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Proximate, mineral, and phytochemical composition of different varieties of pepper (*capsicum spp.* L.) In Rivers State, Southern Nigeria

Azubuike A A*, Jaja E T, Ajuru M G, Amadi N
Department of Plant Science and Biotechnology, Rivers State University, Nkpolu-Oroworukwo, P.M.B. Port Harcourt, Rivers State, Nigeria
Corresponding Author: Azubuike A A
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Abstract
Pepper is widely grown and sold in Rivers State, but few studies have compared multiple commonly consumed varieties concurrently using a common analytical protocol. Therefore, the purpose of this study was to identify and contrast the proximate, mineral, and phytochemical composition of various pepper cultivars in this state. The study was carried out in the nursery, and botanical garden of the Department of Plant Science and Biotechnology, Rivers State University, Port Harcourt, Nigeria. Seeds were planted in the nursery, and later transplanted into 10L capacity ploytene bags that were perforated at the bottom. Proximate, mineral and phytochemical analysis was carried out following standard methods, and the data collected were subjected to analysis of variance (ANOVA). Result showed that: bell pepper had the highest moisture content (12.40±0.14), ash content (10.20±0.14), protein content (14.88±0.00); phosphorus (8.58±0.00), flavonoid (12.31±0.01), carotenoid (1.82±0.02), and alkaloid (9.50±0.00); chili pepper had the highest fat content (8.91±0.00), fibre (20.00±0.00), carbohydrate (45.51±0.07), manganese (0.12±0.00), and calcium (26.51±1.14); and habanero peeper had the highest potassium content (8.27±3.69), sodium (12.22±0.05), tannic acid (2.00±0.00), and saponin (1.64±0.19). The different pepper varieties showed significant variations in their proximate, mineral, and phytochemical composition.

Keywords: Bell pepper, chili pepper, habanero pepper, mineral analysis, nutritional analysis

Introduction
Pepper (*Capsicum* spp.), a member of the Solanaceae family, ranks among the most widely grown and economically important vegetable-spice crops in the tropics (Akinnifesi *et al.*, 2023) [3]. The species *C. annuum* L., *C. frutescens* L., and *C. chinense* Jacq. dominate global production and trade (Tripodi and Kumar, 2019) [24]. Nigeria is the leading producer in West and Central Africa, where the crop supports both household diets and smallholder incomes (Barchenger and Zohoungbogbo, 2026; Olutumise *et al.*, 2022) [6, 21].

Nutritionally, pepper fruits supply moisture, dietary fibre, protein, ash, carbohydrates, and essential minerals such as potassium, calcium, magnesium, phosphorus, iron, and zinc (Nnenna and Alabo, 2021; Evuen *et al.*, 2022; George and Enyi-Onwugbuta, 2023) [8, 11, 18]. In Nigeria, where diets rely heavily on starchy staples and micronutrient deficiencies persist, regular consumption of pepper contributes meaningfully to mineral intake (Abu *et al.*, 2020; Mustapha *et al.*, 2021; Umeri *et al.*, 2024) [2, 17, 27].

Pepper is also rich in secondary metabolites, including alkaloids, flavonoids, tannins, saponins, phenolics, and carotenoids (Peregrine *et al.*, 2021; Ogunoye and Anthonia, 2025) [20, 22]. Capsaicinoids, particularly capsaicin, impart pungency and confer antioxidant, anti-inflammatory, anticancer, and cardiometabolic benefits (Szallasi, 2022; Maharjan *et al.*, 2024) [16, 25]. Together with polyphenols, they largely determine the antioxidant capacity of the crop (Bal *et al.*, 2022 [5]; Alonso-Villegas *et al.*, 2023) [4]. Tannins and saponins, though potentially beneficial at moderate levels, may act as anti-nutrients at high concentrations and therefore require quantification (Sharma *et al.*, 2019, 2023) [23, 24].

Composition varies with species, variety, maturity, agronomic practices, soil, and agro-ecology (Evuen *et al.*, 2022; Ogunoye and Anthonia, 2025) [8, 20]. Local West African *C. chinense* types differ markedly from sweet bell peppers in both pungency and bioactive profile (Barchenger and Zohoungbogbo, 2026) [6]. Non-local compositional data are therefore unreliable for Nigerian applications (Gayathri *et al.*, 2016; Obayelu *et al.*, 2021; Akinnifesi *et al.*, 2023) [3, 10, 19].

Although pepper is widely cultivated and marketed in Rivers State, published data on the proximate, mineral, and phytochemical composition of locally grown cultivars remain limited. Most Nigerian studies have focused on other regions, and few have compared multiple popular varieties under a uniform protocol. This study therefore determined and compared the proximate, mineral, and phytochemical composition of selected pepper cultivars grown in Rivers State, southern Nigeria.

Materials and Methods
Experimental site
The study was carried out in the nursery, and botanical garden of the Department of Plant Science and Biotechnology, Rivers State University, Port Harcourt, Nigeria (4.804 °N, 6.980 °E).

Seed Collection
Seeds of three (3) varieties of pepper (Chili, Habanero and Bell) were sourced from Rivers State Agricultural

Development Project (ADP), Port Harcourt and used in this study.

Nursery and Field Establishment

The seeds were first planted in the nursery section, and after sprouting, they were transplanted into ploytene bags that were perforated at the bottom to allow for easy drainage and facilitate aeration, and filled with 100 kilograms of the 4 mm sieved soil. At 21 Days After Sowing (DAS), all the bags were carefully moved to the botanical garden of the department of Plant Science and Biotechnology, Rivers State University.

Phytochemical Analysis

Phytochemical analysis was carried out following the method reported by Bharti *et al.* (2026) [7]. Healthy fruits of the different varieties of pepper were harvest, cleaned, dried in an oven at a controlled low temperature of 45°C and grinded into a fine powder using a blender. The powdered pepper fruit was then soaked in ethanol, shake properly, and then filtered through Whatman No. 1filter paper to separate the liquid extract from solid plant residues. The solvent was evaporated using a rotary evaporator.

Alkaloids: The extract was treated with Dragendorff's, Mayer's; the formation of a precipitate indicates the presence of alkaloids.

Flavonoids: Dilute sodium hydroxide was added; a color change (e.g., yellow to colorless) confirmed the presence of flavonoids.

Tannins and Phenols: Ferric chloride solution was added; a dark blue or greenish-black coloration indicated phenolic compounds.

Saponins: The extract was shake vigorously with water; persistent, stable foam indicated frothing/saponins.

Terpenoids and Steroids: The Libermann-Burchard test was used; color changes from red/pink to green confirmed the presence of terpenoids.

Mineral Analysis

Mineral analysis was carried based on the method reported by Ilic *et al.* (2016) [12]. Samples were collected, cleaned, dried, and digested in a closed vessel using a heating block or microwave digestion system until a clear solution is obtained.

Macro-elements (potassium, calcium, magnesium, sodium, and phosphorus) and micro-elements (iron, zinc, manganese, and copper) were quantified using Flame Atomic Absorption Spectrometry (AAS) against prepared standard calibration.

Nutritional Analysis

Nutritional analysis was carried out as described by Ezekiel *et al.* (2023) [9]. Samples were collected, cleaned, dried, dissected, and homogenized.

Moisture Content: Weighed samples were dried in an oven at 105 °C until it reached a constant weight. The weight loss equals the water content.

Ash Content (Total Minerals): The dried samples were ignited in a muffle furnace at 550°C until white or grey ash formed, burning off all organic matter.

Crude Protein: The samples were digested using the Kjeldahl method with sulfuric acid and a catalyst to convert organic nitrogen to ammonium sulfate, then titrate to determine total nitrogen and multiplied by a factor of 6.25.

Crude Fat: Fat was extracted from the dried sample using petroleum ether in a Soxhlet apparatus.

Crude Fiber: The fat-free sample was boiled in diluted acid and diluted alkali solutions, the residue was dried, and ash to calculate the fibrous loss.

Carbohydrates: Total carbohydrates were calculated by difference by subtracting the sum of moisture, protein, fat, ash, and fiber percentages from 100%.

Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using Minitab statistical software version 21. Treatment means were separated using least significant difference (LSD), and the results were presented as mean ± standard deviation.

Results

Proximate Composition

The proximate composition of the three pepper varieties is presented in Table 1. Bell pepper recorded the highest moisture (12.40 ± 0.14%), ash (10.20 ± 0.14%), and protein (14.88 ± 0.00%) contents, while chili pepper had the highest fat (8.91 ± 0.00%), fibre (20.00 ± 0.00%), and carbohydrate (45.51 ± 0.07%) contents. Significant differences ($P \leq 0.05$) were observed among the varieties for all proximate parameters.

Table 1: Proximate Composition of Pepper Varieties

Varieties	Moisture	Ash	Fat	Protein	Fibre	Carbohydrate
Habanero	10.25±0.35 ^{b}	9.00±0.00 ^{b}	7.92±0.00 ^{b}	12.51±0.02 ^{b}	18.01±0.01 ^{b}	42.30±0.35 ^{b}
Chili	8.05±0.02 ^{c}	7.01±0.02 ^{c}	8.91±0.00 ^{a}	10.51±0.01 ^{c}	20.00±0.00 ^{a}	45.51±0.07 ^{a}
Bell	12.40±0.14 ^{a}	10.20±0.14 ^{a}	5.00±0.00 ^{c}	14.88±0.00 ^{a}	15.06±0.01 ^{c}	42.46±0.01 ^{b}
LSD	0.702	0.268	0.018	0.047	0.037	0.663

Key: Means with different superscripts within the same row are significantly different ($P \leq 0.05$) and **indicates significant difference

Mineral Composition

Mineral contents of the pepper varieties are shown in Table 2. Habanero recorded the highest potassium (8.27 ± 3.69 mg/100 g) and sodium (12.22 ± 0.05 mg/100 g) levels. Chili pepper had the highest manganese (0.12 ± 0.00 mg/100 g) and calcium (26.51 ± 1.14 mg/100 g), while bell pepper had the highest phosphorus content (8.58 ± 0.00 mg/100 g). Potassium and sodium did not differ significantly among varieties, whereas manganese, calcium, and phosphorus showed significant differences ($P \leq 0.05$).

Table 2: Mineral Composition of the Different Varieties of Pepper

Varieties	Potassium	Sodium	Manganese	Calcium	Phosphorus
Habanero	8.27±3.69 [a]	12.22±0.05 [a]	0.09±0.00 [b]	17.10±0.28 [b]	7.16±0.00 [c]
Chile	5.20±0.09 [a]	9.72±0.77 [a]	0.12±0.00 [a]	26.51±1.14 [a]	8.52±0.00 [b]
Bell	7.21±0.48 [a]	10.75±2.02 [a]	0.10±0.00 [ab]	15.42±2.82 [b]	8.58±0.00 [a]
LSD	6.86	3.99	0.023	5.62	0.018

Key: Means with different superscripts within the same row are significantly different ($P \leq 0.05$), [*]indicates no significant difference, while [**]indicates significant difference

Phytochemical Composition

The phytochemical composition of the pepper varieties is presented in Table 3. Bell pepper recorded the highest flavonoid (12.31 ± 0.01 mg/100 g), carotenoid (1.82 ± 0.02 mg/100 g), and alkaloid (9.50 ± 0.00 mg/100 g) contents. Habanero had the highest tannic acid (2.00 ± 0.00 mg/100 g) and saponin (1.64 ± 0.19 mg/100 g) levels. Significant differences ($P \leq 0.05$) were observed among the varieties for all phytochemical parameters.

Table 3: Phytochemical Composition of the Different Varieties of Pepper

Varieties	Flavonoid	Carotenoid	Tannic acid	Alkaloid	Saponin
Habanero	10.00±0.00 [b]	1.12±0.00 [b]	2.00±0.00 [a]	6.50±0.00 [c]	1.64±0.19 [a]
Chili	8.08±0.02 [c]	1.15±0.00 [b]	1.21±0.01 [b]	9.42±0.03 [b]	1.20±0.00 [b]
Bell	12.31±0.01 [a]	1.82±0.02 [a]	0.80±0.00 [c]	9.50±0.00 [a]	0.60±0.00 [c]
LSD	0.047	0.054	0.029	0.066	0.364

Key: Means with different superscripts within the same row are significantly different ($P \leq 0.05$) and [**]indicates significant difference.

Discussion

The result of proximate analysis (Table 1), showed that bell pepper had considerably more moisture (12.40%), ash (10.20%), and protein (14.88%) than both habanero and chili, but chili pepper had more fat (8.91%), fiber (20.00%), and carbohydrates (45.51%). This pattern is generally in line with previous comparative research on *Capsicum* germplasm, which also found that proximate composition does not follow a consistent trend across species but rather varies significantly with variety and pungency level (Khan *et al.*, 2019) [14]. In comparison to the smaller-fruited, more concentrated hot pepper varieties, bell peppers had higher moisture content, which is consistent with their generally fleshier, thinner-walled pericarp and lower dry-matter accumulation. This difference is also observed in nutrient-quality evaluations of sweet pepper cultivars (Vidak*et al.*, 2021) [28].

On the other hand, reports that sweet, large-fruited pepper varieties can accumulate more nitrogenous compounds during ripening than smaller, pungent types are consistent with the higher protein content of bell pepper in this study. This is because growth-associated and defense-associated (capsaicinoid) pathways have different metabolic allocations (Evuen *et al.*, 2022) [8]. From a nutritional perspective, this suggests that while the higher fiber and carbohydrate content reported for chili pepper in this study, supports its well-established role as a source of dietary bulk and energy in small quantities, bell pepper may function as a relatively better plant-protein source in local diets. The need for variety-specific nutrient labeling rather than treating "pepper" as a nutritionally homogenous food group is reinforced by the significant differences ($p < 0.05$) found across all proximate parameters, which confirm that variety is a strong determinant of nutritional value in *capsicum* (Khan *et al.*, 2019) [14].

Furthermore, according to the result of mineral analysis (Table 2), bell pepper had the highest levels of phosphorus, chili pepper the highest levels of manganese and calcium, and habanero pepper the highest levels of potassium and sodium. Manganese, calcium, and phosphorus varied significantly between varieties, but potassium and sodium did not. Major macro-elements like potassium showed less inter-varietal variability than trace elements in comparative mineral surveys of Nigerian spice crops. The lack of significant variation in potassium and sodium suggests these elements are taken up and accumulated relatively uniformly across *Capsicum* varieties regardless of fruit type (Evuen *et al.*, 2022) [8].

From an agronomic and nutritional standpoint, the higher calcium and manganese content reported for Chili pepper is very important. The higher concentration of calcium in the smaller, more compact chili fruit is consistent with the generally higher structural mineral density reported for thicker-walled, lower-moisture pepper varieties (Vidak *et al.*, 2021) [28]. *Calcium* is closely related to cell-wall integrity and fruit firmness. Despite being consumed in smaller amounts than bell pepper, this finding position chili pepper as a potentially valuable micronutrient contributor because dietary calcium and manganese are crucial for bone health and enzymatic antioxidant function, respectively.

Also, the high sodium and potassium levels recorded for habanero pepperare consistent with earlier research demonstrating that *Capsicum chinense* varieties can accumulate significant macro-mineral concentrations, which has been connected to their cultivation on tropical soils rich in minerals and their relatively higher metabolic activity during fruit ripening (Evuen *et al.*, 2022) [8]. Practically speaking, this calls for a dietary caution: given the persistent public health concern about sodium-related hypertension in West African diets, the naturally elevated sodium levels in habanero pepper should be considered when calculating sodium intake for populations that use it extensively as a condiment.

Additionally, according to the result of phytochemical analysis (Table 3), bell pepper had the highest content of flavonoids, carotenoids, and alkaloids; habanero had the highest levels of tannic acid and saponins; and chili had the lowest values for most phytochemical classes, with the exception of a few. Every difference was statistically significant. This result supports the idea that phytochemical accumulation in *capsicum* is compound-specific rather than consistently linked to pungency, which deviates somewhat

from the widely held belief that pungent peppers are intrinsically richer in phytochemicals than sweet varieties (Bal *et al.*, 2022; Jang *et al.*, 2024) [5, 13]. Also, the dominance of flavonoids and carotenoids in bell pepper is consistent with reports that larger, thinner-walled fruits with extensive chromoplast development during ripening can exhibit pronounced carotenoid and flavonoid accumulation independent of capsaicinoid content. These compounds are strongly linked to pigmentation and photoprotectivepathways (Jang *et al.*, 2024) [13].

Comparative phytochemical screenings of *Capsicum* germplasm, which have demonstrated that tannin and saponin concentrations vary significantly even among closely related hot pepper cultivars and are not necessarily correlated with fruit heat level, are supported by the higher tannic acid and saponin content found in habanero (Lahbib *et al.*, 2021) [15]. By implications: tannins and saponins contribute to antioxidant capacity and, at high concentrations, to anti-nutritional effects like decreased mineral bioavailability and protein digestibility. According to reviews of chili bioactive compounds, the relatively high levels of saponin and tannin in habanero indicate that, although it may provide stronger antioxidant or antimicrobial bioactivity, excessive consumption may slightly impede nutrient absorption (Bal *et al.*, 2022) [5].

In line with the growing interest in *capsicum* as a source of natural bioactive compounds for nutraceutical and food-fortification applications, the higher flavonoid and carotenoid content of bell pepper enhances it as a functional food ingredient with antioxidant relevance (Bal*et al.*, 2022; Jang *et al.*, 2024) [5, 13]. When choosing pepper varieties, it is important to consider the intended nutritional or functional outcome, such as protein and antioxidant density (bell pepper), mineral density (chili), or specific bioactive compound classes like tannins and saponins (habanero), rather than just pungency or culinary tradition. This is demonstrated by the significant inter-varietal differences across all three composition domains examined in this study.

Conclusion

This study examined the variations in the proximate, mineral, and phytochemical composition of habanero, chili, and bell pepper. Findings showed that bell pepper had the highest levels of moisture, ash, and protein; chili pepper had the highest levels of fat, fibre, and carbohydrates; habanero pepper had the highest levels of potassium; chili pepper had the highest levels of sodium and calcium; bell pepper had the highest levels of flavonoids, carotenoids, and alkaloids; and habanero pepper had the highest levels of tannic acid and saponins. The different pepper varieties showed significant variations in their proximate, mineral, and phytochemical composition.

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