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Nutrient Composition and Techno-functional Properties of Three Nigerian Spices and Sensory Acceptability of Traditional Dishes

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Abstract: This study evaluated the functional and micronutrient properties of *Piper guineense* (uziza), *Xylopia aethiopica* (Guinea pepper), and *Tetrapleura tetraptera* (Aidan fruit) spices and also assessed the level of acceptability of the dishes prepared using these spices. The spices were processed before determining the functional, vitamin, mineral, and sensory properties. The results show that the oil absorption capacity, foam capacity, and gelation capacity of the samples ranged from 1.94 – 2.39%, 13.56 – 10.78 g/mL, and 8.45 – 6.00 g/mL, respectively. *Piper guineense* was significantly higher in water absorption capacity (2.27%), bulk density (0.52 mg/100g), and swelling index (1.87 g/mL). Gelatinization temperature ranged between 58.73 °C (*Tetrapleura tetraptera*) and 62.45 °C (*Xylopia aethiopica*). *Piper guineense* had higher levels of Calcium (283.72 mg/100g), Phosphorus (249.96 mg/100g), and Iron (6.34 mg/100g). *Xylopia aethiopica* had higher values for Magnesium (170.55 mg/100g), Copper (1.44 mg/100g), Manganese (2.39 mg/100g), and Zinc (3.83 mg/100g). The vitamin B_1 content of the samples ranged from 0.02 (*Piper guineense*) – 0.03 (*Xylopia aethiopica* and *Tetrapleura tetraptera*) mg/100g. The vitamin B_2 content of samples ranged from 0.02 – 0.03 mg/100g. The vitamin B_{12} content of the samples ranged from 0.28 (*Piper guineense*) – 0.33 (*Xylopia aethiopica*) mg/100g. The vitamin C content of *Piper guineense* (1.84 mg/100g) was higher than that of the other samples. The vitamins A and E contents ranged from 8.27 – 9.58 µg/100g and 0.85 – 1.72 mg/100g, respectively. *Tetrapleura tetraptera* was the highest, while *Xylopia aethiopica* was the lowest. There were variations in the sensory score of the dishes prepared with these spices. Nigerian traditional spices are underexploited despite their culinary significance. This study addressed the knowledge gap on their functional and micronutrient profiles to promote utilization and nutritional benefits. These findings can optimize the use of spices in Nigerian cuisine, enhance food product development, and promote nutritional benefits.

Keywords: Spices; *Piper guineense*; *Xylopia aethiopica*; sensory evaluation; traditional Nigerian foods.

1. Introduction

Plants are known sources of a great category of bioactive chemical substances that function as biochemical and physiological agents in the body, and spices represent a class of plants with such effects

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[1]. Spices refer to the dried part of a plant that contains volatile oils or aromatic flavours. They are food adjuncts commonly added to foods to improve their sensory properties. They can come in various forms: whole, ground, or as an extract, depending on the processing method. They are used in small quantities to flavour dishes and tend to add few calories to food. Spices contribute a wide range of nutrients and bioactive components to foods [2]. The bulk of the major components of spice materials consist of carbohydrates, proteins, minerals, and phytochemicals [3]. Vitamins and minerals are vital substances needed by the body to perform daily functions properly. These essential substances in spices are crucial for boosting the immune system and supporting the body's metabolic processes [2]. Spices contain vitamins, which are organic substances needed in small amounts by humans, that can help protect cells from oxidative damage. These molecules can scavenge free radicals, thus keeping the balance between oxidation and anti-oxidation [4]. They also contain minerals, which are inorganic substances needed in small amounts by humans for normal growth and development [2]. Mineral elements contained in medicinal plants are very important in human nutrition in alleviating micronutrient deficiencies [5].

As a member of the *Annonaceae* family, *Xylopia aethiopica* (Guinea pepper) is widely used as a spice in African cuisines and traditional medicine. It has essential minerals, contributing to the plant's nutritional value and potential health benefits [6]. Significant amounts of minerals, including calcium, potassium, magnesium, and zinc, have been discovered in some plant parts [7]. *X. aethiopica* is a useful dietary supplement because these minerals are necessary for strong bones, the growth of muscles, and other metabolic processes. According to studies, *X. aethiopica* has vitamins A, C, and E, which increase its nutritional value and antioxidant capacity [8]. The vital roles these vitamins play in cellular metabolism, oxidative defense, and immunological function further augment the nutritional value of *X. aethiopica*. The immune system, antioxidant defense, and metabolic processes all depend on these trace minerals. The iron-rich *X. aethiopica* seeds have been shown by research [9] to be beneficial in treating iron-deficiency anemia.

Piper guineense (uziza) a well-known culinary and medicinal herb, is a member of the *Piperaceae* family and is found across West Africa. It is a staple spice in many traditional recipes and has a unique peppery taste [10]. Depending on the plant component studied, different proportions (leaves, seeds, or fruits) were reported [11]. The amount of carbohydrates, proteins, and fibre in various plant components ranged from 30% to 50%, 10% to 20%, and 5% to 15%, respectively [12]. Vitamin A (as β-carotene), vitamin C, riboflavin (B2), and niacin (B3) were identified in high amounts in *Piper guineense* [13]. The leaves and seeds contain significant levels of calcium and potassium [14]. *Piper guineense* also contains trace minerals in varied amounts, including iron, zinc, and copper. These minerals are essential to many different metabolic processes. *Piper guineense's* leaves and seeds exhibit significant concentrations of certain trace minerals [15]. Because these minerals are essential for bone health, muscle activity, and some metabolic functions, *Piper guineense* is a valuable dietary supplement.

Tetrapleura tetraptera (Aidan fruit) is a perennial, single-stemmed plant belonging to the family of *Mimosaceae* [16]. The dry fruit shell, fruit pulp, and seed of *T. tetraptera* were examined for nutritional quality and were found to contain varying amounts of nutrients, including protein, lipids, vitamins, and minerals, which were comparable in content or even higher in content than more popular spices such as red pepper, onion, curry, and ginger [17]. These spices are used in preparing local drinks such as zobo, kunu, and pineapple drinks in Nigeria [3].

Nigerian traditional spices, *Piper guineense* (uziza), *Xylopia aethiopica* (Guinea pepper), and *Tetrapleura tetraptera* (Aidan fruit), are widely used in local cuisine, but their nutritional profiles remain undocumented, limiting their utilization. Existing studies focus on individual spices, but comprehensive data on their functional, vitamin, and mineral composition are lacking. This knowledge gap hinders their optimization in food product development and nutritional enhancement. Since food composition influences sensory attributes and acceptability, this study evaluates the functional, vitamin, and mineral properties of these spices and assesses the acceptability of prepared dishes, providing insights into their culinary value and nutritional benefits. Findings will promote their utilization and enhance dietary diversity. Therefore, this study was conducted to determine the functional, vitamin, and mineral properties of *Piper guineense*, *Xylopia aethiopica*, and *Tetrapleura tetraptera*, and to assess the acceptability of dishes prepared with these local spices.

2. Materials and Methods

2.1. Source of Raw Materials

Freshly dried seeds of *Piper guineense*, *Xylopia aethiopica*, and the dried pods of *Tetrapleura tetraptera* were bought from Ubani main market in Umuahia North Local Government Area of Abia State, Nigeria, between 20th and 24th January, 2025, and were identified at Project Development Institute PRODA, Enugu, Nigeria.

2.2. Sample Preparation

Samples were sorted to remove dirt and unwholesome ones and then washed in water, oven dried at 55°C for 6 hours in a hot air oven (model: KZ 760 4SS China) and milled using a mechanical blender {model: BLG-595(MK2) China} according to the method of Enyi et al. [18] and stored in air tight container until needed for analysis.

2.3. Determination of Mineral Contents

The magnesium, iron, copper, calcium, phosphorus, manganese, and zinc contents of the samples were determined using the method described by AOAC [19]. A diacid mixture, consisting of 2 parts nitric acid and one part perchloric acid, was used to digest 2 g of each sample. The digested samples were recovered and transferred to a volumetric flask (100 ml), and distilled water was used to make it up to the volume. The samples and element standards were analyzed using an atomic absorption spectrophotometer (AAS) (Thermo Fisher iCE FIOS Atomic Absorption Spectrometer). The concentrations of respective elements were also determined.

2.4. Determination of Vitamin Contents

Thiamine (B_1) was determined and calculated using the method described by Okwu and Josiah [20]. Two (2 g) of the sample was ground in a mortar and 75 mL of 0.2N HCl was added. It was heated in a water bath for 30 minutes and cooled. Five (5 mL) of enzyme solution was added and incubated at 37℃ overnight. The material was placed in a 100 mL flask and made up with water. It was filtered, and the filtrate purified by passing through a silicate column. Five (5 mL) of acidic KCl, 3 mL of alkaline Ferricyanide solution, and 15 mL of isobutanol were added to a conical flask and shaken for 2 minutes. It was allowed to separate, and the alcohol layer was taken. Three (3 g) of anhydrous Na_2SO_4 was added to the isobutanol extract, and 5 mL of thiamine solution was taken to another flask. Oxidation and extraction of thiochrome from the sample were carried out. The sample and standard blank were prepared, and 5 mL from each was taken. Three (3 mL) of 15% NaOH was added. The Flourimeter was set at an excitation wavelength of 360 nm and an emissive wavelength of 435 nm. The instrument was adjusted to zero deflection with 0.1N H_2SO_4 against the standard. The flourimeter was read with the sample and the blank. Thiamine was calculated as:

$$\text{Thiamin (mg/100g)} = \frac{100}{\text{W}} \times \frac{Au}{As} \times \text{C} \times \frac{V_f}{V_a} \times \text{D}$$

W = weight of sample, Au = absorbance of the test sample, As = absorbance of standard solution, V_f = total volume of filtrate, V_a = volume of filtrate analyzed, C = concentration of standard, D = dilution factor, where applicable.

Riboflavin (B_2) was determined and calculated using the method described by Onwuka [21]. The sample was ground, and 5 g of it was mixed with 50 mL of 0.2N HCl in a 100 mL conical flask, boiled for 1h, and cooled under tap water. The pH of the mixtures was adjusted to 6.0 using 0.5 M NaOH, then readjusted to 4.5 using 1N HCl to facilitate precipitation of all interfering materials. It was diluted to the 100 mL mark of the flask and then filtered through a double-fold filter paper. Ten (10 mL) of the filtrate was added to each of four separate test tubes. To each of the first two test tubes, 1 mL of distilled water was added, while to each of the remaining two test tubes, 1 mL of riboflavin standard (0.5 µg/mL) was added. One (1.0 mL) glacial acetic acid and 0.5 mL of 3% $KMnO_4$ were added to each of the tubes, and the tubes were shaken vigorously. Fluorescence was measured at 440 nm extinction and at 565 nm emission for the sample tube containing water, and then repeated on the same sample after admixing with 20 mg of $Na_2S_2O_4$. Fluorescence of standard at same 440 nm excitation and 565nm emission was also measured. Riboflavin concentration was calculated with the expression:

$$\text{Riboflavin mg/100m} = \frac{100}{\text{W}} \times \frac{Au}{\text{As}} \times \text{C} \frac{Vf}{\text{Va}} \times \text{D}$$

W = weight of sample analyzed, Au = absorbance of the test sample, As = absorbance of standard solution, Vf= total volume of filtrate, Va = volume of filtrate analyzed, C = concentration of the standard, D = dilution factor where applicable

Cyanocobalamin (B_{12}) was determined using a spectrophotometric method as described by Bender [22]. Two (2 g) of the sample was measured inside a 250 ml volumetric flask, and 50 ml of distilled water was added and shaken for 5 minutes before filtering. Five (5 ml) of the filtrate was measured into a 50 ml volumetric flask. 10 ml of the extraction mixture, consisting of sodium phosphate, anhydrous citric acid, and sodium metabisulfate, was added, then boiled for 10 minutes on a hot plate at 80 °C. The solution was then filtered, and an absorbance reading was taken at 530 nm against a blank. About 100 mg of vitamin B_{12} standard solution was prepared, and 10 ml of the extracted mixture was also added. The absorbance readings were used to calculate the vitamin concentration.

$$\text{Vitamin } B_{12}\ \mu\text{g/100g} = \left(\frac{Peak\ area\ of\ sample}{Peak\ area\ of\ standard}\right) \times Conc\ of\ standard \times\ Dilution\ Factor \times 100$$

Where: Peak area of sample is the area under the curve of the vitamin B_{12} peak in the sample chromatogram, peak area of standard is the area under the curve of the vitamin B_{12} peak in the standard chromatogram, concentration of Standard is the known concentration of vitamin B_{12} in the standard solution (mg/mL), Dilution factor is the dilution factor used to prepare the sample for analysis.

Vitamin C (ascorbic acid) was determined and calculated using the method described by Okwu and Josiah [20]. Five (5 g) of the samples were diluted with 10 % Trichloroacetic acid (TCA) to the 100.0 mL mark of a 100 mL volumetric flask. 2, 6 6-dichlorophenolindophenol was titrated to 10.0 mL of the vegetable filtrate. Ascorbic acid was calculated as:

$$\text{Ascorbic acid (mg/kg)} = (\text{A-B}) \times \text{C} \times 100/\text{s} \times (100/10)$$

Where A = Volume in mL of indophenol solution used in the sample, B = Volume in mL of indophenol solution used for the blank, C = Mass in mg of ascorbic acid equivalent to 1 mL of standard indophenol solution, S = weight of the sample taken (g), 100/10 = total extraction volume/volume of titrated sample

Vitamin E (tocopherol) was determined and calculated using the method described by AOAC [19]. A measured weight of each sample extract (5 ml) was mixed with 50 ml of absolute ethanol, and 100 ml of molar alcoholic sulphide acid solution was added to it. It was boiled under reflux for 30 minutes in a dimly lit environment and then allowed to cool. About 50 ml of distilled water was added to it and then transferred to a separating funnel. An additional 50 ml of distilled water was used to rinse out the flask and was pooled into the separating funnel. The unsaponifiable materials were extracted with two portions of 100 ml acetyl ether, which were added to the separating funnel. The ether extract, which contains vitamin E, was evaporated to dryness. The dried extract obtained above was dissolved in 10 ml of ethanol and used for the vitamin E assay. A standard vitamin E (tocopherol) solution was prepared and diluted to contain 0.5 mg/mL. One ml of the sample extract and the standard were mixed with 5 ml of absolute ethanol in separate flasks, and each was treated with 1 ml of concentrated HNO3 and heated in a water bath for 30 minutes at 90 °C ℃ and then made up to 20 ml with ethanol. The absorbance was measured on a spectrophotometer at 470 nm, with a reagent blank set to zero. The following formula was used to calculate the vitamin A content.

$$\text{Vitamin E } iu/100\text{g} = \frac{100}{w} \times \frac{\text{au}}{as} \times \frac{\text{Vf}}{Va} \times C$$

w = weight of the sample analysed, au = absorbance of the test sample, as = absorbance of standard vitamin E, Vf = volume of standard injected, Va = volume of sample injected, c = concentration of vitamin E standard (iu/mL)

Vitamin A (total carotenoid) was determined and calculated using the method described by Rodriguez-Amaya and Kimura [23]. Five (5 g) of each sample was mixed with 30 ml of absolute alcohol (ethanol) and 3 ml of 50 % KOH solution was added to it. It was separated by boiling gently under reflux for 30 minutes. It was cooled gently in cold water, and 30 ml of distilled water was added to it. The mixture was transferred to a separating funnel, and 50 mL of petroleum ether was added, mixed gently

to avoid emulsion formation. The aqueous layer was discarded, while the upper layer was treated with another 50 ml of petroleum ether. After mixing thoroughly, four 50 ml portions of distilled water were used to wash the mixture in the separating funnel. Each time, the aqueous layer was discarded. At the end the ether layer was evaporated to dryness over a steam bath. The dried vitamin A extract was redissolved in 20 ml of isopropyl alcohol. Standard vitamin A solution was prepared and diluted to contain 5 *iu/mL*. Exactly 1 ml of the standard solution was dissolved in 20 ml of isopropyl alcohol, and the absorbance was read alongside that of the redisolved vitamin A extract at a wavelength of 0.35 nm in a spectrophotometer. The formula, as follows, was used to calculate vitamin A content.

$$vitamin\ A\ iu/100\text{g} = \frac{100\ \times au \times\ \text{c}}{\text{w}\ \times\ \text{as}}$$

w = weight of the sample analysed, au = absorbance of the test sample, as = absorbance of standard vitamin A, c = concentration of vitamin A standard (iu/mL)

2.5. Determination of Functional Properties

Oil absorption capacity was determined and calculated using the method described by Onwuka [21]. Refined soybean oil with a density of 0.92 g/mL was used. Exactly 1 g of the sample was mixed with 10 mL of the oil (V_1), for 30 s. The sample was allowed to stand for 30 min at room temperature and then centrifuged (Centurion Scientific, Model K241) at 10,000 rpm for 30 min. The amount of oil separated as supernatant (V_2) was measured using 10 mL cylinder. The difference in volume was taken as the oil absorbed by the samples. The result obtained was calculated using the equation below:

$$\text{Oil absorption capacity} = \frac{(\text{V}_1 - \text{V}_2)\text{P}}{\text{Weight of sample}}$$

V_1= the initial volume of oil used, V_2= the volume not absorbed, P = the density of oil (0.92 g/mL)

Water absorption capacity was determined and calculated using the method described by Onwuka [21]. One (1 g) of the sample was weighed and placed into a conical graduated centrifuge tube. A waring whirl mixer was used to mix the sample thoroughly, 10 ml was added, and the sample was allowed to stay for 30 mins at room temperature and then centrifuged at 5000 × g for 30 mins. The volume of the free water (supernatant) was read using 10 ml measuring cylinder. Water absorption was calculated as the amount of water absorbed (total minus free water) x 1 g/mL.

$$\text{WAC} = \frac{W_2 - W_1}{\text{W}}$$

W = weight of sample, W_1 = weight of empty tube, W_2 = weight of tube + water to be absorbed

Bulk density was determined and calculated using the method described by Onwuka [21]. A known weight of a measuring cylinder was filled with the samples from a height and leveled. Bulk density was calculated as the ratio of mass to volume occupied by spices.

$$\text{Bulk density (g/mL)} = \frac{weight\ of\ sample}{\text{Volume of sample (ml)}}$$

The swelling index was determined and calculated using the method described by Onwuka [21]. (1) A gram of the sample was weighed into a clean, dry measuring cylinder. The height occupied by the sample was recorded (H_1), and then 5 mL of distilled water was added to the sample. This was left to stand undisturbed for 1 h, after which the height was observed and recorded again (H_2). The swelling index (SI) was then calculated using the equation below:

$$\text{S.I.} \qquad = \frac{H_2}{\text{H}_1}$$

H_2 = final volume of sample after swelling, H_1 = initial volume of sample before swelling.

The gelatinization temperature was determined by the method described by Onwuka [21]. Three (3 g) of the sample was weighed into a test tube, and 10 ml of distilled water was added to determine the gelatin temperature. The mixture was boiled in a water bath with continuous stirring. The temperature of gelatinization was recorded 30 seconds after it was visually observed.

Gelatin capacity of the sample was determined using the method described by Onwuka [21]. Suspensions of 2 to 20% of each sample were prepared in 5 mL of distilled water. The sample test tubes

were heated for 1hour in boiling water (100 °C), followed by rapid cooling under running cold tap water. The test tube was cooled further for 2 hours at 4 °C. Hence, the gelatin property is the least gelatin concentration determined as the concentration at which the sample from the inverted test tube will not fail or slip.

The foam capacity was determined using the method described by Liu et al. [24]. 2 g of the flour sample was dispersed in 100 mL of distilled water. The resulting solution was homogenized for 5 minutes at high speed. The volume remaining at intervals of 0.00, 0.30, 1, 2, 3, and 4 h, up to 24 h, was measured to study foaming stability. Foam capacity was calculated using the formula:

$$\text{Foam capacity} = \frac{Volume\ after\ whipping}{Volume\ before\ whipping} \times 100$$

2.6. Sensory Evaluation

The sensory evaluation was conducted with the consent of 20 trained panelists, comprising both male and female students from the University of Agriculture and Environmental Science, Umuagwo, Imo State, Nigeria. who are familiar with the sensory attributes of taste, texture, mouthfeel, and color. Their preference was rated on a nine (9) point hedonic scale. Where 9 = extremely liked, 8 = liked very much, 7 = liked moderately, 6 = like much, 5 = neither like nor dislike, 4 = dislike, 3 = dislike moderately, 2 = dislike very much, 1 = disliked extremely. The samples were served simultaneously, and drinking water was provided for rinsing of the mouth between samples.

2.7. Statistical Analysis

Data were analyzed using a completely randomized design with three replicates. The replicated experimental data were analyzed for Analysis of Variance (ANOVA) at a 0.05 level of significance and Pearson correlation coefficient at a 0.05 level of significance using one-way ANOVA. All data were presented as mean ± standard error of the mean and as alphabetical mean ranking in case of significant differences observed based on Duncan Multiple Range Test.

3. Results and Discussion

3.1. Functional Properties of the Local Spices

The functional properties of the different spices are shown in Table 1. The oil absorption capacity (OAC), foam, and gelation capacities of the samples ranged from 1.94 – 2.39 %, 13.56 – 10.78 g/mL, and 8.45 – 6.00 g/mL, respectively. UO (*Piper guineense*) had the least values while TO (*Tetrapleura tetraptera*) had the highest values. There were significant ($p<0.05$) differences among samples. Sample UO (*Piper guineense*) was significantly ($p<0.05$) higher in water absorption capacity (2.27 %), bulk density (0.52 mg/100g) and swelling index (1.87 g/mL) while the least values were recorded in sample TO (*Tetrapleura tetraptera*) for water absorption capacity (2.14 g/mL) and swelling index (1.31 g/mL). The gelatinization temperature of the samples ranged from 58.73 – 62.45 °C. TO (*Tetrapleura tetraptera*) had the lowest values, while XO (*Xylopia aethiopica*) had the highest values. There were significant ($p<0.05$) differences among samples.

Table 1. Functional properties of the local spices*

Sample	OAC (%)	WAC (%)	BD (mg/100g)	SI (g/mL)	GT (°C)	FC (g/mL)	GC (g/mL)
XO	$2.31^{b}\pm0.01$	$2.19^{ab}\pm0.01$	$0.48^{b}\pm0.00$	$1.58^{b}\pm0.03$	$62.45^{a}\pm0.07$	$11.56^{b}\pm0.08$	$6.49^{b}\pm0.01$
UO	$1.94^{c}\pm0.02$	$2.27^{a}\pm0.04$	$0.52^{a}\pm0.00$	$1.87^{a}\pm0.04$	$60.61^{b}\pm0.27$	$10.78^{c}\pm0.03$	$6.00^{c}\pm0.00$
TO	$2.39^{a}\pm0.01$	$2.14^{b}\pm0.03$	$0.49^{b}\pm0.00$	$1.31^{c}\pm0.01$	$58.73^{c}\pm0.04$	$13.56^{a}\pm0.06$	$8.45^{a}\pm0.07$

*Values show the mean of duplicate analysis and ± standard deviation. Figures with different superscripts down the column are significantly different ($p<0.05$). **Keys:** XO = Guinea pepper (*Xylopia aethiopica*), UO = African black pepper (*Piper guineense*), TO = Aidan fruit (*Tetrapleura tetraptera*), OAC = oil absorption capacity, WAC = water absorption capacity, BD = bulk density, SI = swelling index, GT = gelatinization temp, FC = foam capacity, GC = gelation capacity

3.2. Mineral Contents of Local Spices

The mineral contents of the different spices are shown in Table 2. The mineral content of the samples was significantly different ($p<0.05$). Sample UO (*Piper guineense*) was significantly higher in Calcium (283.72 mg/100g), Phosphorus (249.96 mg/100g), and Iron (6.34 mg/100g). Sample TO (*Tetrapleura tetraptera*) had the lowest values for Calcium (189.01 mg/100g), Magnesium (144.90 mg/100g), Copper (0.13 mg/100g), Manganese (0.84 mg/100g), Phosphorus (196.49 mg/100g) and Zinc (1.27 mg/100g), while sample XO (*Xylopia aethiopica*) had the least value for Fe (3.82 mg/100g) and significantly higher values for Magnesium (170.55 mg/100g), Copper (1.44 mg/100g), Manganese (2.39 mg/100g) and Zinc (3.83 mg/100g).

Table 2. Mineral contents of the of the local spices*

Sample	Ca (mg/100g)	Mg (mg/100g)	Cu (mg/100g)	Mn (mg/100g)	P (mg/100g)	Fe (mg/100g)	Zn (mg/100g)
XO	$227.19^{b}\pm1.99$	$170.55^{a}\pm0.14$	$1.44^{a}\pm0.02$	$2.39^{a}\pm0.05$	$225.77^{b}\pm1.46$	$3.82^{c}\pm0.06$	$3.83^{a}\pm0.10$
UO	$283.72^{a}\pm1.24$	$161.43^{b}\pm1.23$	$0.19^{b}\pm0.00$	$1.87^{b}\pm0.04$	$249.96^{a}\pm0.91$	$6.34^{a}\pm0.08$	$2.73^{b}\pm0.01$
TO	$189.01^{c}\pm1.99$	$144.90^{c}\pm1.47$	$0.13^{c}\pm0.01$	$0.84^{c}\pm0.02$	$196.49^{c}\pm0.01$	$4.83^{b}\pm0.10$	$1.27^{c}\pm0.05$

*Values show the mean of duplicate analysis and ± standard deviation. Figures with different superscripts down the column are significantly different ($p<0.05$). **Keys:** XO = Guinea pepper (*Xylopia aethiopica*), UO = African black pepper (*Piper guineense*), TO = Aidan fruit (*Tetrapleura tetraptera*)

3.3. Vitamins Contents of Local Spices

The vitamin contents of the different spices are shown in Table 3. The vitamin B_1 content of the samples ranged from 0.02 – 0.03 mg/100g. UO (*Piper guineense*) had the least value, while XO (*Xylopia aethiopica*) and TO (*Tetrapleura tetraptera*) had the highest values. However, there were no significant ($p>0.05$) differences among the samples. The vitamin B_2 content of samples ranged from 0.02 – 0.03 mg/100g. TO (*Tetrapleura tetraptera*) (0.03 mg/100g) was significantly ($p<0.05$) higher than that of the other samples; however there was no significant ($p>0.05$) difference in the vitamin B_2 contents of sample UO (*Piper guineense*) (0.02 mg/100g) and sample XO (*Xylopia aethiopica*) (0.02 mg/100g). The vitamin B_{12} content of the samples ranged from (0.28 – 0.33 µg/100g). UO (*Piper guineense*) had the least value, while XO (*Xylopia aethiopica*) had the highest value. There was no significant ($p>0.05$) difference among the samples. The vitamin C content of sample UO (*Piper guineense*) (1.84 mg/100g) was significantly ($p<0.05$) higher when compared with that of the other samples while sample XO (*Xylopia aethiopica*) (1.40 mg/100g) recorded the lowest vitamin C content. The vitamin A content of the samples ranged from 8.27 – 9.58 µg/100g, while the vitamin E content of the samples ranged from 0.85 – 1.72 mg/100g. Sample TO (*Tetrapleura tetraptera*) (9.58 µg/100g and 1.72 mg/100g) recorded the highest values for vitamin A and vitamin E, respectively, while sample XO (*Xylopia aethiopica*) recorded the lowest values for vitamin A (6.01 µg/100g) and vitamin E (0.85 mg/100g), respectively. There were significant ($p<0.05$) differences among the samples for vitamins A and E.

Table 3. Vitamins contents of the of the local spices*

Sample	Vit B_1 (mg/100g)	Vit B_2 (mg/100g)	Vit B_{12} (µg/100g)	Vit C (mg/100g)	Vit A (µg/100g)	Vit E (mg/100g)
UO	$0.02^{a}\pm0.00$	$0.02^{b}\pm0.00$	$0.28^{a}\pm0.00$	$1.84^{a}\pm0.02$	$8.27^{b}\pm0.04$	$1.24^{b}\pm0.01$
XO	$0.03^{a}\pm0.00$	$0.02^{b}\pm0.00$	$0.33^{a}\pm0.01$	$1.40^{c}\pm0.03$	$6.01^{c}\pm0.16$	$0.85^{c}\pm0.01$
TO	$0.03^{a}\pm0.01$	$0.03^{a}\pm0.00$	$0.29^{a}\pm0.08$	$1.74^{b}\pm0.00$	$9.58^{a}\pm0.03$	$1.72^{a}\pm0.06$

*Values show the mean of duplicate analysis and ± standard deviation. Figures with different superscripts down the column are significantly different ($p<0.05$). **Keys:** XO = Guinea pepper (*Xylopia aethiopica*), UO = African black pepper (*Piper guineense*), TO = Aidan fruit (*Tetrapleura tetraptera*)

3.4. Sensory Properties of Dishes Prepared from Local Spices

The sensory characteristics of the dishes prepared from the local spices are shown in Table 4. The results revealed that there was no significant ($p>0.05$) difference in the colour of uziza/oshosho sauce and white rice (7.80±0.95) and curry/thyme sauce and white rice (7.90±1.35). There was also no significant ($p>0.05$) difference in the colour of local salad-ugba with uziza and uda (7.40±1.50) and

local salad-ugba with ehuru and ogiri, however, curry/thyme sauce and white rice (7.90±1.35) and local salad-ugba with uziza and uda (7.40±1.50) had higher scores for colour than the rest of the meals. Curry/thyme sauce and white rice (8.15±0.81) had significantly (p<0.05) higher scores for mouth feel than the rest of the dishes prepared, whereas there was no significant (p>0.05) difference in mouth feel of uziza/oshosho sauce and white rice (7.40±1.35) and local salad-ugba with uziza and uda (7.45±1.36), while Local salad-ugba with ehuru and ogiri (6.95±1.47) had the lowest score. There was no significant (p>0.05) difference in the texture of uziza/oshosho sauce and white rice (7.70±1.17), local salad-ugba with uziza and uda (7.55±1.23), and curry/thyme sauce and white rice (7.70±1.08). In contrast, local salad-ugba with ehuru and ogiri (7.05±1.39) had the lowest score. There was no significant (p>0.05) difference in the acceptability of the taste of local salad-ugba with uziza and uda (7.45±1.47) and curry/thyme sauce and white rice (7.50±1.28); however, curry/thyme sauce and white rice (7.50±1.28) had higher scores than the rest of the dishes. In contrast, local salad-ugba with ehuru and ogiri (6.75±1.83) had the lowest score. There was no significant (p>0.05) difference in the general acceptability of uziza/oshosho sauce and white rice (8.05±0.69) and curry/thyme sauce and white rice (8.05±0.83), while there was also no significant (p>0.05) difference in the acceptability of local salad-ugba with uziza and uda (7.10±1.52) and local salad-ugba with ehuru and ogiri (7.20±1.44), however, the former had higher scores than the latter.

Table 4. Sensory properties of the dishes prepared from the local spices*

Sample	Colour	Mouth feel	Texture	Taste	General acceptability
A	7.80^{a}±0.95	7.40^{b}±1.35	7.70^{a}±1.17	7.15^{b}±1.90	8.05^{a}±0.69
D	7.40^{b}±1.50	7.45^{b}±1.36	7.55^{a}±1.23	7.45^{a}±1.47	7.10^{b}±1.52
A_1	7.90^{a}±1.33	8.15^{a}±0.81	7.70^{a}±1.08	7.50^{a}±1.28	8.05^{a}±0.83
D1	7.15b±1.66	6.95c±1.47	7.05b±1.39	6.75c±1.83	7.20b±1.44

*Values show the mean of duplicate analysis and ± standard deviation. Figures with different superscripts down the column are significantly different (p<0.05). **Keys:** A = uziza/Oshosho sauce and white rice, D = local salad-ugba with uziza and uda, A_1 = curry/thyme sauce and white rice, D_1 = local salad-ugba with ehuru and ogiri

The oil absorption capacity (OAC) of the spices was higher than the range values 1.41-1.73% reported for powdered red pepper [25]. Similar to water absorption capacity, a food powder's ability to absorb oil may be influenced by its protein concentration and other factors. Ibeabuchi *et al.* [26] reported that the ability of samples to absorb oil may vary depending on the presence of proteins, the physical characteristics of the oil, and the method employed. The powder's lower oil absorption capacity could be explained by the limited number of nonpolar protein side chains that bind oil hydrocarbon side chains [27]. According to Ubbor and Akobundu [28], flours with high oil absorption capacity may be advantageous for structural interactions in foods, particularly for improving palatability, extending shelf life, and retaining flavor, especially in meat or bakery products where fat absorption is desired. Spices may enhance mouthfeel and improve flavor retention due to their ability to absorb oil [21]. Variations in oil absorption capacity can be attributed to differences in lipid content, protein structure, and surface area [29]. *Tetrapleura tetraptera* had a higher OAC (2.39%) compared to other spices, possibly due to its higher lipid content.

The results for water absorption capacity (WAC) showed that all spice powders absorbed water. The result also showed values comparable to those of powdered red pepper (0.86-2.29%), as reported by Woldermariam *et al.* [25]. The differences observed in the WAC of the flour indicate that the samples have variable degrees of water-binding site availability among the starches and different protein concentrations and their interactions with water [30]. This might also be due to factors such as the flour's particle size and molecular structure [31]. The water absorption capacity observed in the samples indicates that they can be used as thickeners, as they absorb water and swell, improving food consistency [32]. Reports have shown that flours with high WAC may not keep well because WAC indicates the maximum water that foods can absorb and retain; therefore, proper storage of such flour should be ensured [33].

The higher foam and gelation capacities and lower swelling index and gelatinization temperature recorded in TO (*Tetrapleura tetraptera*) when compared to other samples could be as a result of the presence of oleanic acid, triglycoside scoplatin and coumarin [34]. It is perhaps the presence of coumarin that is responsible for the aroma the fruits often impart to food and for its potential as a condiment in

soups. In Nigeria, the fruits of Aidan are used in phyto-medicine for the treatment of infertility in women [35]. Sample XO (*Xylopia aethiopica*) was significantly higher in gelatinization temperature than the other samples, and lowest in bulk density than the other samples. This could be because *Xylopia* comprises mainly of xylopic acid, dipterpenic acid 15*β*-acetoxy (-)kauran-16-ene-19-oic acid, three diterpenic alcohols, fats, oils, and essential oils [36]. It is mainly consumed as a spice, flavoring agent, and stimulant [36]. Nutritionally, low bulk density promotes easy digestibility of food products, particularly among children with a weak digestive system [37]. Fruits and seeds are hot to the taste and are used as a stimulant and restorative for childbirth [34]. Sample UO (*Piper guineense*) had the highest bulk density and swelling index properties and the lowest gelation capacities among the rest of the samples. This could be why the seeds of African Black Pepper (*Piper guineense*) are used not only to relieve gripping stomach conditions after delivery but also to restore the uterus to a normal state [34].

Variations in the bulk density of spices can be due to differences in particle size, shape, and arrangement [38]. *Piper guineense* had a higher bulk density compared to other spices, possibly due to its smaller particle size. Variations in the swelling index, foam capacity, and gelation capacity of the spices can also be attributed to differences in starch structure and protein content [29]. While variations in the gelatinization temperature can be due to differences in starch structure and amylose content [38]. *Xylopia aethiopica* had a higher gelatinization temperature compared to other spices, possibly due to its higher amylose content [38].

Spices are proven sources of vital nutrients necessary for the growth and sustenance of various physiological processes in the body; hence, a lack of adequate quantities of these nutrients may lead to a host of disease conditions. In the present study, calcium, magnesium, and phosphorus were the most abundant minerals in all three spices evaluated. Magnesium is essential in glucose and insulin metabolism, chiefly by enhancing tyrosine kinase activity of the insulin receptor. The activity of phosphorylase b kinase is also activated by magnesium, thereby bringing about the release of glucose-1-phosphate from glycogen [39]. *Piper guineense* contains the highest calcium concentration of the three spices. This is like the work of Uduenevwo et al. [40], who reported a higher concentration of calcium in *Piper guineense.* A previous similar study by Borquaye [41] also reported that calcium had the highest concentration among the minerals present in the spices tested. This indicates that the spices may play vital roles in good teeth and bone development, coupled with their essential role as a cofactor in various enzyme-catalyzed reactions, such as blood clotting and several other physiological processes. The high levels of potassium in the spices indicate that they can act as major cations in extracellular and intracellular fluids, respectively, and also help sustain electrolyte balance in body fluids. Sample UO (*Piper guineense*) was significantly higher in Calcium (287.72 mg/100g), Phosphorus (249.96 mg/100g), and Iron (6.34 mg/100g). This result was in disagreement with the results of Udofia and Alozie [42], who reported Guinea pepper (*Xylopia aethiopica*) higher in Calcium (480 mg/100g) and Aidan fruit *(Tetrapleura tetraptera)* higher in phosphorus (149.88 mg/100g). Sample XO (*Xylopia aethiopica*) recorded significantly higher values of Magnesium (170.55 mg/100g), which was in accordance with the findings of Udofia and Alozie [42] who also reported the highest magnesium content in Guinea pepper (*Xylopia aethiopica*) (300 mg/100g). Values reported by Imo et al. [43] for the levels of iron (2.41 mg/g, 2.73 mg/g, 2.65 mg/g), copper (0.08 mg/g, 0.41 mg/g, 0.01 mg/g), Zinc (0.42 mg/g, 0.37 mg/g, 0.31 mg/g), and manganese (0.32 mg/g, 2.06 mg/g, 0.19 mg/g) for *X. aethiopica* and *P. guineense* vary from the values obtained in this study. The observed variations could be attributed to differences in the maturity stage of the fruits/seeds at harvest, soil fertility, and climatic factors in the geographic region where the spices were harvested [29]. Iron helps in the synthesis of haemoglobin and normal functioning of the central nervous system. At the same time, Manganese is a known activator of several enzymes and also necessary for the formation of haemoglobin. Moreover, Zinc has been reported to exhibit catalytic and modulatory activities toward over 300 enzymes. It also aids in maintaining a healthy immune system and enhances sperm development, ovulation, and fertilization [44].

The vitamin B_2 content of sample TO (*Tetrapleura tetraptera*) was significantly higher than that of the other samples; this differs from findings reported by other researchers, who reported higher Vitamin B_2 in African Black Pepper (*Piper guineense*) [34, 36]. Ndefo et al. [45] reported vitamin B_1 and B_2 for *X. aethiopica*, *M. myristica*, and *P. guineense* as 0.15 mg/100g, 0.32 mg/100g, and 0.04 mg/100g, respectively, and 0.05 mg/100g, 0.03 mg/100g, and 0.12 mg/100g, respectively. While, Nkwocha et al. [46] reported vitamin B_{12} contents of *Monodora myristica* seed powder as 0.17 µg/100g.

These values vary from the findings from this study. The presence of these B vitamins in the spices suggests that they could help promote brain function and energy metabolism. All three of these spices contain some B vitamins, but because they are low in these nutrients, it may be necessary to eat them with other foods high in B vitamins to achieve optimal intake. The vitamin C content of sample UO (*Piper guineense*) was significantly higher when compared with that of the other samples; this vary from the findings of Okwu [34] who reported Guinea pepper (*Xylopia aethiopica*) as having the highest ascorbic acid content, but was however, in agreement with the findings of Udofia and Alozie [42] who also reported the highest ascorbic acid content in African black pepper (*Piper guineense*). Vitamin C is essential for protein metabolism, the immune system, wound healing, and iron absorption, all of which are necessary for fighting infections [47]. Sample TO (*Tetrapleura tetraptera*) recorded the highest values for vitamin A, which was similar to the findings of Udofia and Alozie [42] who reported higher content in African black pepper (*Piper guineense*). Vitamin A is essential for healthy skin, the immune system, and eyesight. The values for the vitamin E were lower than the values reported by Dodo et al. [48] for *Piper guineense, Xylopia aethiopica, Ocimum gratissimum, Ricinus communis* and *Pergularia deamia*. The presence of vitamin E in the spices suggests that when these flavorful spices are used to prepare food or medications, they may provide the body with this vitamin. Vitamin E is a potent lipid-soluble antioxidant necessary for preserving the integrity of cell membranes, mucous membranes, and skin by shielding them from dangerous oxygen-free radicals [49]. The variations observed in the vitamin contents of the spices when compared with other findings could be attributed to differences in methods employed during analysis, differences in ripeness, stage of maturity of the fruits/seeds before harvesting them, soil fertility and climatic factors of the geographical region where the spices were harvested [29, 38].

Many studies have evaluated the sensory properties of food, as well as the spice combinations and their effects on food. Some studies have used spices to improve the taste of beef, pork, and sausages; others have examined the possibility of adding spices to bread to assess fungal growth and food packaging [50]. Taste, aroma, texture, flavor, mouthfeel, saltiness, and acceptability are important criteria for evaluating food prepared with different spices. The findings of Aidells and Kelly [51] indicated that spices improve the taste, texture, and flavor of prepared food, which is in line with the findings of this study. A study conducted by Abisoye et al. [53] reported that plant phenolic compounds contribute to quality and nutritional value by modifying saltiness, taste, aroma, and flavor; they also provide health-beneficial effects. Spices add six basic tastes to finished products such as sweet, salty, bitter, sour, spicy, and hot [53]. Spices are not only used for flavoring food but also to enhance its latent flavor [54]. The variations in the sensory scores of the dishes prepared with these spices could be due to differences in the chemical properties of the spices in foods, thereby affecting sensory evaluation, as well as differences in volatile compounds, texture, and appearance [38]. Also, cultural and personal preferences can influence sensory evaluations, as different people have varying preferences for spice flavors and aromas [29].

4. Conclusion

This study provides valuable insights into the functional and micronutrient properties of *Piper guineense*, *Xylopia aethiopica*, and *Tetrapleura tetraptera* spices as well as the sensory acceptability of dishes prepared with these spices. The findings revealed significant variations in the functional properties, vitamins, and mineral content of these spices. The study showed that these spices can enhance nutritional value by providing essential minerals and vitamins, as well as functional properties such as water absorption, bulk density, and swelling index, making them suitable for various food applications and contributing to culinary diversity by offering unique flavor profiles and aromas. *Piper guineense* emerged as the best spice due to its higher vitamin C content, water absorption capacity, bulk density, swelling index, and rich mineral content, particularly calcium, phosphorus, and iron. By incorporating these spices into traditional dishes, food manufacturers and consumers can enhance the nutritional value and acceptability of their products. The variations in functional properties and micronutrient content among the spices suggest opportunities for tailored applications in different food products. Additionally, Nigerian traditional spices are underexploited despite their culinary significance. This study addressed the knowledge gap on their functional and micronutrient profiles to promote utilization and nutritional

benefits. These findings can optimize the use of spices in Nigerian cuisine, enhance food product development, and promote nutritional benefits. These spices can be recommended for use as functional ingredients in the development of value-added food products such as spice blends, seasoning, and condiments. Also, experiment with these spices in modern cuisines to create innovative dishes and flavours, leveraging their unique sensory profile.

Conflict of Interest

The authors declare that they have no competing financial interests or personal relationships that could have influenced the work reported in this paper.

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