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Lignocellulosic and Bioactive Composition of Banana Peels for Pharmacological Applications

Bassey Edem Nyong[1]; Alice Ndem Etim[1]; Esther Offiong Asuquo[1*]; Ifiok Eni Enyong[2] Endurance Egwu Ukam[3]

[1]Department of Chemistry, Faculty of Physical Sciences,
University of Cross River State.
Email: marknyong@gmail.com; aliceetim56@gmail.com; estheroffiong@gmail.com
[2]Department of Pure and Applied Chemistry, Faculty of Sciences,
University of Calabar.
Email: ifiokenyony2017@gmail.com
[3]Department of Biochemistry, Faculty of Physical Sciences,
University of Cross River State. Email: rexukam@gmail.com
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Abstract

The antioxidant potential, Phytochemicals, and lignocellulosic composition of fresh and dry banana peels were investigated to deduce the bioactive ingredients in banana peels and explore their potential uses and also to determine if banana peels could be an excellent natural source of antioxidants among other health-promoting substances. The methanol extract of the banana peels was exposed to different phytochemical tests and lignocellulosic content analysis using the standard method. The research revealed that phytochemicals were higher in the fresh banana peels than in the dried ones while the lignocellulosic contents were higher in dried banana peels than the fresh ones. Phytochemicals present include flavonoids, cyanogenic glycosides, quinones, coumarines, alkaloids and saponins while phenols, phlobatanins, steroid, terpenoid, tannins, and anthraquinones were not detected. Cyanogenic glycoside, alkaloid, flavonoid and saponins were 34.0 ± 0.04, 49.0 ± 0.12, 56.0 ± 0.05, 28.0 ± 0.16 and 27.1 ± 0.17, 44.0 ± 0.07, 52.0 ± 0.13, 24.0 ± 0.02 in fresh and dried banana peels respectively. Similarly, lignin, cellulose, hemicellulose contents was 5%, 15%, 3.8% and 23.4%, 67.6%, and 45.6% in the fresh and dried banana peels respectively. Plants possess antioxidant and antibacterial characteristics due to flavonoids, lignin, saponins, phenols, and alkaloids, all of which are identified in the current study. These findings suggest that dried banana peels, are abundant in phytochemicals, antioxidants, and lignocellulosic components, which could be significant in improving human health and disease prevention as well as serve as a useful raw material in the packaging, paper and biofuel industry.

Keywords: *Lignocellulose; antioxidants; banana peels; pharmacology*

INTRODUCTION

Lignocellulose consist of three biopolymers namely: hemicellulose, lignin, and cellulose[1]. Cellulose is the primary constituent of lignocellulose, accounting for about 35-50% of plant cell walls[2]. Cellulose is extensively used in the textiles, food, paper, and bioplastics industries. For example, cellulose fibers can be extracted from plant waste and used to reinforce bioplastics, which can provide a renewable substitute to petroleum-based plastics[3]. Lignin, on the other hand, is a component of lignocellulose, which is a complex aromatic polymer is present plants' cell walls. While it gives rigidity and strength to plant cell walls, it also serves as a protective barrier against pathogens and environmental stresses[4]. Lignin can be extracted from plant waste and used as a renewable source of energy for bio-based chemicals[5]. Hemicellulose, the third major component of lignocellulose, is a branched heteropolysaccharide made up of different sugars, including xylose, mannose, and arabinose[6]. It provides flexibility and elasticity to plant cell walls. Hemicellulose has numerous potentials in the manufacture of bio-based adhesives, bioplastics, and biofuels[7].

Lignocellulosic biomass refers to plant-derived materials that are made up of hemicellulose, and lignin and cellulose. These materials are abundant, renewable, and widely available from various agricultural and forestry residues, as well as municipal solid waste. Some common sources of lignocellulosic biomass include: corn stover, wheat straw, rice husks, wood chips, sawdust, bark, and banana peels, etc.

Banana is known as Ekobuekuwan in Mbube, Ogoja LGA of Cross River State. It is consumed domestically with rice, groundnut, blended as smoothies, used in fruit salad etc. In industries, banana is used to make butter, bread and some baby food formulations. Banana peels (a waste generated after banana is consumed), are abundant and underutilized by-product of the banana industry. Despite being thrown away as garbage, they are excellent sources of lignocellulosic components, antioxidants, and phytochemicals.

Phytochemicals are plant-based chemicals with beneficial effects on human health. They exist naturally in fruits, grains, vegetables, and other plant-based foods[8]. A variety of phytochemicals, including phenolic acids, flavonoids, alkaloids, saponins, and terpenoids have been identified in banana peels[9]. The medicinal potentials of these chemicals have been reported including antimicrobial, antioxidant, anti-inflammatory, and anticancer properties[9]. Banana peels have also been found to contain higher levels of antioxidants than the fruit itself[11].

Although banana (*Musa Spp.*) fruit is widely consumed globally, but its peels is often discarded as waste. This waste stream has been found to contain a wealth of phytochemicals, antioxidants, and lignocellulosic materials that could be utilized for various applications that contribute to the environmental population. Hence, this research aims to examine the chemicals present in the fresh and dried peels of banana.

METHODOLOGY

Collection and Treatment of samples

Banana (*Musa Spp.)* peels was collected from a local fruit salad vendor in Calabar South, Nigeria. These samples were divided into two groups namely fresh (FBP) and dried banana peels (DBP). The fresh banana peels were cleaned with distilled water to remove any contaminants, then sliced into little pieces, blended to pulp with a kitchen blender, poured into airtight bags and refrigerated to maintain freshness and prevent contamination.

Dried banana peels were prepared by oven-drying the fresh banana peels for 24 hours at 60°C. The oven-dried banana peels were then pulverized and stored in airtight containers for further analysis.

Extraction Procedure

The fresh and dried banana peel samples were extracted with methanol using a Soxhlet apparatus for 6 hours. The extracts were then filtered and concentrated to obtain a crude extract.

Qualitative Phytochemical Screening

The extracts of fresh and dried banana peels were analysed for alkaloids, tannins, saponins, anthraquinones, glycosides, steroids, flavonoids, terpenoids, phlobatanins, quinones, coumarins, and phenols, using AOAC standard procedures.

Quantitative phytochemicals screening

Determination of Cyanogenic glycosides: A 250 cm^3 round-bottom flask was filled with precisely 2 grams of the sample, and one gram of each sample was mixed with 200 cm^3 of distilled water. The flask was then left to stand so that autolysis could take place. After adding an antifoaming agent (tannic acid), 50 ml of a 0.02 M solution of NaCN and 50 ml of a 0.1 M solution of NaOH were added to the sample. Full distillation was then performed in the 250 cm^3 conical flask. A micro-burette was used to titrate the resultant solution with standard $AgNO_3$ solution on a black background after precisely 25 milliliters of it had been pipetted into a beaker containing 2 milliliters of 6 M NH_4OH and 1 milliliter of 10% KI. The terminus is indicated by continuous turbidity. Equation 1 was used to determine the sample's cyanogenic glycoside content.

$$cyanogenic\ glycoside\ \left(\frac{mg}{100g}\right) = \frac{titre\ value\ (cm^3)\ \boldsymbol{X}\ 1.08\ X\ extract\ volume\ X\ 100}{aliquot\ volume\ (cm^3)\ X\ sample\ weight\ (g)} \qquad \textbf{(Eqn. 1)}$$

Determination of Alkaloids: Each sample (2.50 g) was placed in a 250 cm^3 beaker with exactly 200 cm^3 of acetic acid in ethanol, and it was let to stand for 4 hours. After reducing the extract's volume by one-quarter on a water bath, 15 drops of concentrated ammonium hydroxide were added to the extract dropwise till the precipitation was finished right away after filtering. Following three hours of mixed sedimentation, the precipitates were cleaned with 20 cm^3 of ammonium hydroxide and filtered through Whatman filter paper number 42 (125 mm), discarding the supernatant. The residue was dried in an oven using an electronic weighing scale (Drawell), and the percentage of alkaloid is expressed using Equation 2:

$$Alkaloid\ (\%) = \frac{weight\ of\ residue}{weight\ of\ sample}\ X\ 100 \qquad \text{(Eqn. 2)}$$

*Determination of Flavonoid***:** 2.50g of the sample was placed in a 250 cm^3 beaker, filled with precisely 50 cm^3 of aqueous methanol, covered, and left to stand at room temperature for a whole day. The residue was extracted three times using the same volume of ethanol after the supernatant was discarded. The entire solution of every sample was filtered using Whatman filter paper number 42 (125 mm). After that, each sample filtrate was placed in a crucible and dried over a water bath. After cooling in a desiccator, the contents of the crucible were weighed until a consistent weight was reached. Using Equation 3, the proportion of flavonoid was determined.

$$Flavonoid\ (\%) = \frac{weight\ of\ crucible}{weight\ of\ sample}\ X\ 100 \qquad \text{(Eqn. 3)}$$

Determination of Saponin: In a 250 cm^3 conical flask containing 2.5 grams of each powder sample, precisely 100 ml of aqueous ethanol was added. At 55ºC, the mixture was heated over a hot water bath while being constantly stirred. After filtering, the mixture's residue was heated to a constant temperature of 55ºC while being constantly stirred. It was then extracted again using an additional 100 cm3 of aqueous ethanol. At 90 degrees Celsius, the mixed extract evaporated over a water bath. After adding 20 cm^3 of diethyl ether to the concentrate in a 250 cm^3 separator funnel and agitating it strongly, the ether layer was disposed of and the aqueous layer was recovered. There were two iterations of this cleansing procedure. After adding 60 cm^3 of n-butanol, the mixture was extracted twice using 5% sodium chloride. The leftover solution was heated in a water bath for thirty minutes after the sodium chloride layer was discarded. It was then put into a crucible and dried in an oven to a consistent weight. Equation 4 was used to compute the saponin content.

$$Saponin\ (\%) = \frac{weight\ of\ crucible}{weight\ of\ sample}\ X\ 100 \qquad \text{(Eqn. 4)}$$

Lignocellulosic composition

Determination of Lignin: The samples' compositions of lignin, cellulose, and hemicellulose were ascertained using the methodology of (Ververis, 2004). A 5-gram sample was boiled for two hours with 10 milliliters of 18 M H_2SO_4 solution to hydrolyze the cellulose and hemicelluloses. Following the aforementioned treatment, the suspension was filtered through a crucible, and the solid residue was dried for two hours at 105ºC before being weighed (W_1). The residue was subsequently moved into a dry porcelain crucible that had been pre-weighed, and it was heated for an hour at 100ºC. It was reweighed (W_2) after cooling. Equation 5 was used to determine the lignin content.

$$\text{Lignin} = W_1 - W_2 \qquad \text{(Eqn. 5)}$$

Determination of Cellulose and Hemicelluloses: The ground sample (5g) was put into the extraction unit after being filled with petroleum ether in an extraction thimble of a Soxhlet extractor. For six hours, this was cooked while refluxing. After that, a rotary evaporator was used to evaporate the ether. After the defatted sample cooled, it was boiled in an 80% methanol solution, let cool, and then filtered. Following the filtration process, the methanol solvent was evaporated,

and the soluble component was weighed and labeled C_1, while the residue was also weighed and labeled C_2. Equation 6 was then used to determine the cellulose content of the samples based on these findings.

$$\text{Cellulose content } (\%) = \frac{0.9}{0.96} \text{ X } C_1 \frac{\text{V}}{\text{M}} \text{ X } 100 \qquad \text{(Eqn. 6)}$$

Where: 0.9 =the coefficient that results from the molecular weight ratio of the polymer and the monomer hexose; 0.96 = the monosaccharide yield; C_1= the glucose concentration (mol/dm^3); V= the total volume of sugar solution (C_1 + C_2); M = the dry weight of the samples (g)

The hemicelluloses content was then calculated using Eqn. 7

$$\text{Hemicellulose}(\%) \frac{0.88}{0.93} \text{X}(C_1 - C_2) \text{ X } \frac{V}{M} \text{X } 100 \qquad \text{(Eqn. 7)}$$

Where 0.88 = the coefficient that results from the molecular weight ratio of the polymer and the monomer pentose; 0.93 = the conversion yield of xylane to xylose; C_1= the glucose oncentration (g); C_2= the determined reducing sugar concentration (g); V = the total volume of sugar solution (g); M = the dry weight of the defatted sample.

RESULTS AND DISCUSSION

PHYTOCHEMICAL COMPOSITION

The secondary metabolites present in the methanolic extract of fresh banana peels (FBP) and dried banana peels (DBP) is presented in Table 1. Results showed the presence of flavonoids, glycosides, quinones, coumarins, alkaloids, and saponins while phenols, phlobatanins, steroids, terpenoids, tannins, and anthraquinones were not detected in both samples.

Table 1: Secondary metabolites present in banana peels

	FBP	DBP
PHYTOCHEMICALS		
Flavonoid	±	±
Cyanogenic glycoside	±	±
Phenol	n.d	n.d
Quinones	±	±
Phlobatanins	n.d	n.d
Coumarines	±	±
Steroid	n.d	n.d
Terpenoid	n.d	n.d
Alkaloid	±	±
Saponin	±	±
tannins	n.d	n.d
Anthraquinones	n.d	n.d

Note: (±) present; (n.d) Not detected

Phenol, and polyphenols such as phlobatanins, and tannins, which could act as antinutrients if consumed in excess, were not detected in the methanol extract of FBP and DBP used in this study. This result contrast slightly with the findings of other researchers[12-16]. It could be seen that the secondary metabolites discovered in the peels of banana greatly depend on the solvent used for extraction and the kind of extraction method used. Table 2 summarises the active ingredients present in banana peels with respect to different solvents used.

Table 2: Secondary metabolites present in banana peels with respect to type of solvent used

PHYTOCHEMICALS	**Methanol**	**Ethanol**	**Aqueous**	**Acetone**	**Dimethyl Sulfoxide (DMSO)**
Flavonoid	+	+	+	+	+
Cyanogenic glycoside	+	-	+	n.d	+
Phenol	n.d	-	-	+	n.d
Quinones	+	n.d	-	-	-
Polyphenols	-	n.d	-	-	-
Monoterpenoids	-	n.d	-	-	-
Phlobatanins	n.d	-	n.d	-	-
Coumarines	+	-	-	-	-
Steroid	n.d	n.d	-	n.d	+
Terpenoid	n.d	n.d	-	+	+
Alkaloid	+	n.d	+	+	n.d
Saponin	+	n.d	n.d	+	-
tannins	n.d	+	+	+	+
Anthraquinones	n.d	-	-	n.d	-
Sesquiterpens	-	+	-	-	-
References	Present study	Kusuma *et al* (2018)[12].	Olakunle *et al* (2019)[13]	Kibria *et al* (2019)[14]	Bashir *et al* (2021)[15]

Note: (+) present; (n.d) Not detected; (-) not tested

However, from Table 2, all the extract gave positive results for Flavonoids. This indicates that the antioxidant property of banana peels can be assessed irrespective of the solvent used. Other antioxidant compounds such as alkaloids and saponins, were also present in this study. Steroids, particularly phytosterols can act as antinutrients leading to the reduced absorption of fat-soluble vitamins (A, D, E and K). Steroids were not detected in all tests except for acetone solvent. This makes banana peel majorly safe for pharmacological applications. Again, all the other solvents used showed positive result for tannins except for methanol (present study), this could be attributed to the fact that different variety of bananas contain varying levels and types of phytochemicals.

Table 3 shows that quantity of alkaloids, flavonoids, saponin, and cyanogenic glycoside present in the fresh and dried peels of banana. From the results, the fresh peels appeared to have higher amount of the metabolites than the dried peels. This may be due to high percent of moisture, active enzymes, volatile compounds in the fresh peels which helps to preserve the delicate phytochemicals. The dried peels were prepared using oven-drying method. Oven-drying can lead to water loss, evaporation of volatile compounds and deactivation of enzymes, causing phytochemicals to degrade or break down.

Table 3: Total Cyanogenic glycoside, **Alkaloid**, **Flavonoid and Saponin present in the methanol extract of banana peels.**

PHYTOCHEMICALS	DBP (mg/g)	FBP (mg/g)
Cyanogenic glycoside (%)	27.1 ± 0.17	34.0 ± 0.04
Alkaloid (%)	44.0 ± 0.07	49.0 ± 0.12
Flavonoid (%)	52.0 ± 0.13	56.0 ± 0.05
Saponin (%)	24.0 ± 0.02	28.0 ± 0.16

FBP: Fresh banana peel, DBP: Dry banana peel

Cyanogenic glycosides are plant compounds that can cause cyanide toxicity when ingested and metabolized in high doses. They are composed of a sugar molecule and a cyanide-containing aglycone. When the plant is damaged or ingested, enzymes break down the glycoside, releasing cyanide which can lead to cyanide poisoning, respiratory failure, cardiac arrest, headache, dizziness, etc. They are found in various plants such as cassava, bitter almonds, apricot kernels, apple seeds, sorghum, etc. Cyanogenic glycosides were 27.1 and 34.0 mg/g in DBP and FBP respectively. Hence, banana peels should be heat-processed to reduce the level of cyanogenic glycosides.

Alkaloids are well known for their pharmacologic properties such as anti-bacterial, anti-inflammatory, and analgesics[17]. The presence of alkaloids in banana peels suggests their potential usefulness in the development of pharmaceutical and nutraceutical products[18]. The present study revealed alkaloid content of 44.0 and 49.0 mg/g for DBP and FBP respectively. As a lignocellulosic biomass, the alkaloid content of banana peels is higher than 24.3 mg/g present in methanol extract of sponge gourd-*luffa aegyptica*[17].

Similarly, flavonoids are compounds of phenols with remarkable anti-inflammatory, antioxidant, and antimicrobial properties[19]. The flavonoid content was slightly higher in the FBP samples at 56.0% compared to the DBP samples at 52.0%. These values are relatively higher than 8.56 mg/g in aqueous extract; 21.04 mg/g in 80% methanol extract, 18.52 mg/g in 80% ethanol extract and 16.15 mg/g in 80% acetone extract of dried banana peels[16].

The presence of saponins is an indication that the plants possess the property of triggering and clotting red blood cells[17]. Saponins are glycosides with a characteristic soapy-like property and have been associated with various biological activities, including anti-inflammatory, antimicrobial, and cholesterol-lowering effects[20]. The saponin content was also higher in the FBP

samples at 28.0% compared to the DBP samples at 24.0%. These values are higher than 10 mg/g present in methanol extract of sponge gourd-*luffa aegyptica*[17].

Table 4 presents the lignocellulose (lignin, cellulose and hemicellulose) composition of fresh and dried banana peels. All three compounds were extremely higher in the dried peels as compared to the fresh peels. This could be a result of moisture content and other soluble compounds which upon drying, evaporate, leaving the concentrated compounds. High amounts of lignocellulosic compounds are an indication that banana peels may have useful applications in the pulp and paper, biofuel and textile industries.

Table 4: Result for lignocellulosic composition of fresh and dry banana peels

Parameters	FBP	DBP
Lignin (g/mg)	5	23.4
Cellulose (g/mg)	15	67.6
Hemi-cellulose (g/mg)	3.8	45.6

FBP: Fresh banana peel, DBP: Dry banana peel

Cellulose is a long-chain glucose-polysaccharide that gives strength, rigidity, and structure to plant cell walls. The cellulose content of dried banana peels was satisfactory (67.6 mg/g higher than 40%). According to the rating system described by[21], from a chemical structure perspective, plant sources with cellulose concentrations equal to or more than 34 mg/g are described as excellent for the production of paper/pulp. Cellulose has numerous applications in the manufacture of bioplastics, and various bio-chemicals/products[22].

Lignin is a complex biopolymer composed of phenolic units. It acts as a glue to hold cellulose fibers together while also providing rigidity, strength, and resistance to decay. Lignin contents of dried banana peels were also at satisfactory levels (23.4 mg/g lesser than 30%) In practice, dried banana peels require softer pulping conditions (lower temperatures and chemical charges) than softwoods and hardwoods to get a desirable kappa value. It also implies that the material can be bleached more easily and with fewer chemicals than required for the manufacture of paper. Lignin is known for its antioxidant properties and has potential applications in the development of value-added products, such as biofuels, bio-based chemicals, and materials[23].

Hemicellulose is a shorter-chain polysaccharide composed of various sugar units (xylose, arabinose, galactose, etc) and acts as a bridge between cellulose and lignin while providing flexibility and hydration to plant cell walls. The hemicellulose content of dried banana peels in this study was 45.6 mg/g. This is an indication that dried banana peels may have notable industrial applications in paper production, jams/jellies, capsule formulations, biodegradable plastics, biofuels, cosmetics, flocculants in water treatment and wound dressings, etc.

Antioxidants play a crucial role in the human body by neutralizing free radicals, reducing oxidative stress, and protecting cells from damage. This can have far-reaching implications for human health, as oxidative stress is a contributing factor to various chronic diseases, such as cancer,

cardiovascular diseases, neurodegenerative disorders, and diabetes[24]. Antioxidant potentials of banana peels is linked to the compounds present in it (FIG. 1)[16].

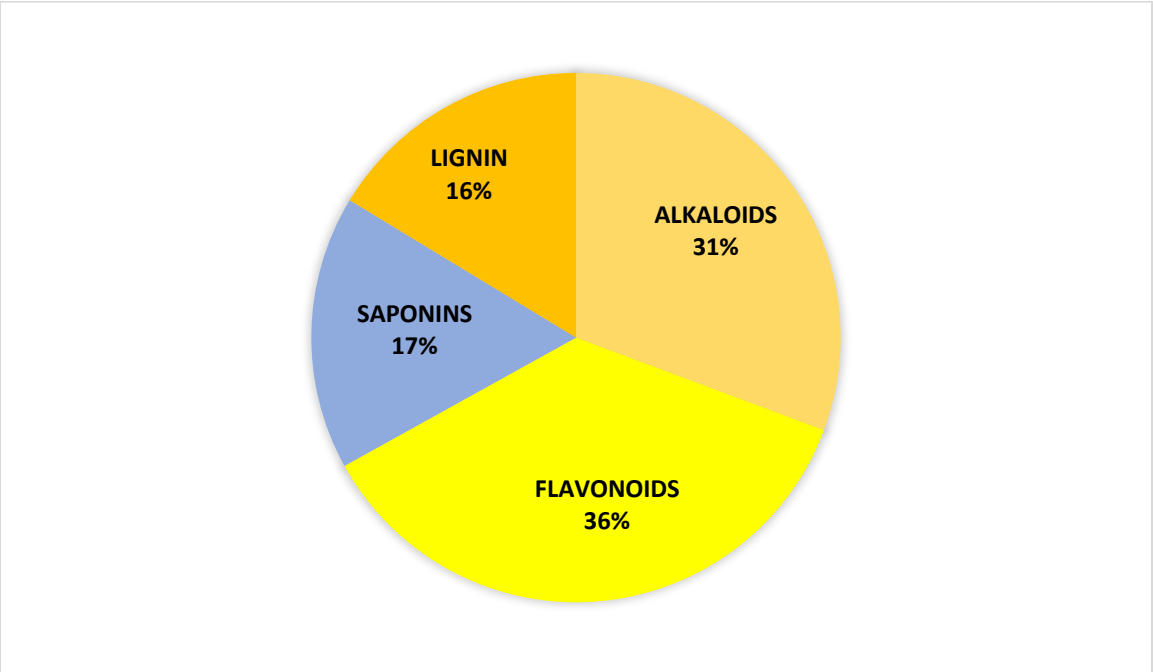

FIG. 1: some antioxidant compounds present in dried banana peels

Alkaloids protect body cells from damage caused by free radicals. Flavonoids can help protect the body against oxidative stress, reduce inflammation, and exhibit antimicrobial effects, making them valuable for healthcare and food applications. Saponins can bind to metal-ions such as copper and iron, which can catalyze oxidative reactions. Lignin and hemicellulose can donate hydrogen atoms to stabilize free radicals. The antioxidant and antimicrobial properties of plants are because of flavonoids, lignin, saponins, phenols and alkaloids and these are also detected in the present work.

CONCLUSION

Antioxidants protect the body from free radical damage and have been associated to a lower risk of chronic diseases such as cancer and heart disease. In addition to the phytochemicals and antioxidants, the structural components of banana peels, such as cellulose, hemicellulose, and lignin, can be valuable materials for various applications. To further develop this potential, it is recommended to isolate and characterize the bioactive compounds responsible for the antioxidant activity. This will help to understand their properties and potential uses. The lignocellulosic components of banana peels, comprising cellulose, hemicellulose, and lignin, can be leveraged for the production of biobased materials, biochemicals, and biofuels, contributing to the circular economy. Given all the medicinal importance associated with the phytochemicals found in banana (*Musa spp)* peels, further investigation should be carried out on the diversity of chemical constitutions and levels of toxicity.

Conflict of Interest

The authors state that the study was done without any commercial or financial links that could be seen as a possible conflict of interest.

Author Contributions

Conceptualization, E.O.A; methodology, E.O.A; formal analysis, E.O.A and I.E.E; writing—original draft preparation, E.O.A, I.E.E and E.E.U; writing—review and editing, I.E.E and E.E.U. All authors have read and agreed to the published version of the manuscript.

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