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Nutritional and phytochemical profiles of common pepper (*Capsicum spp.*) foliage consumed as leafy vegetables in Southeast Nigeria

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Abstract

Pepper foliage is consumed as a secondary plant part and as a traditional leafy vegetable in some climes. The six commonly consumed pepper species namely Cayenne, Anaheim, Bell, Bird's eye, Scotch Bonnet and Habanero were analysed for their nutrient and phytochemical contents on a fresh weight basis. Proximate composition, vitamins were evaluated while minerals were analysed by the dry ash extraction method. Phytochemicals namely alkaloids, saponins and flavonoids were analysed by gravimetry; tannin and phenols by spectrometry; oxalate by titrimetry and hydrogen cyanide were analysed by alkaline picrate assay. Results indicated a significant difference ($p<0.05$) in the nutrient and phytochemical contents of the pepper foliage. Moisture ranged between 86.90 to 88.6% while their energy densities ranged between 34.33 to 45.66 kcal/100 g. Anahiem had the highest crude protein while Scotch Bonnet had the highest carbohydrate contents of 3.50% and 2.70% respectively. Bird's eye, Bell and Scotch Bonnet had the highest ash, fat and crude fibre contents respectively. The order of concentration of vitamins in the pepper foliage was in this order: Vitamin C > Vitamin A > Vitamin E > Vitamin B_2 > Vitamin B_1 > Vitamin B_3. Scotch Bonnet had the highest calcium and magnesium contents, Cayenne had the highest phosphorus, potassium and iron contents while Anahiem and Bell had the highest zinc and sodium contents respectively. The phytochemical profile indicated that oxalate content of the foliage ranged between 0.14 to 0.28 mg/100 g and this classifies them as low oxalate vegetables. Bird's eye had the highest hydrogen cyanide content (9.45 mg/100 g) while Cayenne had the highest phytate content (12.72%). Results indicated the presence of tannins, alkaloids, phytosterols, phenols, flavonoids and saponins. These phytochemicals in the pepper foliage can be beneficial for human wellbeing based on their health-promoting effects.

1. Introduction

Vegetables perform a crucial role in food and nutrition security (Natesh *et al*., 2017). They are important for human health due to their vitamins, minerals, phytochemical compounds and dietary fibre content (Ulgeret *et al.,* 2018). Vegetable consumption is influenced by gender, age, income, education, ancestry and health status of an individual (Giskes *et al*., 2002). Eating leafy vegetables is a component of Africa's culinary tradition and they perform crucial functions in the tradition and food culture of an African family (Otitogu *et al*., 2014). The culinary knowledge of most vegetables depends primarily on the edible properties of one or more primary parts of the plant (Stephens, 2002). Many plants foliage is not commonly consumed as conventional or exotic vegetables by most human populations due to the lack of knowledge of their edibility. Some secondary plant parts of edible crops are consumed as traditional leafy vegetables in localities of various human populations. One of such plant parts consumed as a vegetable for food by some human populations is the foliage of Capsicum species.

Capsicum species is primarily consumed for its fruits while the leaves are consumed secondarily as another edible plant part after cooking (Stephens, 2002). Capsicum *spp*. is a genus of flowering plants in the nightshade family Solanacea (Rhodes, 2009). Several Capsicum species abound with some being dominant in certain localities. Generally, pepper leaves are dark green in colour. In China, pepper leaves are used in certain applications such as mouthwashes, topical relief to reduce symptoms of muscle soreness and in Javanese traditional medicine, the leaf juice is used as an anti-inflammatory to reduce irritation after childbirth

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(Specialty Produce, 2020). Pepper leaves are sold in fresh markets in some places such as Asia, Southeast Asia, South and Central America and Africa (Specialty Produce, 2020). They are cooked as greens and are reported to be mildly bitter compared to moringa leaves (Abilgos-Ramos *et al*., 2012). In Southeast Nigeria, it is consumed in some localities such as Izzi clan in Ebonyi State Nigeria as a traditional leafy vegetable. Nutritionally, pepper leaves are reported to be a good source of vitamins A, B and antioxidants (Specialty Produce, 2020). The nutritional benefits such as its antioxidant properties is in part due to the presence of certain phytochemicals secreted as the plant's secondary metabolites.

The quantity and quality of nutrients and phytochemicals in pepper foliage (leaves) may influence the usefulness of varieties/species for culinary and medicinal purposes. It is in view of this that six varieties that are commonly consumed in the southeast of Nigeria were evaluated for their nutrient and phytochemical contents. These include Cayenne, Anahiem, Bell and Bird's eye pepper and they are varieties of *Capsicum annum* as well as Scotch Bonnet and Habanero pepper which are varieties of *Capsicum chinense* (Bosland, 1996; Brown *et al*., 2013). The knowledge of the nutritional value of these varieties will provide information about the species with the best macronutrient composition but with low antinutritional phytochemicals. This will enhance cultivation not only for the fruits but also for the foliage, hence, enhance food and nutrition security as well as reduce over-dependence on exotic vegetables.

2. Materials and methods

2.1 Collection and preparation of samples

Pepper leaves used for the study was got after planting seeds of the different varieties. Fresh pepper fruits were purchased from a supermarket (Shoprite) while some were from a local market and were identified by a botanist. Seeds were extracted from the respective fruits and planted in a farmyard in Ahiaeke-Ndume situated N5°30'37" and E7°31'44" in Umuahia North Local Government Area of Abia State Nigeria. Planting was done in March 2018. The seedlings were planted 12×15 inches spacing on ridges and allowed to grow for a period between 65 and 70 days to produce enough foliage for analysis. Leaves (the foliage) were used for proximate composition, vitamins, minerals and phytochemical analysis. Harvest was done and analysis was done on a fresh weight basis. Prior to each analysis, each plant foliage was picked, washed and drained of water**.** The pepper species used in this work is shown in Figure 1.

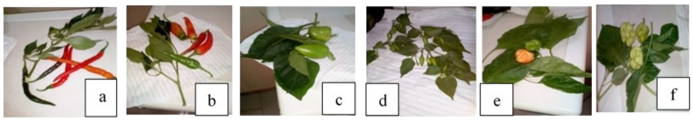

Figure 1. Pepper species used in the work: (a) Cayenne (b) Anaheim (c) Bell pepper (d) Bird's eye (e) Scotch Bonnet (f) Habanero.

2.2 Proximate analysis and energy value calculation

Proximate composition (protein, lipid, fibre, ash, moisture and carbohydrate) of the respective pepper foliage were determined by the method described by James (1995). In brief, moisture was determined by the gravimetric method by heating in an oven at 105°C for 3 hrs to constant weight; total nitrogen was determined by the Kjeldahl method and converted to protein using the factor 6.25. Total fat was extracted by the Soxhlet technique using hexane and subsequently evaluated by gravimetry. Ash was determined by gravimetry of incinerated sample in a muffle furnace at 550°C for 3 hrs. Fibre was analysed after hydrolysis of the defatted sample using 1.25% H_2SO_4 boiled under reflux for 30 mins followed by hydrolysis using 1.25% NaOH and boiled under reflux for another 30 mins. Fibre was determined by gravimetry after drying the recovered residue in an oven at 105°C for 3 hrs to a constant weight. Calorific values of the leaves were estimated by multiplying the percentages of carbohydrate, fat and protein by the factors 3.57, 8.37 and 2.44 respectively (FAO, 2003).

2.3 Determination of minerals

The mineral content of each pepper foliage was determined by the dry ash extraction method described by AOAC (2005). Five g of each pepper foliage was incinerated in a muffle furnace at 550°C for 3 hrs. Three mL concentrated HCl was added to each ashed sample and transferred into a 250mL volumetric flask. Deionised water was used to rinse the crucible used for ashing three times and all the solutions were pooled into respective ashed foliage samples before making up to 100 mL mark using deionised water. The diluted digest was used to analyse the different mineral elements. Sodium and potassium were analysed using an FP640 Flame photometer (Wincom, Hunan China). Phosphorus and zinc were analysed by determining the absorbance of the colour complex formed for molybdovanadate and zinc, respectively. The absorbance was read at 400 nm for phosphorus and 615 nm for zinc (Säbel, 2010) using a UV/Vis 721N spectrophotometer (Measuretech Instrument, Shanghai China). EDTA titration was used for the determination of calcium and magnesium (AOAC, 2005). Iron was analysed by orthophenanthrolinered ferrous complex method (Jackson, 1969).

2.4 Determination of vitamins

The B vitamins, vitamin A and Vitamin E contents of the pepper foliage samples were estimated spectrophotometrically (UV/Vis 721N spectrophotometer, Measuretech Instrument, Shanghai China) using 1 cm pathlength cuvette, according to the methods described by Okwu and Emenike (2006) with some modifications. Briefly, 5 g of each sample was homogenized and extracted using a mixture of absolute ethanol and 5% potassium hydroxide (10:1) and boiled for 30mins under reflux before adding petroleum ether. The extract mix was evaporated to dryness on a rotary evaporator. Small amounts of the residue were re-dissolved in appropriate carrier solvents for each vitamin. Vitamin standards were prepared in the carrier solvents at different concentrations. Their absorbance was read and used to create the calibration curves used to calculate the concentration of the vitamin on a dry weight basis. The absorbance of the vitamins was monitored as followed: thiamine (vitamin B1) at 360 nm, riboflavin (Vitamin B2) at 510 nm, niacin (vitamin B3) at 470 nm, vitamin A at 450 nm and vitamin E at 295 nm.

Vitamin C was determined titrimetrically after homogenizing each sample in 50 mL 5.6 mM EDTA solution. The homogenized samples were filtered using Whatman No.1 filter paper. Approximately 10 mL of 30% potassium iodide was added to 20 mL of filtrate and mixed thoroughly. The mixture was titrated against 0.1M $CuSO_4$ to a dark endpoint using 1% starch solution as the indicator (Okwu and Emenike, 2006).

2.5 Phytochemical determination

The Phytochemicals in each pepper foliage samples were investigated. Total polyphenols were determined by the Folin–Ciocalteu assay (AOAC, 2005), while oxalate was determined by titrimetry as described by (Gupta *et al*., 2005). Total tannins, cyanides and phytic acid contents were determined by Folin-Dennis assay, alkaline picrate assay, and 2,2-bipyrimidine solution assay, respectively, as described by (Yasmin *et al*., 2008). Gravimetric estimations of total alkaloids, total saponins and total flavonoids were carried out following the protocols described by Harborne (1998). Phytosterol was determined spectrophotometrically after precipitation (Kasal *et al*., 2010).

2.6 Statistical analysis

One way analysis of variance (ANOVA) was used to analyse the data (two replicates) using SPSS (IBM, Version 21, USA). Multiple comparisons were made for all experiments using Duncan's Multiple Range Test at a probability of p=0.05 and the results were expressed as mean ± standard deviation.

3. Results and discussion

3.1 Proximate composition

The proximate composition results of the pepper foliage are shown in Table 1. Moisture content ranged between 86 to 88% with foliage from Habanero pepper and Anahiem pepper having the highest and least value respectively. There was a significant difference ($p<0.05$) in moisture content of the pepper foliage except those of Cayenne, Bird's eye and Bell. The moisture content of the pepper foliages was comparable to the moisture content of *Rumex vesicarius* (89.75%) (Alfawaz, 2006), some indigenous vegetables grown in Sri Lanka (Nadeeshani *et al.,* 2018), *Cnidoscolus acontifolius* (82.16%), *Telferia occidentalis* (86.28%) (Otitoju *et al.,* 2014). Moisture in vegetables affects the succulent nature amongst other compounds such as cellulose network and lignin content. Water is an important constituent in food composition databases as it is one of the most diverse components in plant foods that affect the composition of food generally (Greenfield and Southgate, 2003). The high moisture content of the pepper foliage indicates freshness and perishability due to high water activity.

The crude protein content of the foliage showed a range of 1.20 to 3.50%. Anahiem and Scotch Bonnet pepper foliage had the maximum and minimum crude

Table 1. Proximate composition and energy values of pepper foliage

Sample	Moisture (%)	Crude protein (%)	Fat (%)	Crude Fibre (%)	Ash (%)	Carbohydrate (%)	Energy Value (kcal/100 g)
Anahiem	$86.00±0.00^d$	$3.50±0.00^a$	$2.60±0.00^c$	$2.50±0.00^b$	$2.75±0.00^b$	$2.65±0.00^a$	$39.76±0.00^b$
Cayenne	$86.90±0.14^c$	$3.28±0.11^b$	$2.75±0.07^{bc}$	$2.00±0.00^c$	$2.50±0.00^c$	$2.58±0.32^a$	$40.20±0.29^b$
Bird's eye	$87.10±0.14^c$	$3.15±0.00^c$	$2.80±0.00^b$	$2.40±0.14^b$	$3.20±0.07^a$	$1.35±0.55^b$	$35.94±1.26^c$
Scotch Bonnet	$88.60±0.14^a$	$1.20±0.00^e$	$2.60±0.00^c$	$2.90±0.14^a$	$2.00±0.00^d$	$2.70±0.00^a$	$34.33±0.00^d$
Bell pepper	$87.00±0.00^c$	$2.80±0.00^d$	$3.70±0.14^a$	$1.80±0.00^d$	$2.50±0.00^c$	$2.20±0.14^a$	$45.66±0.68^a$
Habanero	$88.00±0.00^b$	$3.15±0.00^c$	$2.40±0.00^d$	$2.80±0.00^a$	$1.30±0.14^e$	$2.35±0.14^a$	$36.16±0.51^c$

Values are presented as means±standard deviation. Values with different superscripts in the same column are significantly different ($p<0.05$)

protein content respectively. There was no significant differences ($p>0.05$) in crude protein contents of Bird's eye and Habanero pepper foliage. The crude protein content of the pepper foliage is quite low, hence cannot make a significant protein contribution to vegan meals. However, Anahiem pepper foliage crude protein content was comparable to the crude protein of a *Amaranthus hybridus* (3.58%) (Medoua and Oldewage-Theron, 2014) but lower than the crude protein content of *Amaranthus viridis* (4.25%), *Sesbania grandiflora* (7.17%) (Nadeeshani *et al.,* 2018) but lower than crude protein for *Psychotria spp* (11.75%), *C. acontifolius* (4.83%), *T.occidentalis* (5.26%) (Otitoju *et al.,* 2014).

Fat content ranged between 2.40 to 3.70% with Habanero and Bell pepper foliage having the lowest and highest values respectively. The fat content of all the pepper foliage was fairly higher than the fat content of all the vegetables reported by Nadeeshani *et al*. (2018) which ranged between 0.29 and 1.81g/100 g, *C. acontifolius* (1.61%), *T. occidentalis* (1.25%) (Otitoju *et al*., 2014); *R. vesicarius* (0.66%) (Alfawaz, 2006). The low-fat content of the pepper foliage agrees with the findings of Ejoh *et al*. (1996) who reported vegetables as a poor source of fat.

The crude fibre content of the pepper foliage ranged between 1.80 to 2.90%. There were no significant differences ($p>0.05$) in crude fibre content in some of the pepper foliage (Table 1). Fibre is indigestible in the upper gastrointestinal tract of humans but nutritionally important. Fibre helps to maintain good digestive health, lower the risk of certain disease conditions such as diabetes mellitus (Type 2), cancer of the digestive system, improve skin health by flushing toxins of the body as well as reduce the risk of metabolic syndromes linked to coronary heart disease and stroke (Nutrition Source, 2020).

Ash is a measure of the mineral content of foods. Ash content of the pepper foliage ranged between 1.30 and 3.20%. Bird's eye pepper foliage had the highest ash content, and this indicates that it will provide more minerals than the other pepper foliage studied. Carbohydrate contents of all the pepper foliage were generally low. Energy values ranged between 34.33 and 45.66 Kcal/100 g. Bell pepper foliage had the highest energy value while Scotch Bonnet pepper foliage had the least value. Energy values of the pepper foliage were higher than the energy values of *A. hybridus* (23.70 kcal/100 g) (Medoua and Oldewage-Theron, 2014), *Amaranthus incurvatus* (13.7 kcal/100 g) (Asibey-Berko and Tayie, 1999) but lower than energy values of *Corchorus tridens* (48.7 kcal/100 g), *Solanum nigrum* (47.5 Kcal/100 g) and *Ipomea batatas* leaves (48.70 kcal/100 g) all on a fresh weight basis (Asibey-Berko and Tayie, 1999). The low energy of foods on fresh weight basis can be attributed to low total solids hence low nutrient densities due to high moisture content.

3.2 Vitamins

The results indicated the presence of water-soluble vitamins B_1, B_2, niacin (B_3) and C as well as fat-soluble vitamins A and E. As shown in Table 2, these vitamins varied significantly ($p<0.05$) in the various pepper foliage. The order of concentration of these vitamins in the pepper foliage was: Vit. C > Vit. A > Vit. E > Vit. B_2 > Vit. B_1 > Vit. B_3. The range of concentration of the vitamins in the pepper foliage were as follows: Vitamin A: 4.89-7.83 mg/100 g; Vitamin B_1:1.06-1.40 mg/100 g; Vitamin B_2: 2.57-3.22 mg/100 g; Vitamin B_3: 0.12-0.32 mg/100 g; Vitamins C: 59.45-87 mg/100 g and Vitamin E: 4.53-5.81 mg/100 g. Cayenne pepper foliage had the highest vitamins A, B_1, B_3 and E contents while Anahiem pepper foliage had the highest Vitamins B_2 and C contents. Vitamin A content of the foliage have the potential to meet the recommended dietary allowance (RDA) of 400 to 1300 μg/day for different life stages and gender groups of healthy individuals (FNB/IM/NA, 2001). Vitamin A content of Anahiem, Cayenne, Bird's eye and Scotch Bonnet were higher than Vitamin A contents of *Psychotria*spp (5.31 mg/100 g), *C. acontifolius* (0.66 mg/100 g) and *T. occidentalis* (1.23 mg/100 g) (Otitoju *et al*., 2014). Vitamin A is needed for normal vision, gene expression, reproduction, embryonic development and immune function (FNB/IM/NA, 2001). Vitamin E content of the pepper foliage is enough to meet with the adequate intake of 4-5 mg/day for infants and partly for intake of 6-7 mh/day for children of healthy individuals (FNB/IM/NA, 2000). Older children, males and females of healthy individuals will have to supplement from other food sources. Vitamin E is a non-specific chain breaking antioxidant (FNB/IM/NA, 2000). Its antioxidative activity is mainly in lipid bilayer of cells.

Vitamin B_1 content of the pepper foliage were higher than vitamin B_1 content of fresh *T.occidentalis* (0.08mg/g)(Okpalamma *et al*., 2013) and *Pterocarpus mildbraedii* (0.25mg/g) (Okpalamma *et al*., 2016). Vitamin B_1 of the pepper foliage can meet 0.2-1.2 mg/day RDA for infants, children, males and females of healthy individuals relatively; but pregnant and lactating females require 1.4 mg/day (FMN/IM/NA, 1998) and so will need supplementation from other food sources. Vitamin B_2 of the pepper foliages will be sufficient to meet with RDA of 0.3-1.6 mg/day (FNB/IM/NA, 1998) for different life stages and gender groups of healthy individuals. Vitamin C content of the all the pepper foliage were higher than 36.6 mg/100 g reported as Vitamin C content of *Amaranthus hybridus* (Medoua and Oldewage-Theron,

Table 2. Vitamin content of pepper foliage

Sample	Vitamin A (mg/100 g)	Vitamin B_1 (mg/100 g)	Vitamin B_2 (mg/100 g)	Vitamin B_3 (mg/100 g)	Vitamin C (mg/100 g)	Vitamin E (mg/100 g)
Anahiem	6.59±0.09[b]	1.26±0.0[b]	3.22±0.0[a]	0.18±0.0[b]	87.00±0.2[a]	4.72±0.00[e]
Cayenne	7.38±0.00[a]	1.40±0.0[a]	3.09±0.0[b]	0.32±0.0[a]	59.45±0.0[c]	5.81±0.03[a]
Bird's eye	6.22±0.00[c]	1.06±0.0[e]	2.84±0.0[c]	0.29±0.2[a]	66.39±0.1[b]	5.06±0.00[c]
Scotch Bonnet	6.42±0.04[b]	1.12±0.0[d]	2.57±0.0[e]	0.17±0.3[b]	59.59±0.1[c]	5.72±0.00[b]
Bell pepper	5.65±0.00[d]	1.21±0.0[c]	2.61±0.0[e]	0.28±0.0[a]	54.97±0.3[d]	4.53±0.00[f]
Habanero	4.89±0.13[e]	1.17±0.0[c]	2.74±0.0[d]	0.12±0.0[c]	59.34±0.16[c]	4.90±0.00[d]

Values are presented as means±standard deviation. Values with different superscripts in the same column are significantly different ($p<0.05$)

2014).Vitamin C content of the pepper foliage will be sufficient to meet with RDA for infants (40-50 mg/day), children 1-8 years (15-25 mg/day) but not sufficient to meet with RDA of >75 mg/day (FNB/IM/NA, 2000) for adult males and females of different life stages of healthy individuals. Therefore, adults have to supplement for Vitamin C from other food sources.

3.3 Minerals

The mineral content of the various pepper foliage is shown in Table 3. Results indicated a significant difference ($p<0.05$) in mineral content of the pepper foliage. The order of concentration of minerals was potassium > sodium > magnesium > calcium > phosphorus > iron > zinc. The concentration of the minerals was as follows: Calcium: 31.32-43.33 mg/100 g; Magnesium: 34.50-74.51 mg/100 g; Phosphorus: 23.89-45.02 mg/100 g; Sodium: 75.49-87.43 mg/100 g; Potassium: 73.45-95.17 mg/100 g; Iron: 2.72-5.77 mg/100 g and Zinc: 1.37-2.47 mg/100 g. Scotch Bonnet pepper foliage had the highest calcium and magnesium contents; Cayenne pepper foliage had the highest phosphorus, potassium and iron contents; Anahiem pepper foliage had the highest zinc content while Bell pepper foliage had the highest sodium content.

Calcium and magnesium contents of the pepper foliage were higher than calcium and magnesium content of vegetables reported by Otitoju *et al.* (2014) which ranged between 0.96 -3.09 mg/100 g and magnesium ranged between 0.71-2.39 mg/100 g; calcium and magnesium contents of selected leafy vegetables grown in Sri Lanka which ranged between 1.52-11.17 mg/100 g and 0.51-1.59 mg/100 g respectively (Nadeeshani *et al.*, 2018). Phosphorus content of the pepper foliage were lower than phosphorus content of vegetables reported by Otitoju *et al.* (2014) which ranged between 58.34 and 243.70 mg/100 g on fresh weight basis. Phosphorus, sodium and potassium content of the pepper foliage will be insufficient to meet with 100-1250mg/day for phosphorus (FNB/IM/NA, 1997), 0.12-1.5g/day for sodium and 0.4-5.1g/day requirement for potassium (FNB/IM/NA, 2004) needed for different life stages of healthy individuals. Therefore, there is need for supplementation from other food sources. sodium is required to maintain extracellular fluid volume and for normal cell function while potassium is required for the maintenance of both intracellular and extracellular fluid volume required for normal cell function as well as blunting the rise of blood pressure in response to excess sodium intake (FMB/IM/NA, 2004).

Zinc and iron contents of the pepper foliage evaluated were higher than zinc and iron contents of some selected Sri Lanka vegetables which ranged between 4.03 and 34.69 µg/g for zinc and 40.65 and 207.34 µg/g for iron (Nadeeshani *et al.*, 2018). In consuming any of this pepper foliage, there is a need to supplement from other food sources in order to meet with RDA of 2-13 mg/d and 7-27 mg/day for zinc and iron respectively (FNB/IM/NA, 2001). Zinc and iron are

Table 3. Mineral content of pepper foliage

Sample	Calcium (mg/100 g)	Magnesium (mg/100 g)	Phosphorus (mg/100 g)	Sodium (mg/100 g)	Potassium (mg/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)
Anahiem	32.71±0.34[d]	68.02±0.25[b]	30.54±0.24[d]	78.59±0.00[e]	92.10±0.00[b]	4.24±0.08[b]	2.47±0.00[a]
Cayenne	31.32±0.36[e]	46.39±0.00[d]	45.02±0.23[a]	84.20±0.23[b]	95.17±0.00[a]	5.77±0.00[a]	2.21±0.04[b]
Bird's eye	38.05±0.00[c]	41.69±0.21[e]	32.56±0.27[b]	80.17±0.00[c]	81.45±0.00[d]	4.25±0.18[b]	1.76±0.00[e]
Scotch Bonnet	43.33±0.35[a]	74.51±0.41[a]	31.09±0.00[c]	79.22±0.00[d]	86.29±0.00[c]	3.43±0.23[c]	2.07±0.04[c]
Bell pepper	32.95±0.00[d]	34.50±0.43[f]	26.31±0.19[e]	87.43±0.36[a]	76.03±0.29[e]	2.72±0.00[d]	1.92±0.06[d]
Habanero	41.77±0.17[b]	56.19±0.00[c]	23.89±0.00[f]	75.49±0.14[f]	73.45±0.39[f]	2.96±0.00[d]	1.37±0.00[f]

Values are presented as means±standard deviation. Values with different superscripts in the same column are significantly different ($p<0.05$)

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Table 4. Phytochemical content of pepper foliage

Phytochemical	Pepper Sample					
	Anahiem	Cyanenne	Bird's eye	Scotch Bonnet	Bell Pepper	Habanero
HCN (mg/kg)	8.45±0.00^{d}	8.43±0.04^{d}	9.45±0.02^{a}	6.95±0.00^{e}	8.91±0.04^{c}	9.41±0.02^{b}
Oxalate (mg/100 g)	0.28±0.06^{a}	0.18±0.00^{bc}	0.24±0.00^{ab}	0.14±0.02^{c}	0.16±0.01^{c}	0.18±0.00^{bc}
Alkaloid (%)	3.10±0.14^{c}	4.85±0.21^{a}	4.00±0.00^{b}	3.90±0.14^{b}	5.10±0.10^{a}	3.00±0.14^{c}
Saponin (%)	3.00±0.00^{a}	2.10±0.14^{c}	1.00±0.00^{d}	1.90±0.14^{c}	2.90±0.14^{a}	2.50±0.00^{b}
Phytate (mg/100 g)	11.45±0.04^{c}	12.72±0.08^{a}	9.76±0.00^{e}	7.65±0.00^{f}	12.30±0.11^{b}	9.98±0.08^{d}
Phenol (mg/100 g)	1.75±0.00^{a}	1.04±0.02^{b}	0.34±0.02^{d}	0.18±0.00^{e}	0.97±0.04^{c}	0.94±0.03^{c}
Tannin (mg/100 g)	1.28±0.00^{f}	1.82±0.03^{d}	2.19±0.00^{a}	1.94±0.05^{c}	2.10±0.03^{b}	1.43±0.03^{e}
Flavonoid (mg/100 g)	4.00±0.00^{a}	2.00±0.00^{e}	3.00±0.00^{b}	2.75±0.07^{c}	2.70±0.00^{c}	2.40±0.14^{d}
Phytosterol (mg/100 g)	0.63±0.05^{c}	1.90±0.04^{a}	1.12±0.05^{b}	0.53±0.00^{d}	0.37±0.00^{e}	0.34±0.00^{e}

Values are presented as means±standard deviation. Values with different superscripts in the same row are significantly different ($p<0.05$).

important essential micronutrients needed for normal body function. Zinc is reported to improve male fertility (Igile *et al*., 2013) and it is a component of multiple enzymes and proteins and is involved in the regulation of gene expression (FNB/IM/NA, 2001). Iron is a component of haemoglobin and numerous enzymes and is also required to prevent microcytic hypochromic anaemia (FNB/IM/NA, 2001).

3.4 Phytochemicals

The concentration of different phytochemicals found in the pepper foliage are shown in Table 4. Results indicated a significant difference ($p<0.05$) in the phytochemical composition of the foliage. Hydrogen cyanide was in the range of 6.95-9.45 mg/kg with foliage from Scotch Bonnet pepper having the least value while Bird's eye pepper had the highest value. Hydrogen cyanide is a systemic poison whose toxic effects is due to the inhibition of cytochrome oxidase hence preventing the uptake of oxygen (NRC, 2002). Hydrogen cyanide is a hydrolysis product of cyanogenic glycosides. Cyanogenic glycosides are reduced by heat temperatures (Kemdirim *et al.,* 1995). Therefore, there is need to process pepper leaves before consumption as opposed to direct use as salad ingredient.

Oxalate content of the pepper foliage ranged between 0.14 and 0.28 mg/100 g. Abdel-Moemin (2014) classified foods with less than 10 mg oxalate as low oxalate foods. Therefore, oxalate content of the pepper foliage identifies them as low oxalate vegetable/foliage. Alkaloids and saponins were in the range of 3-4.85% and 1-3% respectively. Foliage from Cayenne pepper had the highest alkaloid content while foliage from Anahiem pepper had the highest saponin content. Alkaloids are mostly nitrogenous heterocyclic compounds and have various biological activities when consumed by animals including man. Alkaloids have medicinal properties such as cytotoxicity, anti-spasmodic, analgesic and bactericidal properties (Stray, 1998). Oral ingestion of saponins at moderate concentrations through diet has beneficial effects such as being hypocholesterolemic, anti-cancer, anti-infertility and anti-inflammatory effects (Sodipo *et al*., 2000; Agiang *et al*., 2016).

Phytate content of the foliage ranged between 7.65 to 12.72 mg/100 g. Cayenne pepper foliage had the highest concentration. Dietary phytates chelate divalent mineral cations, reducing their bioavailability and hence absorption; they also bind proteins and also reduce starch digestion (Uusiku *et al*., 2010). Akwaowo *et al*. (2000) stated that a phytic acid intake of 4-9 mg/100 g reduces iron absorption in humans by 4-5fold. This implies that improper processing of the pepper foliage can reduce the bioavailability of divalent cationic minerals when consumed. However, phytate losses during cooking has been reported and can be due to interaction of hot water with plant cell walls which rupture and soluble phytates probably leach into the medium (Yadav and Sehgal, 2003). There is a need for heat processing of pepper foliage to ensure reduced phytate content before consumption. Its phytosterol content ranged between 0.34 to 1.90 mg/100 g with foliage from Cayenne pepper having the highest value.

Results indicated the presence of phenols, tannins and flavonoids in the pepper foliage. There were significant variations ($p<0.05$) in these phytocompounds. The range of concentration of phenols, tannins and flavonoids were as follows: Phenols: 0.18-1.75 mg/100 g; tannins: 1.28-2.19 mg/100 g; flavonoids: 2-4 mg/100 g. Anahiem pepper foliage had the highest phenolic and flavonoid contents while Bird's eye foliage had the highest tannin content. Flavonoid and tannin contents of the pepper foliages were higher than flavonoid (0.02-0.05 mg/100 g) and tannin contents (0.21-0.67 mg/100 g) reported for lesser-known vegetables (Agiang *et al.,* 2016). Phenols, tannins and flavonoids contribute to dietary intake of antioxidants because of free hydroxyl groups in their structures and they have varying biological effects. Antioxidative effect of phenolic compounds is due to their ability to serve as free radical terminators, hence having medicinal activity and exhibiting physiological functions (Ajayi *et al*., 2011). Flavonoids antioxidative outcome is owing to its free radical scavenging effect (Omale and Okafor, 2007). Tannins are a class of water-soluble phenolic compounds, and their biological effects depends on type/ class as well as concentration ingested. Tannin content of plant extracts influence their biological activity (Marsh *et al*., 2020). Wong *et al*. (2006) reported that plants which contain substantial quantities of polyphenols can exhibit strong antioxidant activity and contribute to their medicinal properties. This entails that what was present as phenolic, flavonoid and tannin contents in the respective pepper foliage can contribute to the beneficial effects attributed to them.

4. Conclusion

The findings from this study indicated variations in nutrient and phytochemical content of the respective pepper foliage. The high moisture content resulted to low nutrient density. Results indicated the presence of fat- and water-soluble vitamins. Vitamins A, B1 and B2 contents of pepper leaves will be sufficient to meet with the recommended dietary allowance (RDA) for healthy individuals while older children and adults will have to supplement for vitamins E and D from other food sources. Oxalate was low but hydrogen cyanide and phytates were quite appreciable. Therefore, there is need for heat processing before consumption. The pepper foliage had beneficial phytochemicals such as phenols, tannins, flavonoids, saponins, alkaloids. The investigation of nutrients and phytochemicals present in this pepper foliage has provided information for the establishment of dietary guidelines on the consumption of pepper foliage. Therefore, consumption of any of the pepper foliage as vegetable may have additional value such as nutrition security and can prevent hidden hunger with respect to the high vitamin A content.

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