e-ISSN 2805-4356
p-ISSN 2805-4364

10.5281/zenodo.14228201 Vol. 07 Issue 10 Oct - 2024 Manuscript ID: #01650

Assessment of potential heavy metals, polycyclic aromatic hydrocarbons, and phenolic compounds in commonly sold plantains in selected locations in Bayelsa State, Nigeria

R. M. Ayila[1]., G. C. Onwugbuta[2]., & M. O. Onyema[3]

[1,2]*Department of Biochemistry/Chemistry Technology, School of Science Laboratory Technology, University of Port Harcourt, Nigeria.*

[3]*Department of Pure and Industrial Chemistry, University of Port Harcourt, Nigeria*

Corresponding author: *ayilaruth2015@gmail.com*

Abstract

Humans are constantly exposed to pollutants through various pathways including food chain, skin contact, and inhalation. These pollutants, both organic and inorganic pose considerable health risks and concerns to humans. The present study was set out to assess potential heavy metals, polycyclic aromatic hydrocarbons and phenolic compounds present in commonly sold plantains in selected locations in Bayelsa State, Nigeria. Fresh plantain specimens from Ekeremor and Tombia, Bayelsa state, Nigeria were collected, identified and assayed for potential organic/inorganic contaminants and phenolic compounds using Atomic Absorption Spectrophotometer (AAS) and Gas Chromatography/Mass Spectrometry (GC/MS) following standard procedures. Data obtained were analyzed using IBM SPSS and results were presented as mean ± SEM. Our findings showed that the levels of chromium, lead, cadmium, and nickel in plantain samples from Ekeremor and Tombia, Nigeria were significantly higher than in the control sample. The most abundant PAHs were acenaphthylene, acenaphthrene, fluorine, phenanthrene, fluoranthene, pyrene, and chrysene. Furthermore, the highest concentrations of phenol were found in plantain samples taken from Ekeremor (8.28 ± 0.01). Values obtained were mostly above the limits set by the regulators. This poses possible carcinogenic concerns if consumed for a long time. Hence, effective management strategies are required to mitigate possible associated risks and protect public health.

Keywords: Assessment, Organic, Inorganic, Phenolic, Plantain.

How to cite: Ayila, R. M., Onwugbuta, G. C., & Onyema, M. O. (2024). Assessment of potential heavy metals, polycyclic aromatic hydrocarbons, and phenolic compounds in commonly sold plantains in selected locations in Bayelsa State, Nigeria. *GPH-International Journal of Applied Science*, *7*(10), 01-11. https://doi.org/10.5281/zenodo.14228201

INTRODUCTION

Environmental contaminants are responsible for substantial global health risk, as they are associated with various medical complications and environmental insults. Pollutants can access the body via inhalation, direct contact with the epidermis, or through the food chain. Over 90 percent of pollution cases can be attributed to food consumption (Zheng *et al.,* 2020). Hazardous chemicals are detrimental pollutants discharged into the surrounding ecosystem. These substances pose a great threat to plant life, rodents and humans (Martí-Cid *et al.,* 2008: Saronee *et al.*, 2024). Presence of heavy metals in aquatic environments can result from anthropogenic or natural processes, and their discharge can have detrimental effects on fish populations and other resources found in water bodies (Adamu *et al.,* 2016; Alhassan *et al.,* 2016). Certain polycyclic aromatic hydrocarbons (PAHs) possess mutagenic or carcinogenic characteristics due to dysfunctional metabolism which is predicated on cytochrome p450 oxidase system enzymes. Theoutcome is characterized bypalpable decline in antioxidant enzyme levels, and consequent induction of oxidative stress,formation of cataracts, renal and hepatic impairment, premature aging, and cell death (Singh *et al.,* 2008).Heavy metal bioaccumulation in the body causes serious health issues, includingimpaired cognitive and reproductive capacities, high blood pressure, nervous disorder, dysfunctional fetal development, and increased vulnerability to cancer (Singh *et al.,* 2008).

Plantain is a vertical specimen belonging to the Musaceae family and is intricately linked to banana. The plant displays a pseudostemic conical structure composed of spirally arranged leaves (Kumar *et al.,* 2023). Plantains are considered essential food items in our environment and are referred to as "cooking bananas" (Borges *et al*., 2020). Numerous studies have reported the usefulness of plantain (Boris *et al.*, 2023; Ighodaro, 2012).Reports on the assessment of potential heavy metals, polycyclic aromatic hydrocarbons and phenolic compounds in commonly sold plantains in Bayelsa State, Nigeria have been scanty. Hence the present study, presents a preliminary report on the assessment of potential heavy metals, polycyclic aromatic hydrocarbons and phenolic compounds in commonly sold plantain in selected locations in Bayelsa State, Nigeria

MATERIALS AND METHODS

Study Area

The geographical areas under investigation for this study are Ekeremor and Tombia, both of which are oil (crude oil) exploration areas, situated in Bayelsa State. Ekeremor functions as the administrative headquarters of Ekeremor local government, one of Bayelsa State's eight Local Government Areas. It is situated on the Delta State boundary and has a 60 km2 coastline along the Bight of Bonny. Ekeremor has a population of 270,257 individuals. On average, the highland regions of the territory receive 2,200mm of annual precipitation, whereas the lowland or wetland areas receive 3,500mm. The region is known for a temperature variation of 23-31°C and is home to mangrove wetland, saline water, and rain forest ecosystems. The area is occupied by the Ekeremor clan, which is of the Ijaw ethnic group, and their main source of income is fishing.

The monthly mean temperature in Tombia Community, situated in Yenagoa L. G. A., Bayelsa State, fluctuates between 25°C and 31°C. Typically, the greatest temperatures in this region range between 26°C and 31°C. The average annual temperature of the state remains constant, displaying a 2°C discrepancy between the periods of precipitation and absence. Throughout the year, the relative humidity remains elevated, with only a marginal reduction observed during the arid season. Significant annual precipitation is recorded, with values ranging from 3,000mm to 3,500mm. In addition to pockets of mangrove swamp forests and coastal barrier woodlands, freshwater swamp forests predominate the area. Fishing, agriculture, palm oil processing, forestry, palm wine extraction, distillation, commerce, woodcraft, and textile production are all considered primary livelihoods.

Sample Collection and Preparation

Fresh plantain fruits were obtained from Ekeremor and Tombia, Bayelsa State. Control samples were obtained from Choba in Port Harcourt, Rivers State. Plantain samples were peeled. The extracted food samples were washed to remove impurities. Samples were separately homogenized using mortar and pestle. The homogenized samples were stored in a well labeled sterile container until required for heavy metal analysis.The groups separated for PAHs analysis were wrapped with aluminum foil to prevent exposure to light.

Two (2) grams of the prepared Plantain fruitwas weighed using a weighing balance into a 250ml beaker. 10ml of aqua regia (hydrochloric acid (HCl) and nitric acid (HNO_3 mixture) were added into each of the beakers containing the sample. The mixtures were heated on a hot plate until the whole sample digested to a clear solution. The solution was allowed to cool off before it was decanted into a 50ml volumetric flask and made up to the mark with distilled water. The concentration of heavy metals (Zn, Cd, Pb, Ni and Cr) in the sample were determined using AAS (Atomic Absorption Spectrophotometer). Blanks were prepared exactly in the similar manner but without the food sample.

Ten grams (10g) of sample was added to an amber glass bottle. In addition, 10g Anhydrous Sodium Sulphate (Na_2SO_4) was also added into the glass bottle containing the sample. The sample was stirred. The addition of Na_2SO_4 was to remove moisture from the sample. 300 µg/ml of surrogate (1-chlorooctadecane) standard was added to the sample. Thirty (30ml) of dichloromethane (DCM) was added to the sample as extracting solvent and the bottle containing the sample was corked very tight and transferred to a mechanical shaker. The sample was agitated for 5 to 6 hours at room temperature with a mechanical shaker. Following agitation, the samples were allowed to settle for one hour before being filtered through 110 mm filter paper into a clean beaker. The filtrate was concentrated to 1mL by evaporating it overnight in a fume closet.

A glass column was prepared for sample clean-up by packing it with glass cotton. Ten (10g) of Silica gel (10g) was mixed with 50ml of dichloromethane (DCM) to create a slurry, which was then added to the column. Additionally, ten (10g) of Anhydrous Na_2SO_4 was introduced into the column, followed by the addition of pentane. Then, the concentrated sample extract was mixed with 20ml of cyclohexane in a beaker and transferred into the prepared column. The sample was eluted using 30ml of pentane as the solvent, with the eluted sample collected in a beaker placed beneath the column. An additional 20ml of pentane was passed through the column for further elution. After elution, the column was rinsed with 20ml of DCM. The eluted sample was then left to stand overnight at room temperature in a fume cupboard to allow for evaporation.

The separation and detection of PAHs samples were carried out using Agilent 6890N Gas Chromatograph - Flame Ionization Detector (GC-FID) instrument. Three (3µl) of concentrated sample eluted from column was injected into GC vial. The blank DCM was injected into micro-syringe of GC to clean the syringe (3 times) before taking the sample for analysis. The micro-syringe was further rinsed with the sample. Then the sample was injected into the column for separation of compounds in the sample. After separation the compounds were passed through a flame ionization detector. FID detects the compounds in the sample. The amount of PAH was resolved at a particular chromatogram in mg/kg for sample.

The F–C method reported by Adusei *et al.* (2019) was used in the determination of the phenolic compounds. During the experiment, the reagents, and sample solution were prepared as follows: The F–C reagent were diluted to 1:10 with distilled water just before the experiment. Sodium carbonate (7.5% w/v) was also prepared in distilled water. Stock solution of the extract sample resin (1000 µg/mL) and the standard compound, Gallic acid, (500 µg/mL) was prepared in methanol (95% vol/vol).

Data Analysis

Data obtained from the study were carefully entered and coded using Microsoft Excel (2016). Coded data were analyzed using IBM SPSS version 21. One way analysis of variance (ANOVA) was used to determine significant means at 5% significant probability level.LSD post-hoc test was used for multiple comparisons between groups.

RESULTS

The results of the analysis are as shown in the following tables.

Table 1: Heavy metal Concentrations in Plantain obtained from Ekeremor and Tombia in Bayelsa State

Heavy Metal (mg/kg)	Ekeremor	Tombia	Control	FAO/WHO Standard
Lead (Pb)	1.35 ± 0.01[a]	4.58 ± 0.01[b]	0.03 ± 0.01[c]	0.1
Cadmium (Cd)	0.21 ± 0.02[a]	0.62 ± 0.02[b]	0.003 ± 0.00[c]	0.05
Chromium (Cr)	8.43 ± 0.02[a]	13.62 ± 0.01[b]	0.32 ± 0.02[c]	1.30
Nickel (Ni)	2.35 ± 0.01[a]	1.69 ± 0.03[b]	0.02 ± 0.01[c]	1.07
Zinc (Zn)	6.32 ± 0.03[a]	4.01 ± 0.02[b]	1.84 ± 0.02[c]	30

Values are presented in mean ± SEM. N=3. Mean values with same alphabet on same row have no statistically significant difference at $p \leq 0.05$

Table 1 above shows the concentration of Heavy Metals (Pb, Cd, Cr, Ni and Zn) in plantain from two sampling locations (Ekeremor and Tombia) and control, results indicate that chromium had the highest heavy metal load in plantain samples across the sampling locations. In the plantain chromium concentrations were 8.43 ± 0.02mg/kg and 13.62 ± 0.01 for Ekeremor and Tombia respectively and 0.32 ± 0.02mg/kg for control. The concentrations of chromium in plantain for Ekeremor and Tombia were above the World Health Organization (WHO) and the Food and Agriculture Organization (FAO)2014 standard for consumption of chromium of 1.30mg/kg. The result for Lead (Pb) in plantain from Ekeremor and Tombia indicated 1.35 ± 0.01mg/kg and 4.58 ± 0.01mg/kg respectively. These levels were higher than the control which showed (0.03 ± 0.01mg/kg). The concentration of Pb in plantain from Ekeremor and Tombia were above the FAO/WHO (2014)permissible limit. The result revealed high concentration of Cadmium (Cd) (0.21 ± 0.02mg/kg and 0.62 ± 0.02 mg/kg) in plantain from Ekeremor and Tombia respectively. These levels were higher than the control which showed Cd (0.003 ± 0.00mg/kg). The results showed that Cd concentrations were above FAO/WHO 2014 standard for samples from Ekeremor and Tombia. The result for Nickel (Ni) in plantain from Ekeremor and Tombia indicated 2.35 ± 0.01mg/kg and 1.69 ± 0.03mg/kg. These levels were higher than the control which showed Ni (0.02 ± 0.01mg/kg). The concentration of Ni in plantain from Ekeremor and Tombia were above the WHO permissible limit. However, the result for Zinc (Zn) in plantain from Ekeremor and Tombia indicated 6.32 ± 0.03mg/kg and 4.01 ± 0.02mg/kg. These levels were higher than the control which showed Ni (1.84 ± 0.02mg/kg). The concentration of Zn in plantain from Ekeremor, Tombia and control were within the WHO permissible limit (Table 1).

Table 2: Concentrations of Polycyclic Aromatic Hydrocarbons (PAHs) in Plantain obtained from Ekeremor and Tombia town in Bayelsa State

Compound	Ekeremor	Tombia	Control
Naphthalene	5.52 ± 0.01[a]	7.15 ± 0.02[b]	BDL
Acenaphthylene	9.98 ± 0.01[a]	3.95 ± 0.02[b]	1.15 ± 0.01[c]
Acenaphthrene	3.22 ± 0.01[a]	9.52 ± 0.01[b]	BDL
Fluorine	BDL	BDL	BDL
Phenanthrene	9.40 ± 0.02[a]	5.95 ± 0.02[b]	0.62 ± 0.01[c]
Anthracene	BDL	BDL	BDL
Fluoranthene	4.18 ± 0.01[a]	2.22 ± 0.01[b]	BDL
Pyrene	3.02 ± 0.01[a]	3.85 ± 0.10[b]	BDL
Benz(a)anthracene	BDL	1.53 ± 0.02	BDL
Chrysene	6.19 ± 0.02[a]	6.95 ± 0.01[b]	BDL
Benz(b)flouranthene	BDL	BDL	BDL
Benz(k)fluoranthene	BDL	BDL	BDL
Benz(a)pyrene	5.32 ± 0.01	BDL	BDL
Indeno(1,2,3-cd) pyrene	BDL	BDL	BDL
Dibenz(a,h)anthracene	BDL	BDL	BDL

Benzo(g, h,i)perylene	BDL	BDL	BDL

Values are presented in mean ± SEM. N=3. Mean values with same alphabet on same row have no statistically significant difference at p≤0.05; BDL- Below Detectable Limit

Table 2 above showed the concentration of PAHs in the plantain samples from Ekeremor, Tombia and control. It revealed that, Naphthalene, Acenaphthylene, Acenaphthrene, Phenanthrene, Fluoranthene, Pyrene and Chrysene were present in samples from Ekeremor and Tombia. Acenaphthylene showed highest concentration (9.98 ± 0.01) and Pyrene indicated the lowest concentration of 3.02 ± 0.01for sample from Ekeremor. While Acenaphthrene showed highest concentration (9.52 ± 0.01) and Benz (a) anthracene indicated the lowest concentration of 1.53 ± 0.02for sample from Tombia. Only Acenaphthylene and Phenanthrene were detectable in the control with concentrations of 1.15 ± 0.01 and 0.62 ± 0.01 respectively. Fluorine was below detectable limit in samples from Ekeremor, Tombia and control. This trend was observed for Anthracene, Benz (b) flouranthene, Benz (k) fluoranthene, Indeno (1,2,3-cd)pyrene, Dibenz (a, h) anthracene and Benzo (g, h,i) perylene.

Table 3: Concentrations of some Phenolic Compounds in Plantain obtained from Ekeremor and Tombia in Bayelsa State

Phenolic compound	Ekeremor	Tombia	Control
Phenol	8.28 ± 0.01[a]	2.68 ± 0.01[b]	2.30 ± 0.01[c]
2-Chlorophenol	1.13 ± 0.02[a]	4.08 ± 0.01[b]	0.49 ± 0.01[c]
3-Chlorophenol	2.06 ± 0.02[a]	9.87 ± 0.01[b]	0.11 ± 0.01[c]
4-Chlorophenol	1.15 ± 0.01[a]	1.10± 0.02[b]	0.52 ± 0.02[c]
2-Methylphenol	0.26 ± 0.02[a]	5.30 ± 0.01[b]	5.29 ± 0.02[c]
3-Methylphenol	6.04 ± 0.01[a]	2.52 ± 0.01[b]	BDL
4-Methylphenol	1.19 ± 0.01[a]	1.17 ± 0.02[b]	0.35 ± 0.02[c]
2-Nitrophenol	2.13 ± 0.01[a]	7.39 ± 0.02[b]	0.17 ± 0.01[c]
3-Nitrophenol	2.28 ± 0.01[a]	1.63 ± 0.01[b]	0.40 ± 0.01[c]
4-Nitrophenol	1.16 ± 0.02[a]	9.05 ± 0.02[b]	0.18 ± 0.01[c]
Cyclohexyl-4,6-dinitrophenol	1.20 ± 0.00[a]	3.08 ± 0.01[b]	0.52 ± 0.01[c]
2,3-Dichlorophenol	4.53 ± 0.01[a]	1.21 ± 0.03[b]	0.10 ± 0.01[c]
2,4-Dichlorophenol	1.79 ± 0.01[a]	3.17 ± 0.01[b]	0.47 ± 0.01[c]
2,5- Dichlorophenol	1.21 ± 0.01[a]	2.69 ± 0.02[b]	0.11 ± 0.01[c]
3,4- Dichlorophenol	0.48 ± 0.01[a]	5.25 ± 0.04[b]	0.29 ± 0.01[c]
3,5- Dichlorophenol	1.22 ± 0.02[a]	4.78 ± 0.03[b]	0.31± 0.02[c]
4-Chloro-2-methylphenol	1.17 ± 0.01[a]	1.63 ± 0.01[b]	BDL
2-Chloro-5-methylphenol	0.29 ± 0.01[a]	1.17 ± 0.01[b]	BDL
2,3-Dinitrophenol	0.37 ± 0.01[a]	6.15 ± 0.02[b]	BDL
2,4-Dinitrophenol	0.42 ± 0.01[a]	1.85 ± 0.01[b]	0.25 ± 0.02[c]
2,5-Dimethylphenol	0.19 ± 0.01[a]	4.63 ± 0.01[b]	0.12 ± 0.01[c]

Values are presented in mean ± SEM. N=3. Mean values with same alphabet on same row have no statistically significant difference at p≤0.05

Table 3 above showed the concentration of somePhenolic Compounds in plantain samples from Ekeremor, Tombia and control. It revealed that, Phenol (8.28 ± 0.01) had the highest concentration and 2,5-Dimethylphenol indicated the lowest concentration of 0.19 ± 0.01for sample from Ekeremor. 3-Chlorophenol showed highest concentration (9.87 ± 0.01) and 4-Chlorophenol indicated the lowest concentration of 1.10± 0.02 for plantain sample from Tombia.2-Methylphenol showed highest concentration for control plantain sample while 2,3-Dichlorophenol (0.10 ± 0.01) indicated the lowest concentration.

DISCUSSION

Heavy metals are a collection of metallic elements distinguished by their exceptionally high atomic density. They pose serious threat to human health even in minute quantities. The induction of toxicity in plants and animals is contingent upon the concentration of the said compounds surpassing a specific threshold (Singh *et al.*,(2008): Saronee *et al.*,(2023): Saronee *et al.*,(2024): Saronee *et al.*,(2024).Heavy metal bioaccumulation in the human body can cause serious health issues. These can include impaired cognitive and reproductive capacities, high blood pressure, changes in the nervous system, harmful effects on fetal development, and an increased vulnerability to developing cancer (Lee *et al.*,(2011):Saronee *et al.*, (2023): Saronee *et al.*, (2024).Plantain samples collected from Ekeremor (8.43 ± 0.02mg/kg) and Tombia (13.62 ± 0.01mg/kg) exhibited significantly higher levels of chromium compared to the control sample (0.32 ± 0.02mg/kg). The readings are above the threshold of 1.30 mg/kg set by the FAO/WHO. Similarly, the lead concentration in plantain samples collected from Ekeremor was ascertained to be 1.35 ± 0.01 mg/kg, whereas in samples collected from Tombia, the value was 4.58 ± 0.01 mg/kg. The lead concentration was significantly higher than that of the control sample, which was 0.03 ± 0.01 mg/kg. The observed values exceeded the FAO/WHO-mandated permissible limits.In comparison to the control sample (0.003 ± 0.00mg/kg), the concentrations of cadmium in plantain samples obtained from Ekeremor (0.21 ± 0.02mg/kg) and Tombia (0.62 ± 0.02mg/kg) were observed to be elevated. Cadmium (Cd) concentrations in plantain samples from Tombia exceeded the limits established by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO).Cadmiumis a heavy metal with a notoriously detrimental effect on cellular enzymatic systems, it induces oxidative stress and results in nutritional deficiencies. Cadmium isextremely hazardous.The concentrations of nickel in plantain were elevated in Ekeremor (2.35 ± 0.01mg/kg) and Tombia (1.69 ± 0.03mg/kg) in comparison to the control. The concentration of nickel (Ni) in plantain from Ekeremor exceeds the permissible thresholds established by the World Health Organization (WHO) 2014. The zinc concentrations in plantain were determined to be 6.32 ± 0.03mg/kg in Ekeremor and 4.01 ± 0.02mg/kg in Tombia.Heavy metals are characterized by having an atomic mass more than 20 and a specific gravity above 5. This includes cadmium, mercury, copper, arsenic, lead, chromium, nickel, and zinc. Unhealthy quantities of these metals can be hazardous to both plants and animals. The rapid expansion of agriculture and industry, along with the continuous increase in world population has resulted in the emergence of a chronic and enduring problem (Saronee *et al.,* 2029). Moreover, this activity not only cause damage to aquatic ecosystems, the natural surroundings, and agricultural produce, but also presents a substantial risk to human health and welfare as it accumulates in the food web (Saronee *et al.*, 2020: Dan-Jumbo *et al.*, 2024).

The study revealed a notable presence and corresponding increase in the levels of PAHs in plantain samples collected from Ekeremor and Tombia, Bayelsa State, Nigeria, compared to the control samples. Specifically, acenaphthylene, acenaphthrene, fluorine, phenanthrene, fluoranthene, pyrene, and chrysene were found in the highest quantities. The results of this study align with previous research that has identified elevated concentrations of PAHs in food samples collected from contaminated regions (Rengarajan *etal.*,(2015)). Polycyclic aromatic hydrocarbons (PAHs) have been reported to be harmful to the immune system by preventing the development of pre-B, pre-T, and myeloid cells, suppressing B and T cells, thereby destroying the lymphoid tissues, disrupting the production of myeloid cells, and altering the synthesis of cytokines (Burchiel and Gao, (2014): Rengarajan *etal.*,(2015). PAHs impacts the endocrine system, including aromatase enzyme, luteinizing hormone, follicle-stimulating hormone, and gonadotrophin-releasing hormone (Bolden *et al.*,(2017).

Not as many phenols are inherent in plantain samples obtained from the two impacted selected locations in Bayelsa State. The phenol content of plantain can be ascribed to physiological changes. Dixon *et al.*, (2002) reported similar findings that the inclusion of phenols in plantains can enhance its resistance against pests and diseases. The results also indicate the presence of chlorophenols. The maximum quantity of 3-Chlorophenol was detected in Tombia plantains (9.87 ± 0.01). The investigation also identified the presence of polyphenols such as 2-Methylphenol, 2,3-Dichlorophenol, 2,5-Dimethylphenol, 2,3-Dinitrophenol, and 2-Nitrophenol. The ecological impact of these substances is significant, and they can adversely impact human health when consumed through the food chain (Kumar *et al.*, 2016).

In conclusion, the present study revealed the presence of elevated levels of heavy metals, high concentration of PAHs in purchased plantain samples, this is attributed to environmental pollution, which clearly highlight the need for environmental conservation and stricter regulations to reduce the concentration of both heavy metals and PAHs emissions as chronic ingestion of PAHs could elicit negative health consequences.

REFERENCES

Adamu, H. M., Ushie O. A., Ogah, E., Nkom, P. Y., & Usman, U. (2016). Uptake and risk assessment of heavy metals in vegetables grown in Bayara-Bauchi, Nigeria. *Federal University Wukari Trends in Science and Technology Journal.*, 1(1), 50-54

Adusei, S., Otchere, J. K., Oteng, P., Mensah, R. Q., & Tei-Mensah, E. (2019). Phytochemical analysis, antioxidant and metal chelating capacity of Tetrapleuratetraptera. *Heliyon*, *5*(11), e02762.

Alhassan, A. B., Balarabe, M. L., & Gadzama I. M. K. (2016). Assessment of some heavy metals in macrobenthic invertebrate and water samples collected from Kubanni reservoir, Zaria, Nigeria. *Federal University Wukari Trends in Science and Technology Journal*, 1(1), 55-60

Bolden, A. L., Rochester, J. R., Schultz, K., & Kwiatkowski, C. F. (2017). Polycyclic aromatic hydrocarbons and female reproductive health: A scoping review. *Reproductive toxicology (Elmsford, N.Y.)*, *73*, 61–74

Borges, C. V., Maraschin, M., Coelho, D. S., Leonel, M., Gomez, H. A. G., Belin, M. A. F., ... & Lima, G. P. P. (2020). Nutritional value and antioxidant compounds during the ripening and after domestic cooking of bananas and plantains. *Food Research International*, *132*, 109061.

Boris, N. T. J., Laurette, N. N., & Modestine, K. S. M. (2023). Plantain (Musa paradisiaca L.): Production, Consumption and Processing in Cameroon. *American Journal of Food Science and Technology*, *11*(1), 8-14.

Burchiel, S. W., & Gao, J. (2014). Polycyclic aromatic hydrocarbons and the immune system. *Encyclopedia Immunotoxicology*. ed Vohr H-W. Berlin: Springer

Dan-Jumbo D., Saronee F., Azosibe P., Amadi J. E., Gbaranor K. B. (2024). Changes in Biochemical Indices in Lead-Induced Toxicity Following Administration of Methanolic Extracts of Curcuma longa Rhizomes and Cucumis sativus Fruits. Res Bio Sci. 7 (8); 36-44. Doi; 10.5281/zenodo.13898404

De Langhe, E., Perrier, X., Donohue, M., & Denham, T. P. (2015). The original banana split multi-disciplinary implications of the generation of African and Pacific plantains in island Southeast Asia. *Ethnobotany Research and Applications*, *14*, 299-312.

Dixon, R. A., Achnine, L., Kota, P., Liu, C. J., Reddy, M. S., & Wang, L. (2002). The phenylpropanoid pathway and plant defence a genomics perspective. *Molecular Plant Pathology,* 3(5), 371-390.

Ighodaro, O. M. (2012). Evaluation study on Nigerian species of Musa paradisiaca peels. *Researcher*, *4*(8), 17-20.

Kumar, S., Pandey, A. K., & Pandey, A. (2016). Chemistry and biological activities of flavonoids: An overview. *The Scientific World Journal,* 2013.

Kumari, A., Upadhyay, V., & Kumar, S. (2023). A critical insight into occurrence and fate of polycyclic aromatic hydrocarbons and their green remediation approaches. *Chemosphere*, 138579.

Lee, B. K. (2011). Sources, distribution and toxicity of polyaromatic hydrocarbons (PAHs) in particulate matter. In *Air pollution*. IntechOpen, 99–122.

Martí-Cid, R., Llobet, J. M., Castell, V., & Domingo, J. L. (2008). Evolution of the dietary exposure to polycyclic aromatic hydrocarbons in Catalonia, Spain. *Food and Chemical Toxicology*, *46*(9), 3163-3171.

Rengarajan, T., Rajendran, P., Nandakumar, N., Lokeshkumar, B., Rajendran, P., & Nishigaki, I. (2015). Exposure to polycyclic aromatic hydrocarbons with special focus on cancer. *Asian Pacific Journal of Tropical Biomedicine*, *5*(3), 182-189.

Saronee, F., Amah-Tariah, F. S., Chinko, B. C., & Dapper, D. V. (2023). Ameliorative effects of the hydromethanol leaf extract of Craterispermum schweinfurthii on phenyl hydrazine induced anemia in male Wistar rats. International Journal of Recent Research in Life Sciences, 10(3), 19-25. DOI: https://doi.org/10.5281/zenodo.8176890.

Saronee, F., Bekinbo, M. T., Ojeka, S. O., & Dapper, D. V. (2019). Comparative assessment of methanolic extracts of hog plum (Spondias mombin Linn.) leaves and turmeric (Curcuma long L.) rhizomes on blood glucose and glycosylated haemoglobin in male Wistar rats. Journal of Applied Science and Environmental Management, 23(9), 1631-1636. DOI: https://dx.doi.org/10.4314/jasem.v23i9.4

Saronee, F., Dan-jumbo, D., & Azosibe, P. (2024). Aphrodisiac properties of Craterispemum schweinfurthi Leaf Extract in Lead Induced Testicular Toxicity in Male Wistar Rats. Journal of Applied Science and Environmental Management, 28(5), 1513-1518. DOI: https://dx.doi.org/10.4314/jasem.v28i5.23.

Saronee, F., Dan-Jumbo, D., Azosibe, P., & Amadi, J. E. (2024). Modulatory Functions of Craterispermum schweinfurthi on the Hypothalamic-Pituitary Gonadal Axis of Male Wistar Rats in Phenyl Hydrazine Induced Testicular Toxicity. Journal of Complementary and Alternative Medical Research, 25(4), 31-39. DOI: 10.9734/JOCAMR/2024/v25i4530.

Saronee, F., Sunday, O. O., Okekem, A., Ogadinma, N. I., & Datonye, V. D. (2020). Comparative Study of the Effects of Methanolic Extracts of Spondias mombin Leaves and Curcuma longa Rhizomes on Serum Lipid Profile and Electrolytes in Alloxan Induced Diabetes in Male Wistar Rats. Asian Journal of Advanced Research and Reports, 8(3), 1- 9. DOI: 10.9734/AJARR/2020/v8i330198.

Singh, B., Singh, J. P., Kaur, A., & Singh, N. (2008). Bioactive compounds in banana and their associated health benefits–A review. *Food chemistry*, *206*, 1-11.

World Health Organization and Food and Agriculture Organization (2024). Conference Outcome Document: Rome Declaration on Nutrition. Second International Conference on Nutrition. FAO and WHO, Rome. www.fao.org/3/a-m/542e.pdf.

Zheng, S., Wang, Q., Yuan, Y., & Sun, W. (2020). Human health risk assessment of heavy metals in soil and food crops in the Pearl River Delta urban agglomeration of China. *Food chemistry*, *316*, 126213.