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Potential Health Risk Assessment of Polynuclear Aromatic Hydrocarbons (PAHs) In Roasted Plantain Sold In Owerri, Southeastern Nigeria

K. M. Iwuji[1], C. N. Uyo[1], A. U. Ezirim[2], C. O. Emerole[3], U. O. Njionye[1], A. O. Bosede[4], O. C. Ndubueze[5]
[1]*Department of Environmental Management, Federal University of Technology, Owerri (FUTO)*
[2]*Department of Biochemistry, Federal University of Technology, Owerri (FUTO)*
[3]*Department of Public Health Technology, Federal University of Technology, Owerri (FUTO)*
[4]*Department of Environmental Health Science, Federal University of Technology, Owerri (FUTO)*
[5]*Department of Animal Science and Technology, Federal University of Technology, Owerri (FUTO)*
Corresponding Author: Keside Marizu Iwuji

Abstract
Generally, Polynuclear Aromatic Hydrocarbons (PAHs) enter the environment through various routes and are usually found as a mixture containing two or more compounds formed during the incomplete burning of coal, oil and gas, and other organic substances. 11 Polynuclear Aromatic Hydrocarbons (PAHs) levels in commonly consumed roasted plantain food delicacy in Owerri Municipal, a southeastern city in Nigeria were assessed to evaluate possible human health risks associated with its consumption. Freshly roasted plantain samples were purchased from 3 roadside fast-food vendors in the Municipality, preserved in labeled sterile amber bottles with benzene, and taken to the laboratory in an iced-chest. The PAHs concentrations were determined using Gas Chromatography coupled with Flame Ionization Detector (GC-FID) in the analysis of samples. The single factor ANOVA and means plots were used to detect homogeneity in mean-variance and structure of group means of the PAHs determined in the foods, respectively. From the analysis, Phenanthrene and Anthracene comparatively recorded the highest concentrations of (0.169mg/kg) and (0.165mg/kg) respectively while pyrene recorded the lowest concentrations of PAHs. The high concentrations of combined PAHs recorded in roasted plantain could be due to the close proximity of the plantain samples and the source of the heat and the higher temperature required for roasting the plantains. The least concentrations (0.000mg/kg) of pyrene, chrysene, and benzo(a)anthracene in the samples indicate that these PAHs were not abundant in the woods (charcoal) used for their roasting. The study reveals high concentrations of the PAHs in the plantain food sampled. This, therefore, places consumers at great health risk if proper care is not taken.

Keywords: Polynuclear Aromatic Hydrocarbons, Roasted Plantain Food, Food Consumers, Food Vendors, Owerri Municipality.

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I. Introduction

Polynuclear Aromatic Hydrocarbons (PAHs) also referred to as Polycyclic Aromatic Hydrocarbons (PAHs), are a group of chemicals that are formed during the incomplete burning of coal, oil, gas, garbage and other organic substances (McGrath *et al.,*2007). They are a ubiquitous group of several hundred chemically related compounds, environmentally persistent with various structures and varied toxicity (Armstrong *et al.,* 2004).

PAHs can also be formed both during biological processes and as by-products of incomplete combustion from either natural combustion sources (forest and bush fires) or man-made combustion sources (automobile emissions and cigarette smoke). These combustion processes produce a mixture of chemicals with solid residue, well-known as soot (DHSAG, 2009). Over the years, different sources of PAH contamination of food have been found.

PAHs in the environment has become a serious concern worldwide since their exposure at high concentrations gives rise to carcinogenic and genotoxic risks (IARC, 2000). Therefore, its effect on human health depends greatly on their concentrations, types, and extent of exposure (DHSAG, 2009). They are also known to be lipophilic, meaning they mix more easily with oil than water (Decker, 1981; Boehm *et al.*, 1981) and can be found practically everywhere in soil, water, and food. Food items and products could be contaminated by soils, polluted air, and water (WHO, 2005). Therefore the analysis of PAHs in food is a matter of concern (Plaza-Bolanos *et al.*, 2010). These pollutants are capable of presenting significant health risk to human health by oral intake through food, inhalation, and/or even dermal interaction. Exposures through any of the listed routes could bring about health challenges of short- and long-term effects, including some major respiratory and cardiovascular diseases (Perez-Padilla et al. 2010; WHO 2014).

One of the major routes of human exposure to PAHs in non-smoking people is food. Furthermore, their presence in food is of major interest, as they could be found in cereals, grains, flour bread, vegetables, fruits, meat, processed or pickled foods, and even contaminated cow milk (Bartle, 1991; Falco *et al.*, 2003). According to Knize *et al*. (1999) some cooking methods such as roasting, barbecuing and smoking increase the levels of PAHs in foods while steaming and boiling barely introduce PAHs. For non-smoking adults, PAHs level in foodstuff contributes more than 90% of total exposure (WHO, 1998). For a smoker, benzo(a)pyrene intake is estimated to be about 210 ng, which is equivalent to 20 cigars, while the mean intake from food for the same PAH is about 110 ng (SCF, 2002). The formation of PAHs on roasted foods has been observed to be dependent on the proximity of the food from the heat source (Phillips, 1999), the fat content of the food (Knize et al., 1999), duration of roasting (Nawrot et al., 1999), the temperature used (WHO, 1998), whether melted fat is allowed to drop onto the heat source (SCF, 2002), and type of fuel used (SCF, 2002).

On the other hand, PAHs are also found in foods as a result of certain industrial food processing methods such as smoke curing, broiling, roasting, and grilling over open fires or charcoal which permits the direct contact between food and combustion products (SCF 2002). Furthermore, in the food processing industry, food additives such as smoke flavoring products (SFP), lubricants, solvents, propellants, glazing agents, and protective coatings contribute to the contamination of food items by PAHs (Moret and Conte, 2000).

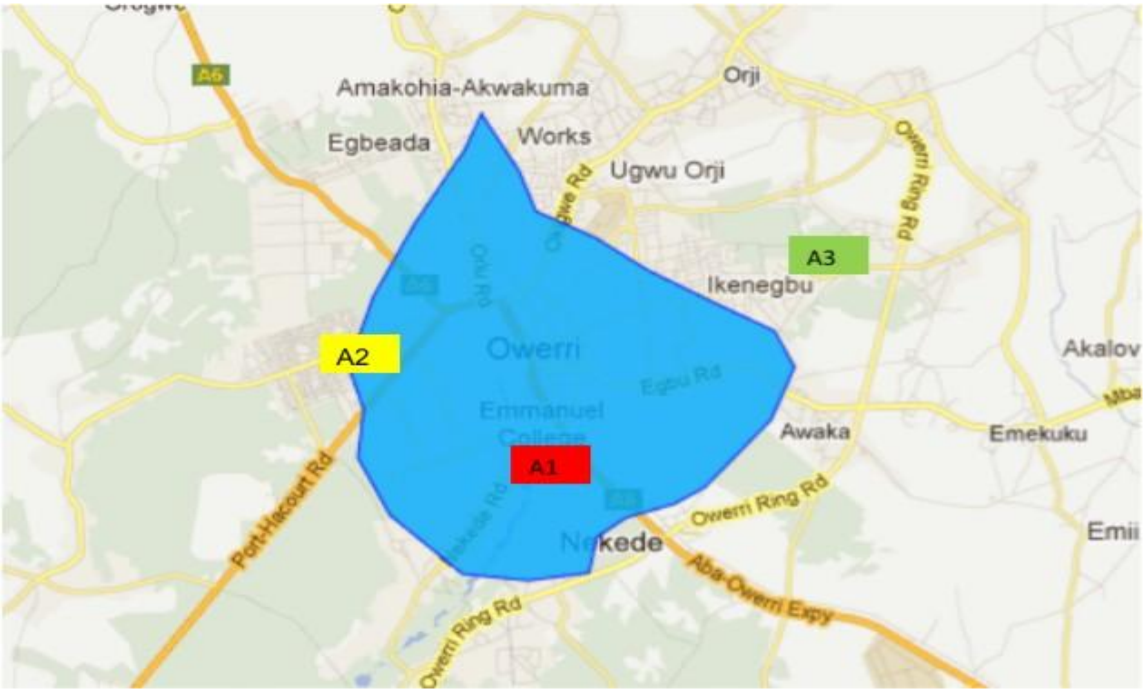
Some studies have shown that high levels of PAH are found for example in foods roasted at high temperatures (SCF, 2002). The health effects of PAHs, under certain circumstances include tumor formation and carcinogenicity in at least, laboratory animals (WHO, 1997; Ogbuagu et al., 2011).

In Nigeria, the consumption of roasted foods, such as plantain (*Musa paradrica*) with the native name '*Bole*', yam, fish, meats (Suya) offers quick supply of protein, carbohydrate, fat, vitamins, and minerals to several consumers, especially of the middle and lower classes. Frequently, these fast food joints which are often sited at strategic locations; especially at the road and street junctions serve the growing interests of passers-by, city, and suburb dwellers. This unhealthy eating habits has lead to an increase in the risk of non – communicable diseases such as Obesity, type 2 diabetes, certain cancers and even Chronic Obstructive Pulmonary Disease (COPD) to the food sellers who inhale biomass from the roasting process found in this regions (Herrera & Lindgren, 2010; Hall et al., 2011;; Kim et al., 2011). To this end, the growing concern remains that a larger population of people could be susceptible to PAHs through inhalation, ingestion, and direct contacts (DHSAG, 2009). The objective of this research was to evaluate the concentration and levels of common PAHs in a roasted food plantain (*Musa paradrica*) as a pointer to potential health hazards to public consumers.

II. Research Methodology

The Study Area

This study was conducted in the Owerri municipal, the capital of Imo State lying within latitudes 4˚45'N and 7˚15'N, and longitude 6˚50'E and 7˚25'E with an area of about 5100 square kilometers. It is located in the southeastern part of Nigeria, habituating majorly the Igbo ethnicity. Also, it is bounded on the North by Amakohia, on the North-East by Uratta, on the East by Egbu, on the South-East by Naze, on the South by Nekede, and on the North West by Irete. Owerri municipal also has two geological regions; the coastal plain and a plateau portion. The vegetation of the study area (Owerri Municipal) is typically a tropical rainforest.



KEY

A1	==➔ Location 1 : No.48 Douglas road, by St. Paul's Catholic. church
A2	==➔ Location 2: Control Junction, Port Harcourt road Owerri.
A3	==➔ Location 3: Mbari Street, Ikenegbu Layout

Figure 1: Map of the study area, showing the samples collection points.

Methods of Laboratory Analysis

Freshly roasted plantain samples were purchased from 3 roadside food vendors and preserved in labeled sterile amber bottles with benzene, and taken to the laboratory in iced-chest. The roasting utilized charcoal as a source of energy and was done with the food placed on wire gauze placed over the burning charcoal. Some plantain food was placed close to the heat source to achieve roasting more gradually while the unroasted plantains were used as our control. All glassware used in the laboratory were washed with detergent and hot water, rinsed with distilled water, and then dried. A gas chromatograph coupled with a flame ionization detector (GC-FID model HP 5890) with a column chromatography for cleaning sample extracts was used in the analysis of samples. A PAH standard mixture containing 1000ppm each of naphthalene, methylnaphthalene, acenaphthylene, acenaphthene, fluorine, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, and chrysene were used. About 10g of plantain sample was mashed in a mortar and transferred into 1 litre separating funnel. 1 mL of concentrated H_2SO_4 was added to release the hydrocarbon contents of the food samples in the separating funnel. 5 mL of N-hexane was subsequently added and samples were vigorously shaken for 5 minutes and then allowed to stand for another 20 minutes. The extract upper layer that formed was collected in a glass vial and passed through a column chromatography that was set up using silica gel and a ball of glass wool for cleaning and removal of biogenics. The GC parameters included a carrier gas (helium), fuel gases (air and hydrogen), back-up gas (nitrogen), detector and in-let temperatures of 35 and 25 °C, respectively, initial and final oven temperatures of 5 and 300 °C, respectively, and hydrogen, air, nitrogen, and helium flow rates of 30, 300, 30, and 30 mL/minute, respectively. The cleaned extract was loaded with a micro-GC syringe into the GC and the GC prompted to run. At the end of the run-time of about 42 minutes, chromatogram results were integrated and printed with an interphase computer.

Statistical Analysis
Descriptive statistics as provided by the MS Word© and SPSS© 17.0 were utilized. The single factor analysis of variance (ANOVA) and means plots were used to detect homogeneity in mean-variance and structure of group means of the PAHs determined in the sample, respectively.

Plate 1: Roasted Plantain sample collected from location A1, Douglas road, Owerri.

Plate 2: Roasted Plantain sample collected from location A2, Port Harcourt road, Owerri

Plate 3: Roasted Plantain sample collected from location A3, Mbari Street Ikenegbu, Owerri.

III. Results and Discussion

The mean concentrations of 11 individual PAHs in the roasted plantain samples are presented in Table 1. From the statistical analysis carried out, it was quantified that there were variations in the levels of concentrations of PAHs found in the roasted plantain samples as collected from different locations and sampling sites. Thus concentrations of 2-methylnaphthalene, 0.021 (± 0.0006245), fluorene, 0.050 (± 0.016190), Phenanthrene, 0.159 (± 0.046680), Anthracene, 0.160 (± 0.0051747) and Fluoranthene, 0.018 (± 0.005239) mg/kg, differs more widely and significantly than the other Polynuclear aromatic hydrocarbon found in the roasted plantain sample (Table 1). The PAHs detected in the plantain samples, Anthracene and Phenanthrene had the highest level of PAH concentrations, 0.160mg/kg and 0.159mg/kg, (± 0.05174) and (± 0.046680) respectively with Benzo(a)anthracene and chrysene having the lowest level of concentrations, both having 0.000mg/kg (± 0.000000). From the analytical result obtained, Naphthalene, 2-methylnaphthalene and Acenaphthylene varied from 0.000 to 0.006 (± 0.002082), 0.007 to 0.028 (± 0.006245) and 0.000 to 0.006 (± 0.001856) mg/kg, respectively.

Also, Acenapthene, fluorene and Phenanthrene have concentrations varying from 0.000 to 0.007 (± 0.002082), 0.005 to 0.055 (± 0.016190) and 0.010 to 0.169 (± 0.046680) mg/kg, respectively.
In the same way, Anthracene, Fluoranthene and pyrene differs by having the range concentrations from 0.005 to 0.165 (± 0.051747), 0.000 to 0.018 (± 0.005239) and 0.000 to 0.005 (± 0.001453) mg/kg, respectively. The same applies to Benzo(a)anthracene and chrysene both having concentrations of 0.000 to 0.000 (± 0.000000) in the roasted plantain sample (Table 1)

Table 1. Descriptive statistical output showing overall levels of PAHs in roasted plantain sample

PAH (mg/kg)	Range	Mini-mum	Maxi-Mum	Mean	Standard error
Naphthalene	0.006	0.000	0.006	0.00400	0.002000
II_methylnaphthalane	0.021	0.007	0.028	0.01900	0.006245
Acenaphthylene	0.006	0.000	0.006	0.00367	0.001856
Acenaphthene	0.007	0.000	0.007	0.00400	0.002082
Fluorene	0.050	0.005	0.055	0.03733	0.016190
Phenanthrene	0.159	0.010	0.169	0.09800	0.046680
Anthracene	0.160	0.005	0.165	0.10833	0.051747
Fluorathene	0.018	0.000	0.018	0.00967	0.005239
Pyrene	0.005	0.000	0.005	0.00233	0.001453
Benzo(a)anthracene	0.000	0.000	0.000	0.00000	0.000000
Chrysene	0.000	0.000	0.000	0.00000	0.000000

Variation plots

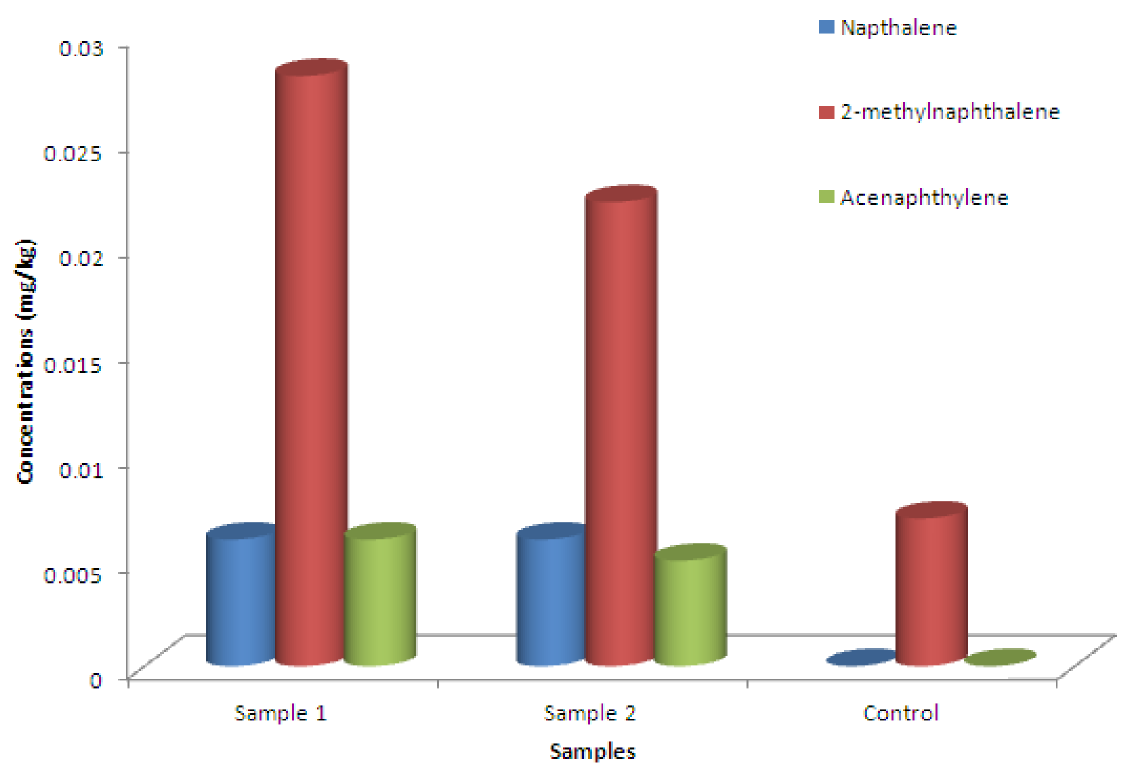


Figure 2. Concentrations of common Polynuclear Aromatic Hydrocarbons in roasted plantain samples from location 1.

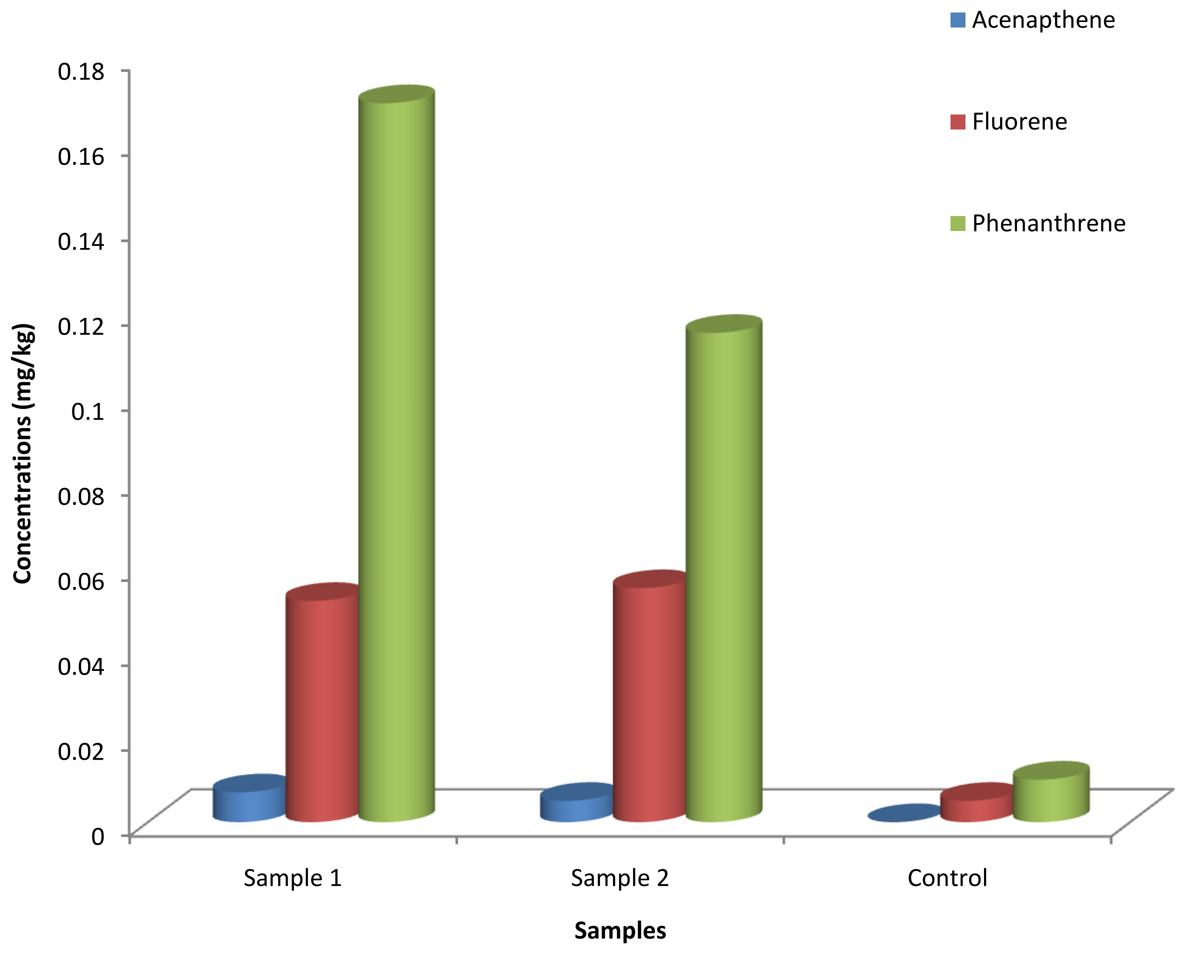


Figure 3. Concentrations of common Polynuclear Aromatic Hydrocarbons in roasted plantain samples from location 2.

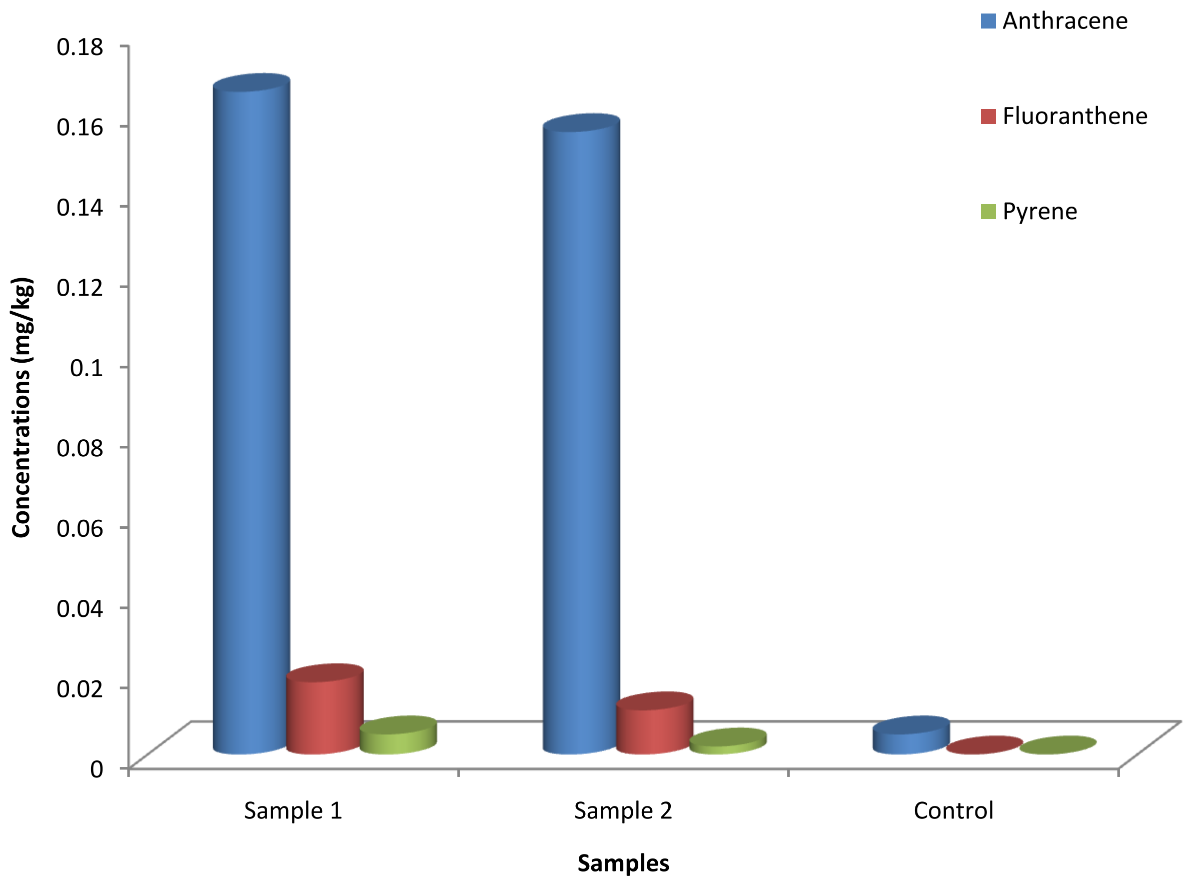


Figure 4. Concentrations of common Polynuclear Aromatic Hydrocarbons in roasted plantain samples from location 3.

At figure 2, 2-methylnapthalene recorded highest concentrations of 0.028 (± 0.006245), 0.022 (± 0.006245) and 0.007 (± 0.006245) mg/kg, at sample 1, 2 and control respectively while naphthalene and Acenaphthylene recorded lower concentrations of 0.006 (± 0.002000), 0.006 (± 0.002000), and 0.006 (± 0.001856), 0.005 (± 0.001856) mg/kg at sample 1 and 2 respectively and were not detected at control sample.

Comparatively at figure 3, Phenanthrene recorded maximum concentrations of 0.169 (± 0.046680) and 0.115 (± 0.0046680) mg/kg at both sample 1 and 2 respectively with minimum concentration of 0.010 mg/kg at control sample. Also, fluorene recorded relatively higher concentrations of 0.052 (± 0.016190) and 0.055 (± 0.016190) mg/kg at sample 1 and 2 respectively and had least concentration of 0.005 mg/kg at control sample while Acenapthene recorded the least concentrations of 0.007 (± 0.002082) and 0.005 (± 0.002082) mg/kg at sample 1 and 2 respectively with no detection at control sample.

On the other hand, Anthracene at figure 4 comparatively recorded highest concentrations of 0.165 (± 0.051747) and 0.155 (± 0.051747) mg/kg at sample 1and 2 respectively with least concentrations of 0.005 mg/kg at control sample. While Fluoranthene and pyrene recorded lower concentrations of 0.018 (± 0.05239), 0.011 (± 0.05239) mg/kg and 0.005 (± 0.001453), 0.002 (± 0.001453) mg/kg at both sample 1 and 2 respectively with no detection at control sample.

Results from this study is similar to studies by Ogbuagu and Ayoade (2012), who reported varying concentrations of PAHs in roasted plantain food in Nigeria. Total PAH in roasted plantain food observed in this study was also compared with PAH observed from other parts of Nigeria (Ossai *et al.*, 2014) and other countries (Nie Jing *et al.*, 2013).

However, the higher concentrations of combined PAHs recorded in roasted plantain could be due to the closer distances the plantain samples were (usually) placed to the source of the heat (as was also observed by

Phillips, 1999) and the higher temperature required for roasting the plantains (as was also observed by the WHO, 1998). The least concentrations of pyrene, chrysene, and benzo(a)anthracene in the sample indicate that these PAHs were not abundant in the woods (charcoal) used for their roasting. The heterogeneity contributed especially by phenanthrene and Anthracene in roasted plantain, corresponds to their maximum concentrations in the sample. Since the maximum allowable limit for PAHs in drinking water of man (which is also a consumable like these foods) is 0.0002 ppm (WHO, 1984), the current study, therefore, reveals much higher concentrations in the foods sampled. This, therefore, places several consumers at potential health risks.

IV. Conclusion and Recommendations

Conclusion

The results show that both the raw and the roasted food samples contain certain levels of PAHs, with the roasted food samples having greater levels of total PAHs as a result of the food processing. However, it should be stated that these food products are contaminated in total PAHs after roasting. The methods of roasting appeared to influence PAH adsorption/absorption on/in the food sampled. Levels of the PAHs were higher than the regulatory permissible limits of the World Health Organization in consumable water. In conclusion, as a result of the roasting of the food samples, it is obvious that the concentration of total PAHs increased and for this reason, an alternative process should be introduced. Considering the carcinogenic potential of the PAHs, the reduction of these contaminants in the diet is highly desirable, and special attention must be given to the intake of roasted foods since a considerable amount of PAHs can be ingested in a single meal.

Recommendations

It is most unfortunate that only a few studies have been carried out on the contributions of PAHs from roasting on Nigerian delicacies. The following recommendations will help abate the health effects associated with the consumption of PAHs through roasted foods;

For consumers;

- Reduce the intake of roasted plantain foods.
- Adopt a safe alternative but less harmful method of roasting such as using oven and electric machines.
- Avoid eating charred roasted plantain and other foods.
- Maintain a balanced and healthy diet by eating plenty of fruits and vegetables.
- When going for roasted plantain food, ensure that the thick back cover/portion of the roasted yam is scrapped off before consuming the inner part.
- Regularly go for a medical check-up to know the levels of PAHs in the system and also to ascertain any potential health risks that could arise from the accumulations of PAHs from eating roasted plantain and other exposure or entry routes.

For the traders:

- There should be enlightenment and awareness programs to educate the general public on the potential health hazards associated with the consumption of PAH in roasted foods.
- These roadside food vendors should ensure that, they continuously turn the plantain as they are being roasted in an even manner to reduce the introduction of higher concentrations of PAHs to a particular portion of the plantain being roasted.
- Roadside food vendors should scrape out the charred and tick cover portion of the roasted plantain, as this outer layer contains the highest level and concentrations of combined PAHs in them.
- Environmental and food regulatory agencies such as Consumer Protection Council (CPC), Environmental Health Officers Registration Council of Nigeria (EHORCON) and NAFDAC, should regularly inspect these sellers to ascertain the conditions under which they prepare these foods for the public to consume.
- From the study, we recommend that these roadside food vendors should prepare the plantain following other food processing methods (such as boiling) instead of roasting to reduce contamination of PAHs.

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