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Macronutrients and Antioxidant Assessments in Selected Vegetables across Kaduna Metropolis, Kaduna State, Nigeria

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ABSTRACT
Vegetables are important components of a healthy diet because they provide essential minerals and bioactive compounds that contribute to normal physiological functions and protection against oxidative stress. This work studied macromineral composition and antioxidant activity of twelve vegetables used in Kaduna Metropolis, Nigeria. Vegetables included avocado, beans, broccoli, cabbage, carrot, cauliflower, celery, eggplant, lettuce, peas, potato and spinach from five markets in the metropolis. Energy Dispersive X-ray Fluorescence (EDXRF) was used to analyses for phosphorus (P), sulphur (S), calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na). Spectrophotometric measurements were used to determine total phenolic content (TPC), total flavonoid content (TFC), vitamin C, ferric reducing antioxidant power (FRAP), and 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging activity. Macrominerals concentrations varied considerably among the vegetables. The highest concentrations were found for potassium (13.63 - 33.18 mg/kg), phosphorus (1.02 - 3.60 mg/kg), sulphur (0.89 - 5.71 mg/kg), calcium (2.17 - 33.92 mg/kg), magnesium (0.70 - 12.63 mg/kg), and sodium (below detection - 28.73 mg/kg); whereas the highest values for the antioxidant parameters were for total phenolic content (12.07 - 156.95 mg GAE/g), total flavonoid content (75.00 - 152.70 mg QE/g), vitamin C (99.53 - 258.39 mg AAE/g), FRAP (11.52 - 82.02 mg AAE/g), and DPPH activity (32.30 – 95.33%). Potato had highest total phenolic content, celery highest vitamin C, avocado highest FRAP value and lettuce highest DPPH radical-scavenging activity. The results indicate that these vegetables contain macro-minerals and antioxidants that may contribute to dietary nutrients and antioxidants intake.

Keywords: Macronutrients, Antioxidant, Assessments, Vegetables, Kaduna, Nigeria

INTRODUCTION

Vegetables are a key food source for rural and urban communities, and play a vital role in people's nutrition and health (Noopur et al., 2023). They are generally believed to be protective foods as they contain beneficial nutrients and bioactive compounds which aid in maintaining normal physiological functions and may have protective effects against nutrition-related diseases (Wang et al., 2023). These nutrients are proteins, vitamins, minerals, dietary fibre and phytochemicals that help keep the gastrointestinal tract healthy, ensure normal vision and promote overall health (Oyegoke et al., 2023; Gupta & Mishra, 2021). The nutritional content of vegetables, therefore, is important to know especially in populations where vegetables are a significant component of the diet.

Mineral content is one of the vital factors to determine the nutritional value of vegetables. The minerals serve a variety of physiological functions including fluid and electrolyte balance, acid base balance, bone formation, energy metabolism, nerve transmission and muscle function. Calcium and phosphorus are the major components of bones and teeth; potassium and sodium are involved in fluid balance, nerve impulse transmission and muscle activity. Magnesium plays a role in various metabolic processes and normal neuromuscular function, while sulphur is a part of the structure and function of important biological compounds (Babaali et al., 2020; Emebu & Anyika, 2011). Vegetables consequently are a good source of these mineral elements in the diet.

However, the mineral content of vegetable crops is not consistent and can differ from species to species, depending on genetic traits, soil type, cultivation methods, location, and the environment. The nutrient content of vegetables can be affected by their cultivation conditions (Hoogendijk et al., 2023) and mineral availability in the soil and interactions among minerals in the plant uptake process. This variation is significant for the evaluation of the mineral composition of vegetables in particular environments, as it can influence the nutrient contribution of vegetables in that environment. These minerals include potassium which is important for fluid balance, transmission of nerve impulses, and contraction of muscles and cardiovascular and nervous systems (Tareen et al., 2023). Calcium and phosphorus are involved in bone and teeth formation and maintenance while Magnesium is involved in carbohydrate and protein metabolism and neuromuscular activity (Keyata 2026; Babaali et al., 2020). Sodium is also needed, but in lesser amounts, for extracellular fluid balance and normal nerve and muscle function.

Vegetables are rich in minerals as well as in antioxidant compounds, which help them in their nutritional and functional value. Phenolic compounds, flavonoids, vitamin C and other phytochemical compounds with antioxidant properties are found in plant foods (Chacón-Fuentes et al., 2025). These compounds may be able to counteract the

activity of reactive molecules and prevent oxidative damage to biological components. One of the key compounds of plants that have been studied for its antioxidant properties is phenolics and flavonoids; they have been a lot of research attention due to their potential health promoting properties (Rizvi et al., 2022). Vitamin C is also an important antioxidant nutrient which helps the body's antioxidant defence system. To assess the antioxidant properties, several complementary analysis methods are used, such as total phenol content (TPC), total flavonoid content (TFC), vitamin C content, ferric reducing antioxidant power (FRAP) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging activity.

Vegetables are valuable foods because of the minerals, vitamins, dietary fibre, phenolic compounds, flavonoids and other bioactive ingredients they contain. Opazo-Navarrete et al. (2021) noted that vegetables could be used as natural sources of functional ingredients. In a similar manner, Tripathi et al. (2025) highlighted the significance of the study of edible vegetables to determine its nutritional value and health benefits for human consumption and use as natural ingredients. Vegetables are especially relevant in terms of nutrition contribution to dietary quality and food security, particularly in developing countries, where plant foods are among those that are important and relatively accessible sources of nutrients. But the contribution is dependent on the specific vegetable eaten, its nutritional content, the quantity consumed, and the type of diet.

Vegetables are important sources of essential minerals such as calcium (Ca), magnesium (Mg), phosphorus (P), potassium (K), sodium (Na), iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu), which are required for normal physiological functions. In Singapore, analysis of 31 green leafy vegetables showed wide differences in Ca, K, Na, P, Mg, Cu, Fe, Mn and Zn concentrations, with several vegetables identified as important sources of calcium and potassium (Tan et al., 2023). Comparative study of nine African leafy vegetables reported substantial differences in K, Ca, Mg, P, Fe and Zn among species (Lugumira et al., 2025). Ibrahim et al. (2021) reported differences in Ca, Mg, K, Na, Fe, Zn and Mn among leafy vegetables sold in Jos, Plateau State. Musa et al. (2025) also reported differences in Na and K among nine leafy vegetables marketed in Lapai, Niger State. Mustapha and Dahiru (2026) found variations in Ca, K, Fe and Zn among cabbage, lettuce and *Moringa oleifera* grown around Gwaigwaye Dam, Katsina State.

Avocado, beans, broccoli, cabbage, carrot, cauliflower, celery, eggplant, lettuce, peas, potato & spinach are popular vegetables in Kaduna Metropolis. The present study therefore, evaluates the macromineral content and antioxidant properties of these selected vegetables from the 5 markets in Kaduna metropolis. Phosphorus, sulphur, calcium, magnesium, potassium and sodium are measured by Energy Dispersive X-ray Fluorescence (EDXRF) technique and antioxidant properties are evaluated by TPC, TFC, vitamin C, FRAP and DPPH assays. The study therefore involves a combined evaluation of the mineral and antioxidant properties of the selected vegetables in Kaduna metropolis of Kaduna State, Nigeria and adds to the existing body of knowledge on the nutritional and potential health promoting benefits of locally available vegetables

MATERIALS AND METHODS

Sample Collection

Vegetable samples (12) of different type such as carrots, sweet potatoes, celery, lettuce, spinach, cabbage, broccoli, cauliflower, eggplant, avocado, peas and beans were collected each from five different markets locations in Sabo, Central, Tudun Wada, Kawo, and Mando in the Kaduna metropolis and these gave sixty (60) samples altogether. The samples were wrapped into paper bags and properly labelled. The same vegetable types from different markets were pooled together to form a composite of each sample that represents a vegetable type within Kaduna Metropolis (Imongben et al., 2026).

Sample Preparation and Preservation

The 12 vegetable samples (carrots, sweet potatoes, celery, lettuce, spinach, cabbage, broccoli, cauliflower, eggplant, avocado, peas, and beans) were washed thoroughly with distilled water to remove the dust particles and other contaminants on the surface of the vegetables. The samples were dried in an oven at 105 °C until they became crisp and cut into pieces with a knife. Vegetable samples were dried, ground to powder and were used in this study. 100 g of each vegetable sample was kept for analysis. Samples were placed in labeled and sealed plastic bottles (Noli and Tsamos, 2016).

Determination of Macromineral Contents of Vegetables

Powdered 5 g sample of each vegetable was mixed with a 0.3 g of binder starch for better consistency. The mixture was pressed into 32 mm diameter pellets using a hydraulic press at 20 tons of pressure. The samples were analysed for Na, K, Ca, Mg, P, S and Cl using EDXRF. All prepared samples were made in replicates for statistical reliability (Garzon et al., 2026).

Determination of Total Phenolic Content

Vegetable sample total phenol concentration was measured by the Folin-Ciocalteu method using UV/Visible spectrophotometer (Esievo et al., 2020). The extraction solution (1mL) was placed in a 25mL volumetric flask and distilled water (9mL) added to it. Folin-Ciocalteu phenol reagent 1 ml of 10 % was added to the mixture and shaken vigorously. Then 10ml of 7% sodium carbonate solution (Na2CO3) was added to the mixture after 5 minutes. The solution had a distilled water solution to the mark. The mixture was allowed to stand at room temperature for 90 minutes and the absorbance of sample solution was measured at 760 nm on an Agilent Carry 60 ultraviolet UV/Visible spectrophotometer. The phenolic content in the sample is reported in mg of gallic acid equivalents/g of extract.

Gallic Acid Calibration Curve

The stock solution was serially diluted to produce a series of solutions containing 20, 30, 60, 80 and 100 µg/mL of gallic acid. The 1 ml of each concentration of gallic acid standard solution was transferred to a 25 ml of volumetric flask and 9 mL of distilled water was added to the volumetric flask. To the mixture was added 1 ml of 10% folin-ciolate reagent and shaken vigorously. After 5 minutes, 10 ml of 7% sodium carbonate solution (Na_2CO_3) was added to the mixture. Distilled water was added to make up the 25 ml volumetric flask. The solution mixture was allowed to incubate for 35 minutes at room temperature. An Agilent Carry 60 ultraviolet (UV/Visible spectrophotometer was used to measure the absorbance of the standard solutions at 760 nm. This result was used to prepare absorbance-concentration curve.

Determination of Flavonoid Content

The content of flavonoids was determined by the aluminium chloride method by using UV/Visible Spectrophotometry. 1 ml was transferred into a 10 ml volumetric flask and 3 ml of distilled water was added to it. Sodium nitrite 0.30 ml of 5 %

solution was added and after 5 minutes 0.3 ml of 10 % aluminium chloride was added. After 5 minutes 2 ml of 1M sodium hydroxide solution was added and up to the mark with distilled water. The absorbance of the solution is then measured at 510 nm on an Agilent Carry 60 UV/Visible spectrometer. The total flavonoids content was calculated as mg Quercetin equivalent/g extract (Esievo et al., 2020).

Quercetin Calibration Curve

The stock solution of quercetin is serially diluted in order to prepare a series of 20, 30, 60, 80 and 100 µg/ml of quercetin standard solutions. Each standard solution of Quercetin was placed (1 ml) in 10 ml volumetric flask and distilled water (3 ml) added. Then 0.30 ml of 5% sodium nitrite was added and after 5 minutes 0.3 ml of 10% aluminum chloride. This was followed by the addition of 2ml of 1M sodium hydroxide after 5 minutes and then the mixture was diluted to 10ml with distilled water. Reaction solution is measured in an Agilent Carry 60 UV/Visible spectrophotometer at 510 nm. This was used to produce a graph of absorbance vs concentration (a standard curve)

Determination of Vitamin C Content

A sample was prepared by weighing 10.0 g of the sample into a beaker. The sample was added to 50ml of metaphosphoric acid acetic acid solution and transferred into the conical flask of 250ml. This was thoroughly mixed and put into water bath for 10 minutes. Then the solution was filtered through Whatman filter paper. The remaining 5% metaphosphoric acid-acetic acid was added to this to make up the mark 10 in a volumetric flask of 10 ml capacity (Sandeep et al., 2022).Two drops of the bromine solution was added and mixed. Then two drops of thiourea solution was added into the sample solution to remove access of the bromine solution. The content of Vitamin C was estimated by 2,3-DNPH method by UV/Visible spectrophotometry. 1 ml of the 30 sample solution was placed in a 10 ml volumetric flask and then 2,3-dinitrophenylhydrazine solution 1 ml was added to it. After 3 hours this was incubated and after 3 hours it was cooled down on an ice bath, 5 ml of H_2SO_3 acid was added and made up to the mark with distilled water. UV/Visible Spectrophotometer was used to measure absorbance at 520 nm.

Ascorbic Acid Calibration Curve

Different concentrations of standard solution of ascorbic acid were prepared by serial dilution from stock solution. Weighing each solution, 1 ml was added to a 25 ml volumetric flask of each solution. 1ml of each reagent Dinitrophenylhydrazine was weighed and added to respective flasks. This solution was incubated for three hours and then 5.0 ml of sulfuric acid was added and the volume was made up to the mark with distilled water. The absorbance of the reaction solution was measured at 520 nm by using Agilent carry 60 UV/visible spectrophotometer.

Determination of Ferric Reducing Antioxidant Power (FRAP)

Reducing property of the vegetable extracts were evaluated by the reduction of FeCl3 solution as described by Oboh et al., (2012). 2.5ml of extracts of varying concentration (500, 250, 125 and 62.5 µg/ml) were each mixed with 2.5ml of phosphate buffer (pH 6.6) and 2.5ml of 30mM potassium ferricyanide. This mixture was incubated for 20 minutes and then 2.5ml of 600mM trichloroacetic acid was added. This mixture was made to centrifuge at 3000 rpm for 10 minutes and 2.5 ml of supernatant was mixed with 2.5 ml of distilled water and 1 ml of 6 mM ferric chloride. A UV/Visible spectrophotometer (Agilent carry 60) was used to measure the absorbance at 700nm.

Determination of DPPH Free Radical Scavenging Activity Assay

The free radical scavenging activity (2,2-diphenyl-1-picrylhydrazyl (DPPH)) of extracts from the vegetables was determined according to (Oboh et al., 2012). In the sample, the colour of the solution from purple to yellow is due to the antioxidant property. The 0.1 mM DPPH solution was obtained by dissolving in 1 mL of methanol. The extracts were diluted to various concentrations (600, 300, 150, 75 and 37.5µg/mL) and 1 mL of each extract was added to 1 mL of methanol. Then, the plant extract samples at various concentrations were mixed with 1 ml of DPPH solution in dark and at room temperature for 30 minutes. An Agilent carry 60 UV-Visible spectrophotometer was used to measure absorbance at 516 nm.The ascorbic acid was used as a control and the inhibition rate was calculated as follows:

$$\%inhibition = \frac{A_o - A_e}{A_o} * 100 \quad (1)$$

Ae=absorbance of sample, Ao=absorbance of control

RESULTS AND DISCUSSION

The results of macrominerals' contents of vegetables were presented in Tables 3.1.

Table 1shows the macronutrients (P, S, Na, K, Ca and Mg) in the evaluated vegetables. The average content of the macronutrient in the selected vegetables in this study ranged with values 2.17–33.92 mg/kg for Ca, 1.02–3.60 mg/kg for P, 0.70–12.63 mg/kg for Mg, 0.00–28.73 mg/kg for Na, 13.63–33.18 mg/kg for K and 0.89–5.71 mg/kg for S (on a dry weight basis).

The result obtained in Table 1shows that Na ranges between 0.00 mg/kg and 28.73 mg/kg. A relatively high concentration of sodium was found in cauliflower 28.73 mg/kg, followed by carrot 12.63 mg/kg, then broccoli 0.27 mg/kg while others (avocado, cabbage, celery, potato, pea, lettuce, spinach, beans and eggplant) were detected below the limit of detection of the instrument used. Adults require 500mg/day, infants 120-200 mg/day and children 225-500 mg/day (Fagbohun *et al.*, 2012). The deficiency will result in muscular cramps, high blood pressure and heart failure (Fagbohun *et al.*, 2012). Muhammad *et al.*, (2013) reported high values for Na in the range of 5.8 -12.8 g/Kg for bell pepper and onion which is in agreement with the carrot recorded in this study. Głosek-Sobieraj *et al.*, (2019) reported a higher value of potato in the range of 0.66–1.61 g/Kg. The overall average concentrations of the macronutrients were in the order of potassium > calcium > magnesium > sodium > sulphur > phosphorus. In this study, Ca was determined with values between 2.17 mg/kg and 13.81 mg/kg.

Table 1: Macronutrients Content of Selected Vegetables and Crops (mg/kg)

	P	S	Ca	Mg	K	Na
Avocado	1.63±0.10	1.50±0.15	7.55±0.71	5.66±0.57	39.35±3.93	0.00±0.00
Beans	2.68±0.28	3.81±0.38	9.03±0.80	3.38±0.35	36.86±3.69	0.00±0.00
Broccoli	1.93±0.21	2.95±0.30	2.17±0.20	1.58±0.16	18.36±1.83	0.27±0.03

	P	S	Ca	Mg	K	Na
Cabbage	3.60±0.51	3.70±0.37	5.35±0.38	3.81±0.39	32.83±3.28	0.00±0.00
Carrot	1.81±0.19	0.96±0.10	6.82±0.63	12.63±1.27	27.97±2.80	12.63±1.26
Cauliflower	1.95±0.19	3.75±0.38	3.13±0.18	0.70±0.07	25.76±2.58	28.73±2.88
Celery	2.18±0.33	2.96±0.30	3.55±0.31	3.09±0.31	23.53±2.36	0.00±0.00
Eggplant	1.96±0.22	1.50±0.15	5.78±0.58	6.68±0.67	31.89±3.19	0.00±0.00
Lettuce	1.38±0.21	1.53±0.16	13.81±1.25	2.67±0.27	30.37±3.03	0.00±0.00
Pea	1.67±0.19	5.71±0.57	13.75±0.82	1.79±0.18	39.33±3.93	0.00±0.00
Potato	1.02±0.11	0.89±0.09	3.36±0.32	2.67±0.27	33.18±3.32	0.00±0.00
Spinach	2.00±0.20	1.76±0.18	33.92±3.09	7.33±0.75	13.63±1.37	0.00±0.00

The lowest Ca levels recorded in this study were in broccoli samples and the highest in spinach samples. The daily nutrient requirement for adults is 800 mg, during pregnancy and lactation 1200 mg, for infants 300-600 mg, and for children 800-1200 mg (Babaali, *et al.*, 2020). Akpata (2011) reported that pumpkin leaves contained a calcium concentration of 3.38±0.012 mg/g, followed by bitter leaves (3.01±0.012 mg/g). Adotey *et al.* (2009) also reported that the calcium content of onions was 0.60 g/kg and the calcium content of garden eggs was 0.10 g/kg. Calcium levels recorded in this study were less than 1000 mg per day. Akpata (2011) reported that pumpkin leaves contained a calcium concentration of 3.38±0.012 mg/g, followed by bitter leaves (3.01±0.012 mg/g). Adotey *et al.,* (2009) also reported that the calcium content of onions was 0.60 g/kg and the calcium content of garden eggs was 0.10 g/kg.

S was determined in this study with values between 0.89 mg/kg in potatoes and 5.71 mg/kg in peas. The sulphur in peas is the highest (5.71mg/kg) among the selected vegetables. All diets adequate in protein contain adequate amounts of sulphur (Babaali, *et al.*, 2020). Sulphur helps to protect cells from damage and helps in promoting the loosening and shedding of skin. Its deficiency will result in cystinuria (Excessive urinary excretion of cystine) and renal calculus.

The phosphorus content measured in this study ranged from 1.02 to 3.60 mg/kg. The lowest value is recorded in the potato sample and the highest value was recorded in the cabbage sample. Phosphorus has a similar function to calcium in the body and has similar daily requirements. It is involved in the formation of bones and teeth and helps store and use energy in the body (Emebu and Anyika, 2011). Deficiency causes ticketing and osteomalacia. Other related studies have shown that calcium requirements can vary from culture to culture due to diet, genetics, lifestyle, and geography (FAO/WHO, 2011).

Mg content determined in this study ranges between 0.70 and 12.63 mg/kg. The lowest value was recorded in the cauliflower sample and the highest value in the carrot sample. Carrot has the highest concentration of Mg (12.63 mg/kg) in this study. However, Apkata, (2011) reported a high concentration of magnesium in bitter leaves and pumpkin leaves which are leafy vegetables. Magnesium is required in the body to maintain water balance and control nerve impulse transmission, carbohydrate, and protein metabolism (Babaali, *et al.*, 2020). Its deficiency will result in weak muscles, convulsions, as well as inhibition of muscle and nervous systems.

In this study, K was determined at values between 18.36 mg/kg for broccoli and 33.18 mg/kg for potato. The potassium content recorded in this study was compared with that of Asaolu *et al.,* (2012) and were found in lower concentrations in pumpkin leaves (130.23 mg/100 g), lettuce (168.96 mg/100 g), and bushbuck (99.01 mg/100 mg/100 g). Potassium controls nerve impulses and muscle contractions, contributing to maintaining fluid balance in the body and proper functioning of the muscles and nervous system (Ndie, 2013). Deficiency causes hyperkalemia, hypokalemia, paralysis, and hypertension. Generally, the values of macronutrients recorded in this study are lower than those reported in literature (Renthlei *et al.*, 2016; Masson *et al.*, 2010). However, the study showed that all the vegetable samples contained varied mean levels of macronutrients which could be attributed to factors such as variation in the genetic makeup of plant species and competitive interactions between metal ions within the lithosphere or variation in the amounts of the mineral in the soils where the vegetables grew (Anyawu *et al.*, 2003). Test of significance shows there is no statistically significant difference in the level of macronutrients in each of the vegetable samples selected for analysis ($p > 0.05$) whereas statistical significance exists among the macronutrients themselves ($p < 0.05$).

Antioxidants

Total Phenol Content (TPC) of Selected Vegetables

The results shown in Table 3.3 shows that the total phenolic content of all selected vegetable samples ranges from 12.07 for peas to 156.96mg GAE/g dry weight for potatoes. In this study, peas were observed to have the lowest total phenolic content compared to other vegetable samples. The analysis of total phenols in the 12 selected vegetables shows that potato, eggplant, broccoli, cabbage, celery, and carrot are the ones that had high phenol content. This vegetable contains more phenols than beans, peas, cauliflower, and spinach. González-Burgos and Gómez-Serranillos (2012) reported that the vegetable with the highest total phenolic content was lettuce. This is consistent with the opinion of Nirmala et al., (2020), who reported higher TPC values of 226.3 ± 1.13 mgGAE/g dry weights in some fruits. Phenolic compounds are one of the major compounds known to act as primary antioxidants or radical stoppers (Fawole et al., 2009).

Total Flavonoid Content (TFC) of Selected Vegetables

The results shown in Table 3.3 shows that the total phenolic content of all selected vegetable samples ranges from 12.07 for peas to 156.96 mgGAE/g dry weight for potatoes. Flavonoid in the selected vegetables shows that celery, potato, spinach, peas, broccoli, eggplant and lettuce contain high flavonoids while the lowest flavonoid concentration is found in avocado with 75.00 mg quercetin equivalents (QE)/g. Jideani et al., (2021) showed that vegetables rich in flavonoids such as beans, broccoli, endive, leek, onion, and tomato were able to influence absolutely on cancerous conditions as they stimulate enzymes involved in the detoxification of carcinogenic substances and inhibit inflammation associated with local production of free radicals. The study is in agreement with Nirmala, et al., (2020) who reported a high value of 135.17 mg quercetin equivalents (QE)/g in fruits.

Vitamin C Content of Selected Vegetables

In this work for the determination of vitamin C in the selected vegetables that were collected from 5 five different markets potato with 258.39 mgAAE/g value shows a maximum amount of vitamin C and carrot shows the minimum amount of vitamin C with 99.53 mgAAE/g. (Table 3.3). When these selected vegetables are consumed regularly, they could prevent vitamin C deficiency that leads to so many problems such as; easy gum bleeding around the teeth and spontaneous breaking of capillaries under the skin producing pinpoint hemorrhage (Asaolu, 2010). This was in contrast to Mohammed et al., (2016) who reported lower ascorbic acid (Vitamin C) that ranged from 0.67± 0.02 mgAAE/g to 18.00± 3.12 mgAAE/g in selected fruits and vegetables.

Table 2: Antioxidant Content and their Activity in Selected Vegetables from Kaduna Metropolis using UV/Visible Spectrometry

	Flavonoid mgQE/g	TP mgGAE/g	Vit. C mgAAE/g	FRAP mgAAE/g	DPPH %
Avocado	75.00±2.39	102.83±1.16	165.09±2.67	82.02±0.57	63.72±8.26
Beans	117.23±1.91	25.13±1.93	167.92±1.33	75.86±1.29	32.30±9.35
Broccoli	119.93±9.08	116.09±0.78	207.31±12.33	18.18±8.57	72.08±9.09
Cabbage	93.31±1.19	106.03±0.78	123.82±9.01	56.36±0.86	87.90±6.10
Carrot	93.23±1.33	101.36±2.07	99.53±3.33	31.11±7.00	50.85±1.08
Caulif	95.78±1.19	96.33±1.81	158.02±3.00	13.95±0.86	71.23±3.35
Celery	152.70±2.39	111.61±1.68	202.12±3.00	11.52±1.33	79.33±0.60
Eggplant	106.32±0.38	126.60±1.68	199.06±3.00	39.29±1.00	86.97±8.13
Lettuce	106.93±0.72	109.69±1.29	120.05±3.00	53.55±7.13	95.33±1.68
Peas	123.83±5.39	12.07±5.17	191.27±2.33	32.02±0.29	71.66±0.36
Potato	135.78±2.15	156.95±5.03	258.39±3.00	32.63±8.71	55.75±12.56
Spinach	127.70±2.87	98.35±1.03	213.21±3.33	33.33±3.29	79.61±9.21

FRAP= ferric reducing antioxidant power**,** DPPH= 2,2-diphenyl-1 picrylhydrazyl, TP=Total Phenol

Ferric Reducing Antioxidant Power Assay of Selected Vegetables

The antioxidant assay concerning ferric reducing antioxidant power was determined for Avocado, Beans, Broccoli, Cabbage, Carrot, Cauliflower, Celery, Eggplant, Lettuce, Pea, Potato, and Spinach collected from five different markets is presented in Table 3.3.

The highest content of ferric reducing antioxidant power (FRAP) was observed in avocado (82.02 mgAAE/g), while the lowest was in celery (11.52 mgAAE/g) (Table 3.3). The order of decreasing antioxidant activity in terms of FRAP among the selected vegetable samples is as follows; avocado > beans > cabbage > lettuce > spinach > peas > carrot > eggplant > potato > broccoli > cauliflower > celery. The results show that FRAP in the selected vegetables indicates that avocado, beans, cabbage, lettuce, spinach, peas, carrot, eggplant, potato, broccoli, cauliflower, and celery acts as a natural source of antioxidants. According to Zuwariah et al., (2021), the FRAP activity in their study of green leafy vegetables ranged from 1.380–27.827 mg/g, they found that spinach had 1.38 mg/g FRAP activity. This value is lower than the value obtained for green spinach in this study.

DPPH Radical Scavenging Assay of Selected Vegetables

Results of 2,2-diphenyl-1-picrylhydrazyl (DPPH) on radical scavenging activity in vegetable samples include avocados, beans, broccoli, cabbage, carrots, cauliflower, celery, eggplant, lettuce, peas, potatoes, and spinach from five different markets are shown in Table 3.3. The 2,2-diphenyl-1-picclihydrazyl (DPPH) free radical scavenging test showed that lettuce was the most active of all the vegetable samples examined. The DPPH values of all vegetable samples ranged from 32.30 µg/ml for beans to 95.33 µg/ml for lettuce.. DPPH is a free radical donor that accepts electrons or hydrogen to become a stable diamagnetic molecule (Oboh et al., 2012). The highest DPPH activity was 95.33 µg/ml in lettuce, 86.69 ug/ml in eggplant and 87.90 ug/ml in cabbage. Gacche et al., (2010) reported that cauliflower contained 67.2 %, cabbage 32.3%, and spinach 20.3% of DPPH scavengers; however, in this study, cauliflower contained 71.23 µg/ml and cabbage contained DPPH scavengers contained 87.90 µg/ml and spinach 79.61 µg/ml. ml, which is higher than that reported by Gacche et al., (2010). Antioxidant test results showed that extracts of the selected vegetables can scavenge radicals to a very high degree.

Conclusion

This study assessed the macromineral composition and antioxidant properties of twelve selected vegetables obtained from five markets in Kaduna Metropolis. The findings demonstrated that the vegetables contained varying concentrations of essential macrominerals, including potassium, calcium, magnesium, sodium, sulphur, and phosphorus. Potassium was the predominant macromineral across the selected vegetables, while sodium generally occurred at the lowest concentrations. The variation observed among the vegetables may be associated with differences in plant species and the mineral composition of the soils and growing environments.

The antioxidant assessment further showed that all the selected vegetables contained measurable levels of phenolic compounds, flavonoids, vitamin C, and exhibited ferric-reducing and DPPH radical-scavenging activities. Potato recorded the highest total phenolic content and vitamin C concentration, celery recorded the highest flavonoid content, avocado showed the highest FRAP value, while lettuce recorded the highest DPPH activity. These differences indicate that the vegetables possess different nutritional and antioxidant characteristics and that no single vegetable provides the highest value across all assessed parameters.

Overall, the results indicate that the selected vegetables can contribute to dietary intake of essential minerals and antioxidant compounds. Regular consumption of a variety of these vegetables, rather than reliance on a single vegetable, may therefore provide a broader range of nutrients and bioactive compounds. The study also highlights the importance of monitoring the mineral composition of vegetables and their growing environments to support food

quality and nutritional safety. Further studies involving a larger number of samples, seasonal variations, soil characteristics, and assessment of additional nutritional and potentially toxic elements are recommended to provide a more comprehensive evaluation of the nutritional quality of vegetables consumed in Kaduna Metropolis.

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