc., 1995).

Delistraty D. (1997). Toxic equivalency factor approach for risk assessment of polycyclic aromatic hydrocarbons. *Toxicol. Environ. Chem.* 64: 81 – 108.

European Food Safety Authority (EFSA) (2008). Polycyclic aromatic hydrocarbons in food: Scientific opinion of the Panel on Contaminants in the food chain. *European Food Safety Authority*, (Question N° EFSA-Q-2007-136), 724, 1-114.

European Union. Commission Regulation (EC) No 1881/2006. (2006). *Official J. of European Union* L364 1881/2006 European Union. Commission Regulation (EU) No 835/2011. (2011). *Official J. of European Union* L214/5 835/2011

Fetzer J. C. (2000). "The Chemistry and Analysis of the large Polycyclic Aromatic Hydrocarbons". New York.

Fretheim, K. (1983) Polycyclic Aromatic Hydrocarbons in Grilled Meat Products A Review. *Food Chem.* 10: 129–139.

Gevao B., Jones K. C. and Hamilton-Taylor J. (1998). Polycyclic aromatic hydrocarbon (PAH) deposition to and processing in a small rural lake, Cumbria, UK. *Sci. Total Environ*. 215:231–242.

Howsam M. and Jones K. C. (1998). Sources of PAHs in the environment. In Neilson A. H. (ed). The Handbook of *Environ. Chem.*, Vol. 3, Berlin: Springer: 137 – 174.

IARC (1983). Monographs on the evaluation of the carcinogenic risk of chemicals in human; Polynuclear Aromatic Compounds, Part 1, Chemical, environmental and experimental data. Vol. 32, IARC, Lyon, France.

Knize, M. G., Salmon, C. P., Pais, P. and Felton, J. S. (1999), Food heating and the formation of heterocyclic aromatic amine and PAH mutagens/carcinogens, In: Jackson, L.S. Knize M.G. & Morgan J.N. (Eds.). Impact of processing on food safety. New York: Kluwer Academic.

Masih, A., Saini, R. and Taneja, A., (2008). Contamination and Exposure Profiles of Priority Polycyclic Aromatic Hydrocarbons (PAHs) in Groundwater in a Semi-Arid Region in India. *Inter. J.l of Water*, 4(1-2), 136-147.

Moreda, W., M. C. P´erez-Camino, and A. Cert. "Gas and Liquid Chromatography of Hydrocarbons in Edible Vegetable Oils." *J. of Chromatography* A 936: 159–171.

Mottier, P., V. Parisod, and R. J. Turesky. (2000). "Quantitative Determination of Polycyclic Aromatic Hydrocarbons in Barbecued Meat Sausages by Gas Chromatography Coupled to Mass Spectrometry." *J. of Agric. & Food Chem.* 48: 1160–1166.

Nawrot, P. S., Vavasour, E. J. and Grant, D. L. (1999). Food irradiation, heat treatment and related processing techniques: Safety evaluation, In: Van der Heijden K., Younes, M. Fishbein L. & Miller S. (Eds.). International Food Safety Handbook, New York: Marcel Dekker, p. 306-308.

Ogbuagu D. H. and Ayoade A. A. (2012). Presence and Levels of Common Polynuclear Aromatic Hydrocarbons (PAHs) in Staple Foods of Nigerians. *Food and Public Health 2(1)*: 50-54.

Ogbuagu, D. H; Okoli, C. G; Gilbert, C. L. and Madu, S. (2011). Determination of the contamination of groundwater sources in Okrika mainland with polynuclear aromatic hydrocarbons (PAHs). British *Journal of Environ & Climate Change*, 1(3), 90-102.

Oke O. L., Redhead J. and Hussain M. A. (1998). *Roots*, tubers, plantains and bananas in human nutrition. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO) and the Information Network on Post-Harvest Operations (INPhO).

ISSN 2398-1385

Phillips, D. H. (2002). Polycyclic Aromatic Hydrocarbons in diet. *Mutation Research*, 443, 139-147.

Pickering R. W. (1999). A toxicological review of polycyclic aromatic hydrocarbons. *J. Toxicol. Cutan. Ocul. Toxicol*. 18: 101-135

Scientific Committee on Food (SCF). (2002). Opinion of the Scientific Committee on Food on the Risks to Human Health of Polycyclic Aromatic Hydrocarbons in Food. (Brussels: Scientific Committee on Food (SCF),

Simko, P. (2002). "Determination of Polycyclic Aromatic Hydrocarbons in Smoked Meat Products and Smoke Flavouring Food Additives." *J.of Chromatography* B 770: 3–18.

Staffan L. (2003). Analysis of PAHs and their transformation products in contaminated soil and remedial process. Sweden: Sofjadern Offset AB

Sugimura T., Wakabayashi K., Nakagama H. and Nagao M. (2004). Heterocyclic amines: Mutagens/carcinogens produced during cooking of meat and fish. *Cancer Sci*. 95 (4): 290–9.

World Health Organizations (WHO) (1997). Non-heterocyclic Polycyclic Aromatic Hydrocarbons. Environmental Health Criteria, International Programme on Chemical Safety, World Health Organization, Geneva, Vol. 202.

Zuzana Z. and Thomas W. (2015) The Occurrence of 16 EPA PAHs in Food – A Review, *Polycyclic Aromatic Compounds*, 35:2-4, 248-284.