



**Analysis of Polycyclic Aromatic Hydrocarbons in Roasted Plantain and Maize Samples**

**Consumed in Ile-Oluji, Ondo State, Nigeria**

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**Abstract**

Smoking is one of the oldest methods commonly used for food preservation, and it allows food to obtain characteristic organoleptic features, mainly taste, smell, and color. In addition, smoke shows antibacterial and antioxidant qualities. Aside from the desirable qualities, the smoking process also generates substances that are undesirable regarding health and safety, like polycyclic aromatic hydrocarbons (PAHs). This study examined the presence and concentration of PAHs in roasted plantain and maize sold in some locations within Ile-Oluji Town, Ondo State, Nigeria. Roasted plantain and maize samples were collected from different locations within Ile-Oluji. The samples were extracted and analyzed for PAHs using Gas Chromatography–Mass Spectrometry (GC–MS). The results revealed varying levels of PAHs such as acenaphthylene, fluorene, phenanthrene, anthracene, Benz(a)anthracene, benzo(k)fluoranthene, and indeno(1,2-cd) pyrene, with mean concentrations ranging between 0.0100 mg/kg and 0.1775 mg/kg in roasted plantain samples and acenaphthylene, fluorene, phenanthrene, anthracene, benzo(k)fluoranthene, indeno(1,2-cd) pyrene, benzo(a)pyrene and dibenzo(a,h)anthracene, with mean concentrations ranging between 0.0100 mg/kg and 0.0200 mg/kg in roasted maize samples with some values exceeding European union (EU) maximum limit and World Health Organization (WHO) permissible limits for food safety. The findings indicate that roasted plantain and maize in Ile-Oluji may pose potential health risks to consumers due to PAHs contamination. It is therefore recommended that plantain and maize vendors adopt safer roasting methods, while regulatory authorities enforce public health policies to reduce consumer exposure to these harmful compounds.

**Keywords:** Plantain; maize; polycyclic aromatic hydrocarbons; food safety; organic compounds

## **Introduction**

Polycyclic aromatic hydrocarbon are hazardous organic chemicals consisting of two or more benzenoid group. Those containing up to four benzene rings are known as light PAHs (L-PAHs) and those containing more than four benzene rings are known as heavy PAHs (H-PAHs). H-PAHs are more stable and toxic than L-PAHs. They are ubiquitous pollutants in the environment. The presence of PAHs in the environment is of global concern because of their health-related challenges [1].

The widespread presence of PAHs, coupled with their lipophilic nature, facilitates their accumulation in fatty foods, particularly those subjected to thermal processing such as roasting, grilling, or smoking [2]. Among various food items, maize and plantains are staple components of many diets globally and are particularly significant in African communities. Maize and plantains are a critical carbohydrate source in many tropical countries [3]. Those PAHs that are considered to be less toxic may even increase the carcinogenicity of other PAHs [4]. Sixteen of the PAHs that are considered as priority by the American Environmental Protection Agency (AEPA) are; naphthalene, acenaphthylene, acenaphthene, fluorine, anthracene, phenanthrene, fluoranthene, chrysene benzo (a) anthracene, pyrene, benzo (k) fluoranthrene, benzo (b) fluoranthene, benzo (a) pyrene, dibenzo (a,h) anthracene, dibenzo (b,c) fluoranthene and benzo (g, h, i) perylene [5]. PAH toxicity is dependent on the route of exposure, concentration level, duration, and PAH mixture composition to which the individual is exposed; a composite exposure of two or more PAHs is likely to be more carcinogenic than an individual PAH. Among different PAHs, Benzo(a)pyrene is the most extensively studied member [6]. Smoking is one of the oldest methods commonly used for food preservation, and it allows food to obtain characteristic organoleptic features, mainly taste, smell, and color. In addition, smoke shows antibacterial and antioxidant qualities. Aside from the desirable qualities, the smoking process also generates substances that are undesirable regarding health and safety, like polycyclic aromatic hydrocarbons. Smoking, baking, grilling, or barbecuing are mentioned primarily among different types of heat treatment that significantly contribute to PAHs formation, resulting from incomplete wood combustion [7,8].

However, traditional methods involving direct contact with wood smoke from incomplete combustion can contaminate food with PAHs if not carefully controlled or if overly intense smoking is used. Smoking food involves the partial burning of wood, often hardwood, softwood,

or bagasse. BaP serves as a marker for the presence and potential health effects of carcinogenic PAHs in smoked foods [9]. The consumption of roasted plantain and maize, has become an integral part of the Nigerian diet due to its, affordability, and social appeal.

In Ile-Oluji, roasted plantain and maize are commonly sold at several roadside spots, attracting students, traders, and local residents alike. While this contributes to the carbohydrate's intake, the method of preparation poses potential health risks. The traditional roasting process, which involves exposing plantain and maize to direct heat from charcoal or firewood, often results in the formation of polycyclic aromatic hydrocarbons, toxic compounds generated through incomplete combustion. Despite the established health risks associated with PAHs, there is no documented research on the levels of PAHs in plantain and maize sold in Ile-Oluji. This creates a knowledge gap in understanding the safety of plantain and maize consumed in this community.

This study aims to investigate the levels of these contaminants in this roasted plantain and maize. Studies carried out in some developing countries have reported elevated levels of PAHs in street-vended foods, often exceeding international safety limits [10-11]. In Nigeria, studies have shown that there is significant contamination in roadside foods due to poor environmental sanitation and lack of regulatory enforcement [12]. Previous studies have shown that street-vended and roasted foods are vulnerable to contamination by (PAHs) due to environmental pollution and roasting processes [13].

### **Materials and Methods**

The materials and reagents used in this study were of analytical and GC-MS grade to ensure accuracy and reliability of results.

**Reagents:** Dichloromethane (DCM), Diluted PAH standard solution containing known compounds, Anhydrous sodium sulfate ( $\text{Na}_2\text{SO}_4$ ), n-Hexane, Isotopically labeled PAH solution (used as an internal standard)

**Apparatus:** Analytical weighing balance, Column Chromatography Setup (packed with silica gel and alumina), Evaporation system (rotary evaporator or air-drying setup) Sample Vials (1.5 mL) Refrigerator for sample preservation. Gas Chromatography–Mass Spectrometry (GC-MS), Agilent Technologies 8860A (GC) model interfaced with a mass selective detector (Model: 5975C (MSD)).

### **Sample Collection**

Roasted samples were collected from different vending locations within Ile-Oluji, Ondo State, Nigeria. The collection sites included four major spots known for high patronage consumption.

samples were randomly purchased from different vendors. The samples were purchased in the peak period of hours of preparation and consumption, thereby ensuring that the samples were representative of the typical consumer exposure. Immediately after purchase, each sample was wrapped in aluminum foil to avoid direct contamination and external influence. They were labeled according to their respective collection points for easy identification.

All samples were then transported to the laboratory using an insulated ice chest maintained at approximately 4 °C to minimize degradation and loss of target analytes [14].

### **Sample Preparation**

The collected samples were first removed from refrigeration and allowed to thaw at room temperature. Each sample was carefully unwrapped from the aluminum foil and homogenized to ensure uniformity. The homogenized samples were then weighed using an analytical balance to obtain representative portions for analysis. Approximately 10 g of each sample was taken and placed into clean, labeled glass containers. To avoid contamination, all laboratory apparatus used during preparation were thoroughly rinsed with distilled water and dried before use.[14].

### **Extraction of PAHs**

Extraction of PAHs from the homogenized samples was carried out using a solvent extraction method. This step was necessary to isolate the PAHs from the complex sample matrix for subsequent analysis. Approximately 10 g of each prepared sample was weighed into a clean 250 mL conical flask. A mixture of n-hexane and dichloromethane (1:1 v/v) was used as the extraction solvent due to its high efficiency in dissolving non-polar compounds such as PAHs. About 50 mL of the solvent mixture was added to each flask. The flasks were then sealed and subjected to mechanical shaking for about 2 hours to ensure maximum contact between the solvent and the sample matrix. After shaking, the mixture was filtered using Whatman No. 1 filter paper into a clean round-bottom flask. The filtrate, which contained the extracted PAHs, was then concentrated using a rotary evaporator at 40 °C under reduced pressure to reduce the solvent volume to about 2 mL. The concentrated extracts were stored in amber glass vials with Teflon-lined caps to prevent photodegradation of PAHs. The vials were then kept at 4 °C until required for clean-up and chromatographic analysis [15].

### **Clean-up of Extracts**

After solvent extraction, the crude extracts usually contain fats, oils, pigments, and other interfering compounds that may affect the resolution and sensitivity of GC-MS analysis. Therefore, a clean-up step was carried out using column chromatography packed with activated silica gel. A glass column was prepared by packing it with silica gel (60–120 mesh, previously activated at 105 °C for 24 hours) and topped with a thin layer of anhydrous sodium sulfate to remove residual moisture. The extract was concentrated to a small volume under a gentle stream of nitrogen gas and then carefully loaded onto the column.

Elution was carried out using n-hexane and dichloromethane (3:1 v/v) as the mobile phase, which selectively separated polycyclic aromatic hydrocarbons (PAHs) from non-target interferences. The purified eluate was collected in clean amber vials, concentrated again under nitrogen to about 1 mL, and stored at 4 °C prior to GC-MS analysis [15].

### **GC–MS Analysis**

The purified extracts obtained after column clean-up were subjected to Gas Chromatography–Mass Spectrometry analysis for the identification and quantification of polycyclic aromatic hydrocarbons [14].

## **Results and Discussion**

Table 1 presents the concentrations of target polycyclic aromatic hydrocarbons detected in roasted plantain, while Table 2 presents the concentrations of target polycyclic aromatic hydrocarbons detected in roasted maize obtained from different locations in Ile Oluji, Ondo State.

Table 1: Concentrations of target PAHs from in roasted plantain (*Musa paradisiaca*) from various locations in Ile Oluji, Ondo State

Compounds	C1	C2	C3	C4	Mean
Concentration	(mg/kg)				
Acenaphthylene	0.0300	0.0300	0.3000	0.3500	0.1775
Fluorene	0.0100	BDL	0.0100	0.0100	0.0100
Phenanthrene	0.0100	0.0200	0.0100	0.0100	0.0125
Anthracene	0.0100	BDL	0.0100	0.0100	0.0100
Pyrene	BDL	BDL	BDL	BDL	BDL
Benz(a)anthracene	0.0300	BDL	BDL	BDL	0.0300

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Chrysene	BDL	BDL	BDL	BDL	BDL
Benzo(k)fluoranthene	0.0100	BDL	BDL	BDL	0.0100
Benz(a)pyrene	BDL	BDL	BDL	BDL	BDL
Indenol (1,2, cd) pyrene	0.0100	BDL	BDL	BDL	0.0100
Dibenzo(a,h)anthracene	BDL	BDL	BDL	BDL	BDL
Benzo(g,h,i)perylene	BDL	BDL	BDL	BDL	BDL
EU max. value for PAH	(0.0050 mg/kg) for Benz(a)pyrene (0.030 mg/kg) for sum of four PAHs (PAH4)				

C1: Roundabout; C2: Temidire; C3: Olorungbohunmi; C4: Odolua

BDL: Below detection limits

Table 2: Concentrations of Target PAHs from in Roasted Maize (*Zea mays*) from various locations in Ile Oluji, Ondo State

Compounds	B1	B2	B3	B4	Mean
Concentration	(mg/kg)				
Acenaphthylene	0.0100	0.0100	0.0200	0.0100	0.0150
Fluorene	BDL	0.0100	BDL	BDL	0.0100
Phenanthrene	0.0100	0.0100	0.0100	0.0100	0.0100
Anthracene	BDL	0.0100	BDL	BDL	0.0100
Pyrene	BDL	BDL	BDL	BDL	BDL
Benz(a)anthracene	BDL	BDL	BDL	BDL	BDL
Chrysene	BDL	BDL	BDL	BDL	BDL
Benzo(k)fluoranthene	BDL	BDL	BDL	0.0100	0.0100
Benz(a)pyrene	BDL	BDL	BDL	0.0100	BDL
Indenol (1,2, cd) pyrene	BDL	BDL	BDL	0.0200	0.0200
Dibenzo(a,h)anthracene	BDL	BDL	BDL	0.0100	0.0100
Benzo(g,h,i)perylene	BDL	BDL	BDL	BDL	BDL
EU max. value for PAH	(0.0050 mg/kg) for Benz(a)pyrene (0.030 mg/kg) for sum of four PAHs (PAH4)				

B1: Olorungbohunmi; B2: Buleiin; B3: Roundabout; B4: Oke alafia

BDL: Below detection limits

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A total of Twelve (12) PAHs were analyzed in the two samples. Out of these, seven (7) PAHs were detected at varying concentrations in roasted plantain samples, while five (5) were below detection limits; Eight (8) PAHs were detected at varying concentrations in roasted maize samples, while four (4) were below detection limits.

The results of this study show that several PAHs were present in the roasted plantain and maize samples analyzed. The compounds detected in the roasted plantain samples include acenaphthylene, fluorene, phenanthrene, anthracene, Benz(a)anthracene, benzo(k)fluoranthene, and indeno(1,2-cd) pyrene, with mean concentrations ranging between 0.0100 mg/kg and 0.1775 mg/kg. On the other hand, pyrene, chrysene, benzo(a)pyrene, dibenzo(a,h)anthracene, and benzo(ghi)perylene were below detection limits across all the sampled locations.

The compounds detected in the roasted maize samples include acenaphthylene, fluorene, phenanthrene, anthracene, benzo(k)fluoranthene, indeno(1,2-cd) pyrene, benzo(a)pyrene and dibenzo(a,h)anthracene, with mean concentrations ranging between 0.0100 mg/kg and 0.0200 mg/kg. On the other hand, pyrene, chrysene, Benz(a)anthracene and benzo(ghi)perylene were below detection limits across all the sampled locations.

Among the PAHs detected, phenanthrene concentration in plantain (0.1775 mg/kg) is the highest, while mean concentration (0.0100 mg/kg) is the lowest of PAHs detected in all the samples. Some of these values are higher than the European Union (EU) recommended maximum limits for PAHs in food products. The EU regulation states that benzo(a)pyrene, which is considered the most dangerous PAH, should not exceed 0.005 mg/kg, while the combined limit for four major PAHs (benzo(a)pyrene, benzo(a)anthracene, chrysene, and benzo(b)fluoranthene) should not exceed 0.030 mg/kg. The presence of benzo(a)pyrene and other carcinogenic PAHs such as indeno(1,2-cd) pyrene and benzo(k)fluoranthene at higher levels in this study is a cause for concern.

The high PAH levels in the roasted plantain and maize samples can be linked to the method of preparation. Plantain and maize is traditionally roasted over open flames, usually with charcoal or firewood. Incomplete combustion of these fuels releases PAHs, which then deposit on the surface of the plantain and maize. This agrees with reports by Adeyeye [16] and Coroian *et al* [17], who found that grilling meat over direct flame leads to significant PAH contamination. Olabemiwo [18] reported that high-heat cooking methods that expose food to flames or burning charcoal, such as smoking, curing, broiling, roasting, and grilling, can lead to contamination by PAHs and the

presence of these chemicals in food is a major concern due to their potential health risks. Lee *et al.*, [7]. and Wu *et al.*, [8]. also reported that heat treatment like smoking process also generates substances that are undesirable regarding health and safety, like polycyclic aromatic hydrocarbons resulting from incomplete wood combustion. The concentrations obtained in this study are similar to those reported in other Nigerian and international studies on roasted and smoked foods [18]. This suggests that regular consumption of roasted plantain and maize samples prepared under such conditions could expose consumers to harmful levels of PAHs. Long-term exposure may increase the risk of chronic health problems, including cancers, respiratory disorders, and other degenerative diseases.

The level and type of PAHs detected depend on factors such as cooking temperature, duration and degree of exposure to smoke or open flames concentrations of PAHs in roasted plantain and maize samples. The finding aligns with the general understanding of how different smoking materials affect the levels of polycyclic aromatic hydrocarbons. The results can be explained by the completeness of combustion for each material. Silva *et al* [19], in his study, found that the sum of the average amounts of the low molecular weight PAHs such as naphthalene, phenanthrene, anthracene and pyrene, were found higher than the high molecular weight PAHs having 4 to 6 aromatic rings such as benzo(a)anthracene, benzo(a)pyrene, indeno (1,2,3, cd) pyrene in the smoked fish samples. Similar results were obtained by Borokovocova *et al* [20]. The high molecular weight polycyclic hydrocarbons are generally classified to be carcinogenic [21]. Comparable findings between fresh and roasted maize and plantain have been reported in similar studies [22], suggesting that traditional roasting practices in developing countries may consistently contribute to elevated PAH exposure. These findings raise concern that roasted plantain and maize sold in smaller towns such as Ile-Oluji may also contain potentially harmful levels of PAHs.

### **Conclusion**

This study investigated the presence of polycyclic aromatic hydrocarbons in roasted plantain and maize sold in Ile-Oluji. The results show that roasting of plantain and maize over charcoal leads to the formation and accumulation of PAHs, some of which are known carcinogens such as benzo(k)fluoranthene. The detection of these compounds in roasted plantain and maize samples highlights a potential food safety risk for consumers, particularly due to the regular consumption of this delicacy in Nigeria. Based on the findings consumers should be sensitized on the possible health risks associated with frequent consumption of roasted plantain and maize and other roasted

foods and roasted plantain and maize vendors should adopt safer roasting techniques such as using indirect heating, controlling temperature, and avoiding direct contact of plantain and maize with flames.

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