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Phytoconstituents and Polycyclic Aromatic Hydrocarbon (PAH) Content of Roasted *Dioscorea dumetorum* (Bitter Yam)

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ABSTRACT

Background and Objective: Most of the staple foods enjoyed by the populace are prepared by either roasting or smoking methods. The primary purpose of this study was to evaluate the proximate concentration and distribution of PAHs and anti-nutrients in roasted *Dioscorea dumetorum* (bitter yam) consumed by people in Nigeria. **Materials and Methods:** Materials used include charcoal, firewood, bitter yam and pieces of plastic. All chemicals used were of analytical grade. The bitter yam was roasted with firewood, charcoal and augmented charcoal and the levels of Polycyclic Aromatic Hydrocarbons (PAHs), the proximate analysis and the anti-nutrient content were investigated using standard methods. **Results:** The proximate analysis showed that crude fibre, protein, fat, ash and carbohydrate content varied with changes in the roasting method and were lower than the fresh sample. This study also showed that roasting decreased the anti-nutrient content of yam samples while those roasted with firewood recorded the least content. None of the PAHs detected was above the permissible limit of 5 μg g^{-1} stipulated by the World Health Organization (WHO). Yam roasted with augmented charcoal accumulated the highest PAHs (4.4426 μg g^{-1}) when compared to those roasted with firewood (3.4742 μg g^{-1}) and charcoal (1.8044 μg g^{-1}). Fluoranthene and dibenzo(a,h)anthracene were detected in all the roasted yam samples. **Conclusion:** This study showed that roasting decreases anti-nutrient content in *Dioscorea dumetorum* and that Naphthalene will be the most deposited PAH after roasting.

KEYWORDS

Anti-nutrient, polycyclic aromatic hydrocarbons, roasting, bitter yam, proximate composition

INTRODUCTION

Food contamination refers to corrupted food due to the presence of some biological, chemical or physical substances such as toxins and microbes making it unsuitable for consumption[1]. These substances can find their way into food during agricultural production, environment, storage, transportation, sale and processing. Contaminants in foods may come from the application of pesticides to crops, from the

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transport of industrial chemicals in the environment or from chemicals used in food packaging products. 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[2]. 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. The PAHs can also be formed during other food preparation processes, such as the smoking of meats. Polycyclic aromatic hydrocarbons (PAHs) comprise over 200 organic compounds containing two or more fused aromatic rings[3]. According to the number of aromatic rings, they can be classified as light (2-3 rings) or heavy (4–6 rings) compounds.

However, environmental PAHs can originate from natural sources, such as forest fires and volcanic emissions and from sources associated with human activity (i.e., artificial or anthropogenic sources), such as coal burning, vehicle exhaust emissions, engine lubricating oils and cigarette smoke[4]. The pyrolytic process that generates PAHs involves three fundamental factors, high temperatures, reduced oxygen levels and organic matter resulting in incomplete combustion. This process generally yields a complex mixture of PAHs, which in turn can accumulate in the environment, affecting water, air and soil, thereby entering the food chain[5]. Conversely, PAHs can be formed during food processing, such as smoking or drying-especially when the fuel is only partially combusted[6], as well as during preparations involving high temperatures or open flames, such as grilling, toasting, roasting and frying. Importantly, chronic human exposure to PAHs can explain the increase in the prevalence of some diseases, such as lung cancer in smokers and intestinal diseases in non-smokers[7]. In particular, foods containing a high content of lipids (e.g., beef, poultry and fish) are excellent delivery systems for these molecules, allowing their passive absorption by the gastrointestinal tract[8]. This study tried to evaluate the PAH accumulating ability of bitter yam roasted with different techniques and determine the anti-nutrient and its proximate composition.

MATERIALS AND METHODS

Study area: This work was carried out during the wet season. It was carried out at the Department of Biochemistry, University of Nigeria Nsukka. This work was done from September to October, 2022.

Plant materials: The plant materials used for this study was a yam tuber *Dioscorea dumetorum* (Bitter yam), locally known as Una purchased from a farmer at Ogige Market, University of Nigeria, Nsukka, Enugu State, in March, 2021.

Reagents: The reagents used to prepare and extract samples were of analytical grade quality.

Preparation of *Dioscorea* sp. samples for roasting: The yam samples (one tuber) obtained were divided into nine portions for each species and were divided into three main groups each weighing 160±1.2 g: (a) First group comprised *Dioscorea* sp., roasted with firewood and kerosene to aid combustion, (b) Second group comprised *Dioscorea* sp., roasted with charcoal and kerosene to aid combustion and (c) Last group comprises *Dioscorea* sp., roasted with charcoal and 5 g of plastics added to enhance combustion (Augmented charcoal). The yam samples were laid on a mesh tray above the burning firewood or charcoal.

Determination of proximate and anti-nutrient content

Determination of moisture content: The method used to determine the moisture content during the proximate was according to the AOAC method (Hot air oven method 925.10)[9]. Four porcelain dishes were cleaned and dried in a hot air oven at 100°C for 30 min. The surface moisture was removed by cooling the desiccators for 5 min. The porcelain dishes were weighed to obtain their initial weight before a known quantity (2 g) of the samples was weighed into the dishes and oven-dried at 150°C. After drying, the porcelain dishes were removed and cooled in desiccators (a glass desiccator made in China) to prevent the re-absorption of moisture. After cooling, the porcelain dishes were weighed again and the moisture percentage was calculated as:

$$\text{Moisture (\%)} = \frac{A - B}{C} \times 100 \quad (1)$$

Where:
A = Total weight (dish and sample) before drying
B = Total weight (dish and sample) after drying
C = Initial weight of the sample in grams

Determination of ash content: This was done as described in the AOAC method[9]. The ashing was carried out by weighing four ashing dishes and oven-drying them for 25 min at 100°C and cooled in desiccators. A known quantity (2 g) of the samples was charred on desiccators to remove carbon. The samples were put in a muffle furnace (with dimensions 100×100×225 and a maximum working temperature of 1000°C and made in West Bengal, Kolkata, India) at 600°C until ashing was completed. The dishes containing the samples were cooled after ashing in desiccators.

Determination of protein content: The crude protein content was evaluated using the Micro Kjeldahl method as described by AOAC[9]. The first thing that was done was to digest 10 g of each sample using catalysts such as concentrated H_2SO_4, $CuSO_4$ and Na_2SO_4 crystals. The mixtures were heated till a clear liquid was obtained. A 100 mL volumetric flask was weighed and the digested samples were transferred in for distillation. The distillation was done using the Kjeldahl distillation apparatus. In a 100 mL conical flask, two drops of methyl blue were added into 10 mL of boric acid and used as the collector for the distillation process. A known quantity (10 mL) was introduced into the distillation chamber and the gradual introduction of concentrated NaOH (10 mL). During the process (distillation), the presence of ammonia (NH_4) in excess boric acid changes the purple color of boric to green. This process took about 5-10 min. The trapped ammonia was titrated using 0.1 NHCl.

The Crude protein content was with the following equations:

$$\text{Nitrogen (\%)} = \frac{Vt \times NA \times Df \times MWn}{SW} \quad (2)$$

Where:

Vt	=	Titre volume
NA	=	Normality of Acid
Dilution Factor (Df) (100 mL/5 mL)	=	20
MWn Molecular weight of nitrogen	=	14.01
SW	=	Weight of sample

Therefore, to convert nitrogen content into protein content:

A×6.25% protein 1/4% nitrogen 6.25

Where:
6.25 = Conversion factor of nitrogen to protein

Determination of fat content: The fat content was evaluated using the soxhlet extraction method as described in the AOAC method[9]. A known quantity of sample (2 g) was weighed into dry soxhlet thimbles and put in a soxhlet condenser which was fixed to an extraction flask (already weighed) containing 100 mL of petroleum ether. The thimbles were removed from the chamber separating the petroleum ether completely. They were cooled in a desiccator and weighed. The fat content in percentage was calculated as shown below:

$$\text{Fat (\%)} = \frac{V - W}{X}$$

Where:
W = Weight of flask and extracted fat (g)
V = Weight of the sample and flask (g)
X = Weight of the sample (g)

Determination of crude fibre content: Crude fibre content was determined using the AOAC method[9]. A known quantity of sample (10 g) was added into a beaker and 100 mL of 1.25% diluted sulphuric acid (H_2SO_4) was also added for digestion for 30 min. After digestion, the mixture was filtered through a flask containing a calico cloth. The NaOH was neutralized with one percent HCl and was cleaned. The residue was oven-dried for 30 min and was cooled and weighed (as Wa). The sample was oven-dried for two hours cooled to room temperature and weighed again (as Wab) and the crude fibre content in percentage was calculated as follows:

$$\text{Crude fibre (\%)} = \frac{\text{Wa - Wab}}{\text{Weigh of sample}} \times 100 \quad (3)$$

Determination of carbohydrate content: The carbohydrate content of the samples was obtained by the difference in hundred and the sum of the other proximate compositions. This was done as stipulated below:

Carbohydrate = 100-(moisture (%)+ash (%)+crude fat (%)+crude protein (%)+crude fibre (%))

Determination of oxalate concentration: This was done as described in the method of Karamad *et al.*[10]. The titration strategy was used to evaluate the oxalate content of the samples. A known quantity of the sample (2 g) was placed in a volumetric flask (250 mL) containing 190 mL of distilled water. A solution of 6M HCl (10 mL) was added to the samples and the suspension was digested for an hour at 100°C. The samples were cooled, made up to the 250 mL mark of the flask and also filtered. The samples were divided into two in a beaker to have 125 mL and 4 drops of an indicator (methyl red) were added with a dropwise addition of concentrated NH_4OH until it changed to a yellow color. It was heated to 90°C, cooled and filtered to remove the precipitate containing Fe^{2+}. It was heated again to 90°C and 10 mL of 5% $CaCl_2$ solution was added to the samples while it was continuously stirred. The sample cooled overnight and the solutions were centrifuged for 5 min at 2500 rpm. The resulting supernatant was decanted and the precipitates were dissolved in 10 mL of 20% H_2SO_4, completely. The filtrated sample was pooled together and made up to 200 mL. A known quantity of (125 mL) of the filtrate was taken and heated close to boiling point and titration was carried out against 0.05 M standardized $KMnO_4$ solutions until a pink color was obtained which persisted for about 30 sec and the oxalate content was calculated.

Determination of phytate concentration: The phytate concentration was evaluated as described by Lolas and Markakis[11], Russel[12]. The samples were weighed (2 g) into a 250 mL conical flask containing 100 mL of 2% concentation. The HCl was allowed to stand for 3 hrs. It was then filtered through a double-layer filter paper (Whatman). The filtrate (50 mL) was placed into a 250 mL beaker and distilled water (107 mL) was added. A known quantity (10 mL) of 0.3% ammonium thiocyanate solution was added to the beaker as an indicator and titrated with standard iron chloride solution containing 0.00195 g iron mL^{-1} and until the color changed to brownish-yellow which stayed for 5 min and the percentage of the phytate calculated.

Sample preparation for GC-MS analysis: This was done as described in Siddique *et al.*[13]. Potassium hydroxide solution (2 M) was mixed with 30 g of yam sample. It was added into 100 mL methanol-water solution in the ratio 9:1 v/v with an addition of 2 g of $Na_2S.9H_2O$. The sample was put in a water bath set at 70°C and refluxed for 2 hrs. A known quantity (100 mL) of an organic solvent, n-hexane was put in via the condenser and after 15 min, the sample was cooled by introducing cold water (100 mL). The resulting blend was kept in the dark overnight, concentrated with 60 mL n-hexane from which the organic layer was later extracted. The extraction was done (2X) with 30 mL of n-hexane, the extracted layer was dried with anhydrous sodium sulfate and filtered. The n-hexane layer was further concentrated to about 2 mL using a rotary evaporator set at 35°C. Column chromatography was used to purify the concentrate. Silica gel was used as the stationary phase while organic solvents were used as the mobile phase. Column packing was done by making a slurry of silica gel. The slurry was prepared by introducing 40 mL of n-hexane into 20 g of silica gel which was run down the column. When the slurry settled, the sample mixture was added into the column and eluted by passing n-hexane (50 mL) through the column and this was followed by 8 mL of n-hexane-dichloromethane (3:1, v/v) mixture. The rotary evaporator was used to concentrate the eluted solvent to approximately 1 mL. It was filtered by passing it through a microporous syringe (0.45 µm) in vials and kept in the refrigerator at-20°C for analysis.

Analysis of PAHs using GC-MS: The PAHs were quantified using the GC-MS method shown in Siddique *et al.*[13]. An agilent GC-MS (7890B) that had DB-5MS capillary with dimensions 30 m, 0.25 mm ID and 0.25 µm film thickness was used. The chromatograph was coupled to a Mass Spectrometer (5977A). A known volume (1 µL) of the sample solution was injected in a splitless mode by using helium (purity >99.995%) as a carrier gas that flows at a rate of 1 mL min^{-1}. The operating condition is as follows: The oven temperature was at 80°C for 1 min, with a rate of 25 and 260°C min^{-1}, rate 10°C min^{-1} to 300°C for 6.3 min. The detector temperature was 150°C for the ion source, 230°C for the quadrupole and 150°C for the ion source.

Statistical analysis: The Statistical Product and Solution Service (SPSS) version 20 was used to analyze the data obtained. A One-way Analysis of Variance (ANOVA) was used and variations between groups were considered significant at $p<0.05$.

RESULTS

The weight of the bitter yam after roasting was recorded at 147.02±0.3, 143.7±0.4 and 144.8±0.2 g for yam roasted with firewood, charcoal and charcoal augmented with polyethylene bottles, respectively. The yam roasted with charcoal lost more water (10.18±0.2%) when compared to other yam samples, while the yam roasted with firewood had the lowest percentage of water loss (8.63±0.2%). This is shown in Table 1.

Table 2 shows the proximate analysis of the roasted samples. It showed that samples roasted with charcoal recorded the highest crude fibre (16.78%), protein (2.43) and moisture content, those roasted with firewood had the highest ash content (9.93%), while the carbohydrate content of the augmented charcoal recorded the highest composition (49.41%). However, the fresh yam had a higher composition of all the proximate analyses when compared to all the roasting methods carried out.

Table 1: Weight of bitter yam (*Dioscorea dumetorum*) samples before and after roasting

Yam samples	Wet weight (g)	Dry weight (g)	Water loss (%)	Water (%)
Fresh yam	160±1.2			
Roasted with firewood	161±0.2	147.02±0.3	8.63±0.2	8.63±0.2
Roasted with charcoal	160±0.3	143.7±0.4	10.18±0.2	10.18±0.2
Roasted with augmented charcoal	161±0.2	144.8±0.2	10.06±0.3	10.06±0.3

Results expressed as Mean±Standard Deviation

Table 2: Proximate composition of bitter (*Dioscorea dumetorum*) yam samples

Yam samples	Crude fibre (%)	Protein (%)	CHO (%)	Moisture (%)	Fat (%)	Ash (%)
Fresh yam	14.50±0.2	2.45±0.2	49.59±0.2	20.00±0.2	3.1±0.2	10.1±0.2
Roasted with firewood	16.40±0.3	2.40±0.1	49.13±0.2	19.20±0.2	2.9±0.2	9.93±0.2
Roasted with charcoal	16.78±0.2	2.43±0.3	49.25±0.2	18.60±0.4	3.0±0.2	9.80±0.1
Roasted with augmented charcoal	16.31±0.4	2.41±0.2	49.41±0.3	18.90±0.2	3.0±0.1	9.78±0.2

CHO = Carbohydrate

Table 3: Antinutrient composition of bitter yam (*Dioscorea dumetorum*) samples

Yam samples	Phytate (%)	Oxalate (%)	Tannins (%)	Saponins (%)
Fresh yam	18.6±0.2	15.40±0.2	32.2±0.2	6.21±0.2
Roasted with firewood	14.8±0.3	13.56±0.1	26.5±0.3	5.40±0.4
Roasted with charcoal	16.2±0.2	14.30±0.2	28.7±0.1	5.70±0.2
Roasted with augmented charcoal	15.4±0.2	14.90±0.2	28.4±0.2	5.50±0.3

Table 4: Polycyclic Aromatic Hydrocarbon (PAHs) detected in bitter yam (*Dioscorea dumetorum*) in μg g^{-1}

PAH Compounds	Fresh Yam	Firewood	Charcoal	Augmented charcoal
PAH Compounds	Bitter yam	Bitter yam	Bitter yam	Bitter yam
Acenaphthylene	-	0.4850±0.01	0.0031±0.000	
fluorene	0.024±0.01	0.1401±0.01	0.4123±0.01	
Naphthalene	0.110±0.01	0.6811±0.01	0.6100±0.1	-
Fluoranthene	0.021±0.00	0.5463±0.01	0.4127±0.01	1.2541±0.1
Phenanthrene	0.200±0.00	-	-	0.1012±0.01
Dibenzyl(a-h)anthracene	-	0.2532±0.00	0.2120±0.01	0.6211±0.01
Benzo (α) anthracene	-	0.4730±0.01	0.2613±0.01	0.6952±0.01
Acenaphthene	0.145±0.01	0.5889±0.01	-	0.2178±0.01
Benzo (a)pyrene	-	0.2580±0.00	0.1652±0.01	-
Benzo (g_h_i) perylene	-	-	0.0000	-
Benzo (k) Fluoranthene	-	-	-	0.3989±0.01
Pyrene	0.031±0.00	0.1887±0.01	-	0.6452±0.01
Benzo (b) Fluoranthene		-	-	0.0968±0.00
Total	0.5310±0.01	3.4742±0.1	1.8044±0.1	4.4426±0.1

Table 3 shows *Dioscorea dumetorum* (bitter yam) roasted with charcoal recorded higher concentrations when compared to *Dioscorea dumetorum* roasted with firewood and *Dioscorea dumetorum* roasted with charcoal augmented with polyethene bottles, except for the oxalate concentration of which the *Dioscorea dumetorum* roasted with charcoal augmented with polyethene bottles was higher (14.9±0.2%). *Dioscorea dumetorum* roasted with firewood had the lowest concentrations when compared to the *Dioscorea dumetorum* roasted with charcoal and charcoal augmented with polyethylene bottles.

The detected PAHs from the roasted yam show different levels after analysis as seen in Table 4. A total of eight PAHs were detected out of the 13 priority PAHs investigated except for the samples roasted with augmented charcoal. Fluoranthene recorded the highest concentration having 1.254 μg g^{-1} and was found in a sample roasted with augmented charcoal. The lowest concentration of PAHs was acenaphthylene (0.0031±0.1 μg g^{-1}) as observed in the sample roasted with just charcoal. The yam samples roasted with augmented charcoal accumulated the highest level of PAHs (4.4426±0.1 μg g^{-1}) when compared to those roasted with firewood and just charcoal. The yam sample roasted with firewood showed that naphthalene recorded the highest concentration of PAHs (0.6811±0.01 μg g^{-1}) when compared to other identified

Table 5: Percentage composition of molecular weight PAHs in roasted bitter yam

Number of Rings	Firewood (%)	Charcoal (%)	Charcoal augmented (%)
2	37.5	25.0	22
3	12.5	12.5	22
4	25.0	12.5	44
5	25.0	25.0	12

PAHs while the least was dibenzyl(a-h) anthracene with 0.2532±0.00 µg g^{-1}. When roasted with just charcoal acenaphtylene recorded the least detected concentration (0.0031±0.00). Samples roasted with augmented charcoal detected benzo(b) Fluoranthene which was not seen in other roasting methods. It was also the PAH that had the least concentration when compared to the other PAHs detected in the sample roasted with augmented charcoal.

Table 5 shows the percentage composition of the low molecular weight and high molecular weight PAHs. It shows that the samples roasted with firewood and charcoal had 50% low molecular weight PAHs as well as high molecular weight PAHs. However, those roasted with firewood showed that the 2-ringed PAHs of the low molecular weight were about 37.5% PAHs while the 3-ringed were 12.5%. No single ring PAH was detected. The 4 and 5-ring PAHs of the high molecular weight PAHs were 25% each. The samples roasted with charcoal showed that the low molecular weight PAHs had 2 and 3-ringed PAHs to 25 and 12.5% in composition, respectively while the high molecular weight PAHs had the 4 and 5-ringed PAHs to be in 12.5 and 25% composition. Those roasted with augmented charcoal recorded 56% (44 and 12% of the 4 and 5-ringed PAHs, respectively) of the high molecular weight PAHs while the low molecular weight PAHs recorded 44% (22% each of the 2 and 3-ringe PAHs).

DISCUSSION

Roasting as a method of food preparation is a process that has been in existence globally for a long time. However, roasting has been implicated in adding and also increasing the PAH content of these roasted foods. Furthermore, reports have also shown that they have been seen in other food samples such as plantain, fish, meats, fruits, green leafy vegetables and oil[14,15]. This study investigated the proximate and anti-nutrient content of roasted bitter yam (*Discorea dumetorum*).

The findings of this study showed that the yam samples roasted with just charcoal lost more water when compared to those roasted with just firewood and augmented charcoal. The sequence of the water lost in the roasted samples is in the following order: Charcoal>augmented charcoal>firewood. The sequence may be due to the fact that the charcoal produced more heat than the firewood[16]. The amount of heat produced by the augmented charcoal may have been impacted negatively due to the plastics that were added to the charcoal to aid combustion. The samples roasted with firewood lost the least quantity of water because they produced lower heat when compared to charcoal. This can also be due to that firewood has more organic materials to burn off which reduces the amount of heat generated[17].

The proximate composition of the roasted yam samples irrespective of the technique showed that they were all lower than the fresh yam sample. This suggests that roasting may have contributed to the variations observed in the carbohydrate, protein, ash, crude fibre and moisture content of *Discorea dumetorum*. This work is in line with the reports of Nworah *et al*.[2] that showed that fresh plantain samples also recorded higher composition of all the parameters investigated for proximate analysis. The anti-nutrient investigation showed that roasted samples had a lower content of the anti-nutrient in bitter yam. The findings of the work also suggest that those samples roasted with charcoal and even the augmented charcoal contained more anti-nutrients when compared to those roasted with firewood. These findings are in contrast with Egbuonu and Nzewi[18], who reported lower concentrations of these anti-nutrients.

The study detected priority PAHs in the roasted samples at different levels and also in the control. The presence of PAHs in the fresh yam samples could be a result of man-made activities (increasing the amount of PAHs deposited within the soil and also in the environment). Furthermore, fresh *Discorea dumetorum* may have accumulated these PAHs from contaminated soil. Studies have also shown that soils with rich organic content save higher deposits of PAHs. There were reports that PAHs have also been found in plants above the maximum permissible limit[19]. These findings are also in tandem with the reports of Nworah *et al*.[2] that observed the presence of PAHs in fresh plantain samples. It was also observed that the roasted yam samples had more PAHs when compared to the control and this may be as a result of the roasting. The *Discorea dumetorum* samples roasted with augmented charcoal accumulated mote PAHs when compared to those roasted with firewood and charcoal. This can be a result of the increased smoke from the plastics during the roasting process as a result of incomplete combustion[20]. The values obtained for the individual and total PAHs in the roasted samples did not exceed the maximum allowable limit of 5 μg g^{-1}. This is in tandem with Sahin *et al*.[21] which also reported PAH levels below permissible limits after roasting meats.

The sources of PAHs in roasted yams in other to reaffirm that the PAHs detected in these yams were a result of roasting. It is also called forensic diagnosis, usually achieved by using the priority pollutant ratio. The ratio of low molecular weight PAHs (LMW-PAHs) to high molecular weight PAHs (HMW-PAHs) has also been used to evaluate PAHs' origin, especially within the environment. This has always suggested that when LMW-PAHs are abundant, it implies that the sources of those PAHs detected are of oil origin (petrogenic), while when they are sparse compared to HMW-PAHs, there is every possibility that they are as a result of incomplete combustion of organic materials (pyrogenic). The source can be evaluated using the priority pollutant ratio by estimating the phenanthrene/anthracene (Ph/An) or fluoranthene/pyrene (Fl/Py) quotient. It has also been suggested that when the phenanthrene/anthracene quotient is less than 10 (<10), it implies that the source could be pyrogenic, while when it is above 10 (>10), it may be petrogenic. When the value of the (Fl/Py) quotient is estimated and it is less than 1 (<1), it implies that it is probably a petrogenic source, while when the quotient is greater (>1), it could be pyrogenic[22]. From the study, the HHMW-PAHs were higher in proportion (>50%) in the samples roasted with the augmented charcoal while the other samples had an equal ratio of the HMW-PAHs and LMW-PAHs. The HMW-PAH ratio detected in the sample roasted with augmented charcoal could be because of the plastics that were added to aid combustion. The pollutant priority ratio showed that the value obtained for those roasted with firewood was 2.895 for bitter yam, while for those roasted with augmented charcoal was 1.943. These values reaffirm that the main source of PAHs that were detected in these roasted yam samples was from roasting and as a result of pyrolysis.

The four priority PAHs (benzo[a]pyrene (BaP), (benz[a]anthracene (BaA), benzo[b]fluoranthene (BbF) and chrysene (Chr)) classified as carcinogenic were all detected except for chrysene. The Benz[a]anthracene was detected in the yam samples irrespective of the roasting method. The detection of carcinogenic PAHs in these roasted samples varied as the roasting method varied. The benzo[a]pyrene usually used as a yardstick to the other PAHs was detected in those samples roasted with charcoal and firewood. It was not detected in the fresh yam and also in the sample that was roasted with augmented charcoal. Benzo (b) fluoranthene was only detected in the sample roasted with the augmented charcoal. Phenanthrene, fluoranthene and acenaphthalene are PAHs that are used in making plastic materials were detected differently in both fresh and yam samples. This may be due to environmental contamination[22]. In addition, even though they aren't included among the carcinogenic PAHs, they could lead to hazardous conditions if ingested beyond permissible limits over a lifetime. It will be necessary to compare the accumulating ability of bitter yam and other yam species to see the variations and find out the species that accumulate fewer PAHs.

CONCLUSION

The finding of this work suggests that it is good to roast bitter yam since it reduces the level of anti-nutrients. It also suggests that naphthalene accumulated more than other PAHs. However, it is Fluoranthene that accumulated more when roasted with augmented charcoal. The findings also suggest that HMW-PAHs do not accumulate more than LMW-PAHs in roasted bitter yam and this can be safe for consumption.

SIGNIFICANCE STATEMENT

This work was done due to the increasing awareness of the effect of roasting foods for consumption. Research has shown that roasting can increase the content of PAHs in food. Furthermore, these roasted foods are usually obtained from street vendors and they usually use other materials to aid combustion and facilitate roasting. Bitter yam is one of the types of foods that diabetics are advised to consume due to its low glycaemic index. This prompted the idea of roasting bitter yam with firewood, charcoal and augmented charcoal to see the rate at which bitter yam can accumulate different PAHs. This showed that roasting bitter yam with firewood and charcoal will deposit more naphthalene than other PAHs except for those roasted with augmented charcoal.

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