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Analysis of the Leaves of Five Sweet Potato Varieties for Their Nutrient, Mineral and Phytochemical Properties

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Authors' contributions

This work was carried out in collaboration among all authors. Author AA designed the study, wrote the protocol, performed the laboratory analysis and wrote the first draft of the manuscript. Authors AG and CAA managed the analyses of the study. Author ARSS performed the statistical analysis while author AR supervised and author BM to grow the crops. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To determine the nutrients, minerals and phytochemicals contained in leaves of five sweet potato varieties.
Study Design: The study was carried out in the dry season from November 2018 to March 2019, using a randomized complete block design (RCBD).During planting, 10 cm length of each 30 cm long soft wood vine cutting was inserted into the soil and immediately watered. A space of 60cm was left between the plants and there were five vine cuttings planted per ridge. The order of planting the vine cuttings was the same on each replicate ridge. Each treatment had three replications with each replicate having five plants to give a total of75 vine cuttings in all. Leaves of the sweet potato varieties; Agric white (AW), Agric orange flesh (AO), Red skin (RS), Orange flesh (OF) and Red local (RL) were parceled; each variety in a separate parcel, appropriately labelled

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and sent to the Food Science Laboratory of Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, for analysis.
Study Site: The sweet potatoes were cultivated in the experimental field of Ecological Agriculture Department, Bolgatanga Technical Universityin Bolgatanga Municipality of Upper East Region, Ghana.
Methodology: Proximate analysis was done and nutrient content expressed in percentages (%). Concentrations of the minerals iron (Fe), potassium (K), calcium (Ca), zinc (Zn), manganese (Mn) and magnesium in milligrams per kilogram (Mg/Kg) were determined. Total phenolic content (TPC) as well as the concentrations of carotenoids and Flavonoids were also estimated and expressed in Mg/Kg. Antioxidant properties of the leaves was determined and reported in mg/Kg.
Results: Proximate analysis of the leaves show that all five sweet potato varieties are very nutritious. Leaves of AW variety recorded the highest protein (6.17± 0.43%) and carbohydrates (8.61 ± 0.32%). The content of crude fibre is generally high in leaves of all varieties, ranging from1.42 ± 0.50% in AO to 2.42 ± 0.18% in OF. The proportion of fat in all the varieties is similar, averaging 2,096 ± 0.046%, with the highest of 2.25 ± 0.06% in AO. The two orange flesh varieties, OF and AO, had the highest and higher concentrations of iron (Fe) of 2,020.41 and 467.11 mg/Kg respectively. Magnesium (Mg) is the element that occurred in highest concentration of all the minerals, with an average concentration of 7,991.02 mg/Kg. The OF variety contained the highest concentration of total phenol of 875.00 ± 95.86 mg/Kg. With an average of 4,915.00 ± 166.00 mg/Kg, the concentration of flavonoids in all five varieties in the current study is similar. The concentration of total carotene decreased in the order RL>RS>AW>AO>OF, with the RL variety containing 124.22 ± 10.00 mg/Kg while the OF one possessed 49.39 ± 2.00 mg/Kg. The content pattern of beta carotene was RL> RS> AW> OF> AO, with RL variety containing 4.56 ± .03mg/Kg as AO had 1.57 ± 0.53 mg/Kg. The capacity of phytochemicals in the sweet potato varieties to scavenge and inhibit free radicals as well as reactive oxygen species [using the DPPH (1,1-diphenyl-2-picrylhydrazyl) assay] was highest in the OF variety (51.073%).
Conclusion: Leaves of the five sweet potato varieties studied are rich in diverse nutrients and phytochemicals. Therefore, encouraging the growth and consumption of both leaves and root tubers is a cheaper means of reducing malnutrition and enhancing good public health. It is therefore, essential for more investigations to establish the nutrient content and nutrachemical capabilities of both roots and leaves of the different varieties of sweet potato in the different environments so as to equip the general public with appropriate information to guide dieting choices.

Keywords: Sweet potato; varietie; leaves; nutrients; minerals; phytochemicals.

1. INTRODUCTION

The vegetable crop, sweet potato, identified scientifically as *Ipomoea batatas,* is a member of the *Solanales o*rder and *Convolvulaceae* family. It is a crop with loads of benefits to humanity. Almost all parts of the plant body is usable for human nutrition and enhancement of good health [1-8].

Sweet potato plants do not require stringent growing conditions, are easy to cultivate in the absence of costly inputs like fertilizers and is resistant to pests and diseases. These features make the crop to be cultivated in almost all the tropical and subtropical countries in the world, with China having the highest production and consumption levels of the crop [2,7,9-15].

The root tubers are the parts of the plant body that everyone generally cultivates the crop for. Therefore, research has traditionally, mainly centred on the nutritional capacity of the root tubers [9-10,12-16]. These findings have contributed massively to our understanding of the sweet potato root tubers as rich sources of not only the major food components like protein, carbohydrate, crude fibre and lipids, but also both major and minor minerals. They have also revealed sweet potato root tubers as being fortified with vitamins and their precursors as well as other health-enhancing phytochemicals [17,18].

However, recent works have exposed the vines and leaves, which were regarded as useful only as animal feed [19], to bealso rich and in some instances, richer sources of the same organic food nutrients especially carbohydrates and proteins. The leaves of sweet potato have been found to contain useful minerals like potassium (K), sodium (Na), magnesium (Mg), calcium (Ca),

iron (Fe), zink (Zn) and manganese (Mn), etc. Theyas well are fortified with health beneficial phytochemicals including phenolic compounds, flavonoids, etc. which exhibit antioxidant properties [1-2,4,7,20-24]. In keeping with these discoveries, various workers have published data on the potential of sweet potato as a medicinal plant in the treatment of pathogenic conditions, cancer, ulcer, diabetes, inflammations, etc. [7,12-13,19,25] cited in [4].

These findings all point to the overwhelming usefulness of this vegetable crop. They also reveal that healthy living is achievable just by eating the appropriate plant foods like sweet potato, which is within the reach of persons with low income as pertains in resource-challenged countries like Ghana. In an era when people are resorting to using natural products to achieve good health and avoid the use of chemotherapy for want of its side effects, the importance of investigating the nutrient, vitamin and phytochemical potential of different varieties of sweet potato cannot be over emphasized.

Studies have revealed that the type and concentration of nutrients, minerals, vitamins and their precursors as well as the phytochemicals in any plant varies with the variety of the plant [4,22-23,26].

The condition of the soil on which the crop is cultivated, with respect to the concentrations of the chemical constituents of these nutrients, minerals and phytochemicals also determine their relative concentrations in the crop [9-10,13].These necessitate the cultivation of the different sweet potato varieties on different soil types in order to fully understand their nutrient, mineral and biochemical fortification. This in turn can inform healthy dieting and the promotion of public health to people in the different geographic regions of the world. The current study seeks to determine the nutrient and phytochemical capacity of the leaves of five varieties of sweet potato grown in the Bolgatanga Municipality of the Upper East Region in Ghana.

2. METHODOLOGY

2.1 Study Site

The five varieties of sweet potato were cultivated in the experimental field of the Department of Ecological Agriculture, Bolgatanga Technical University (10.8257° N, 0.8649° W) in the Bolgatanga Municipality (10.7875° N, 0.8580° W) of the Upper East Region, Ghana, by Ayimbire et al. [27].

However, the leaves were analysed in the Food Science Laboratory of Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

The location of Bolgatanga Municipal is on 10.7875°N, 0.8580°W. It is one of the emerging cities (Figs. 1 and 2) with a total population of 131,550. Females dominate the citiy's population, constituting 52.3% with males making up 47.70%. Given its status as an emerging city, slightly more than half (50.20%) of the population in the municipality is rural [28].

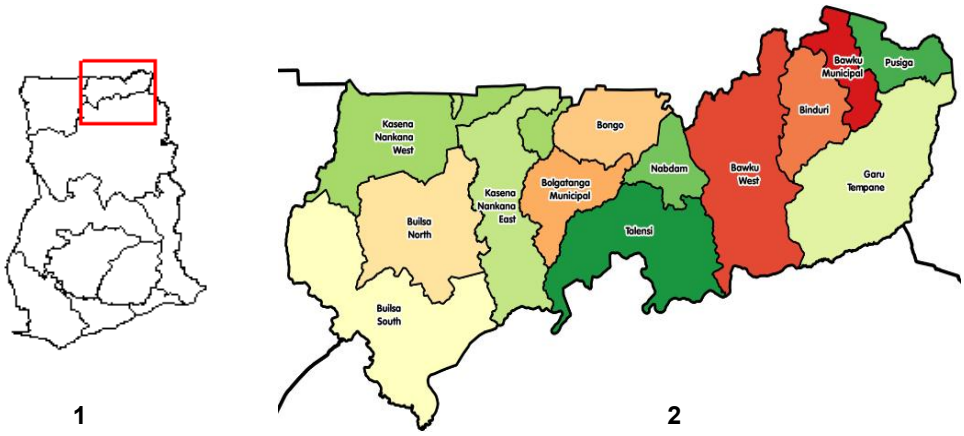

Fig. 1. Map Ghana showing Upper East Region
Fig. 2. Map of Upper East Region of Ghana with Bolgatanga Municipal in themiddle

Bolgatanga Municipal is in the guinea savannah vegetation zone with a mean temperature of 21°C which can fall to as low as 14°C in December, the harmattan period. The hottest part of the year is usually in March or April when temperature may rise to about 45°C. The commencement of the rainy season is erratic, swinging between April and July to end in October or November. Common rock type is granite. Hence the soil originating from the rocks is sandy loamy with humus enrichment in some places. The concomitant vegetation is grassland with well-spaced deciduous trees, some of which, like shea (*Vitallaria paradoxa*), the African locus bean tree "dawadawa" (*Parkia biglobosa*, baobab (*Adansonia digitata*)", silk cotton tree (*Ceiba pentandra*) etc. bear important economic fruits. Majority of the citizens are farmers growing maize, millet, guinea-corn, sorghum, rice, groundnuts, beans and sweet potatoes during the rainy season although some farm tomatoes, onions and rice through irrigation in the dry season [28].

2.2 Soil Sampling

Soil was sampled in accordance with the protocol of Motsara and Roy [29]. Three soil samples were removed from 0-20cm depth in a random manner, from replicate beds with the help of a hoe, into black, clean plastic bags. Hence, nine samples were removed from each replication to to give a total of 27 from all three replications, prior to transplanting. Samples from each replicate were added together, mixed homogeneously in a clean bucked and 20 g of it removed and properly labeled. Three such 20 g samples from replicate ridges were sent to the Crop and Soil Sciences laboratory of Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. Thus, three soil samples were analysed before transplanting and. The same procedure was used to analyse the same number of soil samples after planting [27].

2.3 Varietal analysis of sweet potato leaves for nutrient, mineral, carotene and phytochemicals

The study was carried out in the dry season from November 2018 to March 2019 by Ayimbire et al. [27], using a randomized complete block design (RCBD). During planting, 10 cm length of each 30 cm long soft wood vine cutting was inserted into the soil and immediately watered. A space of 60cm was left between the plants and there were five vine cuttings planted per ridge. The order of planting the vine cuttings was the same on each replicate ridge. Each treatment had three replications with each replicate having five plants to give a total of 75 vine cuttings. vines with leaves of the five sweet potato varieties, namely Agric white (AW), Agric orange flesh (AO), Red skin (RS), Orange flesh (OF) and Red local (RL) were cut after about five months of growth. Samples were parceled; each variety in a separate parcel, appropriately labelled and sent to the Food Science Laboratory of Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, for analysis. Samples were analysed for the following:

i. Proximate estimation in percentages (%),using the official method of analysis of the AOAC, [30].
ii. Total carotenoids and beta carotene contentin milligrams per gram (mg/Kg), was carried by use of methods developed by Mackinney [31] and Maclachan and Zalick [32].
iii. Concentration of the minerals Iron (Fe), Zink (Zn), Magnesium (Mg/Kg), Potassium (K) manganese (Mn) and Calcium (Ca) in milligrams per kilogram (mg/kg),using atomic absorption spectrophotometer, AAS Model Nov AA 400p
iv. Concentration of flavonoids were also estimated using ethanol solution and measuring absorbance at 420 nm [33].
v. Total phenolic content (TPC) was determined using Folin-Ciocalteau method [34,35], with gallic acid as standard.
vi. Antioxidant properties of the leaves was determined using the 1,1- diphenyl-2 picrylhydrazyl (DPPH) radical-scavenging assay [36].

The five sweet potatoes varieties were coded as follows: Agric Orange flesh (AO), Red Skin (RS), Agric White (AW), Orange flesh (OF) and Red local (RL).

2.4 Proximate analysis in percentages (%)

2.4.1 Moisture content and total solids: oven drying method

5g of each variety sample was transferred to labelled, previously dried and weighed dishes. The latter were placed in an oven thermostatically controlled at 105 degrees for 5 hours. Dishes were removed and placed in a desiccator to cool to room temperature and weighed. They were dried again for 30 minutes,

cooled and weighed. Drying, cooling and weighing were repeated until a constant weight was reached. Alternatively, samples were dried in a thermostatically controlled oven for at least 8 hours where a constant weight would be achieved. The determination at least duplicated and the averages found.

Calculations:

$$\%\text{moisture (wt/wt)} = \frac{\text{wt } H_2O \text{ in sample}}{\text{wt of wet sample}} \times 100$$

$$\%\text{moisture (wt/wt)} = \frac{\text{wt of wet sample-wtof dry sample}}{\text{wt of wet sample}} \times 100$$

$$\%\text{total solids (wt/wt)} = \frac{\text{wt of dried sample}}{\text{wt of wet sample}} \times 100$$

2.4.2 Ash content

5g of each variety sample was weighed into a tarred crucible. Samples were pre-dried. Crucibles were placed in cool muffle furnace. Tongs, gloves and protective eyewear were used when the muffle furnace was warm. Test samples were ignited for 2 hours at about 600°C. Muffle furnace Turn off and opened only after the temperature has dropped to at least 250°C. The door was carefully opened to avoid losing ash that may be fluffy. Using safety tongs, crucibles were quickly transferred to a desiccator with a porcelain plate and desiccant. Desiccator was dlosed and crucibles allowed to cool prior to weighing.

Calculations

$$\%\text{Ash} = \frac{\text{wt of ash}}{\text{Wt of sample}} \times 100$$

$$\%\text{Ash} = \frac{(\text{wt of crucible+ ash}) - \text{wt of empty crucible}}{(\text{wt of crucible+ sample}) - \text{wt of empty crucible}} \times 100$$

2.4.3 Fat content: soxhlet extraction

A 250ml, previously dried (air oven at 100°C) round bottom flask was accurately weighed. 5.0g of dried sample was weighed to 22 ×80mm paper thimble or a folded filter paper. A small piece of cotton or glass wool was placed into the thimble to prevent loss of the sample. 150ml of petroleum spirit B.P 40-60°C was added to the round bottom flask and the apparatus assembled. The condenser was connected to the soxhlet extractor and refluxed for 4 - 6 hours on the heating mantle. After extraction, thimble was removed and solvent recovered by distillation. The flask and fat/oil was heated in an oven at about 103°C to evaporate the solvent. Flask and contents were cooled to room temperature in a desiccator. Flask was weighed and weight of fat/oil collected was determined.

$$\%\text{ FAT (dry basis)} = \frac{\text{fat/oil collected} \times 100}{\text{Weight of sample}}$$

$$\%\text{ FAT (dry basis)} = \frac{(\text{wt of flask + oil}) - \text{wt. of flask} \times 100}{\text{Weight of sample}}$$

2.4.4 Crude fibre determination

2.g sample from crude fat determination was weighed into a 750ml Erlenmeyer flask. 200ml of 1.25% H_2SO_4 was added and flask was immediately set on hot plate and connected to condenser. The contents came to boil within 1 minute of contact with solution. At the end of 30 minutes, flask was removed and immediately filtered through linen cloth in funnel and washed with a large volume of water. Filtrate (containing sample from acid hydrolysis) was washed back into flask with 200ml 1.25% NaOH solutions. Flask condenser was connected and boiled for exactly 30 minutes. It was then filtered through Fischer's crucible and washed thoroughly with water and 15ml 96% alcohol added. Crucible and contents were dried for 2 hour at 105 °C, cooled in desiccator and weighed. Crucible ignited in a furnace for 30 minutes, cooled and reweighed.

$$\%\text{ Crude fibre} = \frac{\text{weight of crude fibre} \times 100}{\text{Weight of sample}}$$

$$\%\text{ Crude fibre} = \frac{\text{wt of crucible + sample(before – after) ashing} \times 100}{\text{Weight of sample}}$$

2.4.5 Protein determination

2.4.5.1 Digestion

To the digestion flask, was added 2g of sample and a half of selenium –based catalyst tablets and a few anti-bumping agents. 25ml of concentrated H_2SO_4 was added and the flask shaken so that entire sample is thoroughly wet. Flask placed on digestion burner and heated slowly until boiling ceased and the resulting solution was clear. It was cooled to room temperature. Digested sample solution was transferred into a 100ml volumetric flask and made up to the mark.

2.4.5.2 Distillation

To flush out the apparatus before use, Distilled water was boiled in the steam generator of the distillation apparatus with the connections arranged to circulate through the condenser, for

at least 10 minutes. If the tip of the condenser was beneath the surface of the distillate, the receiving flask was lowered and heating continued for 30 seconds in order to carry over all liquid in the condenser.

25 ml of 2% boric acid was pipetted into 250ml conical flask and 2 drops of mixed indicator added.

The conical flask and its contents were placed under the condenser in such a position that the tip of the condenser is completely immersed in solution. 10ml of the digested sample solution was measured into the decomposition flask of the Kejdahl unit, fixed and excess of 40% NaOH (about 15-20ml) added to it. The ammonia produced was distilled into the collection flask with the condenser tip immersed in the receiving flask till a volume of about 150ml– 200ml is collected. Before distilling another sample and on completion of all distillations, the apparatus was flushed as stated above. Steam was passed only until 5ml of distillate was obtained.

2.4.5.3 Titration

The distillate was titrated with 0.1N HCL solution. The acid was added until the solution was colorless. If additional acid was added, the solution turned pink. The nitrogen content, was determine at least in duplicates, and a blank determination run using the same amount of all reagents as used for the sample. The blank corrected for traces of nitrogen in the reagents and including digestion as well as distillation.

2.4.5.4 Calculation

$$\% \text{ total nitrogen} = \frac{100 \times (Va-Vb) \times NA \times 0.01401 \times 100}{W \times 10}$$

Va- volume in ml of standard acid used in titration
Vb- volume in ml of standard acid used in blank
NA- normality of acid
W- Weight of sample taken

2.4.5.5 Nitrogen free extract (NFE)

Calculation

NFE (%) =100 - (% moisture +% fat + % crude fibre +% protein +% ash)

2.4.6 Carbohydrate

Calculation

Carbohydrate (%) = % crude fibre + % NFE

or

Carbohydrate (%) =100 - (% moisture +% fat +% protein +% ash)

2.5 Carotenoids Estimation

The estimation of carotenoids content according to the method, Mackinney [31] and Maclachan and Zalick [32], respectively.

50mls of acetone was added to about 100mg of the fresh sample in a separating funnel. Mixture was swirled a little and 10ml petroleum ether quantitatively added. The usual liquid – liquid extraction procedure was carried out. The flask was positioned upright in the ring clamp and the stopper removed till there was partitioning. The lower layer was discarded as the upper layer was transferred into a glass test tube.

The optical densities (O.D) were read at wavelengths with the help of a UV spectrophotometer.

The carotenoids contents were expressed in mg/g fresh sample and calculated according to the formulae given below:

$$\text{Beta carotene} = \frac{0.216(OD.663nm) - 0.304(OD.505nm) + 0.452(OD.453)\ x\ V}{d \times 1000 \times W}$$

$$\text{Total carotenoids} = \frac{7.6(OD.480nm) - 1.49(OD.510nm)\ x\ V}{d \times 1000 \times W}$$

where,
V= final volume of the extract.
d= length of light path
W= fresh weight of sample
O.D= optical density of a given wavelength

Concentrations of the minerals; Magnesium (Mg), Potassium (K), Calcium (Ca) Iron (Fe) and Zinc (Zn) in milligrams per kilogram (mg/kg) were determined using atomic absorption spectrophotometer, AAS Model Nov AA 400p.
The five sweet potatoes varieties were coded as follows: AW = Agric white, AO = Agric orange flesh, RS = Red Skin, RL = Red local, OF = Orange flesh.

2.6 Determination of Total Flavonoids

Total flavonoid was determined using the method of Ordonez et al. [34] on the formation of a complex, flavonoid-aluminium.

A volume of 0.5 mL of 2% AlCl3-ethanol solution was mixed with 0.5 mL of the extract (1 mg/mL).

The resultant mixture was incubated for 1 hour for yellow colour development which indicated the presence of flavonoid. The absorbance was measured at 420 nm using UV-VIS spectrophotometer. Total flavonoid content was calculated as quercetin equivalent (mg/g) using the equation obtained from the graph (Fig. 3), where x is the absorbance and y is the quercetin equivalent. The concentration (mg/g) was then converted to mg/Kg.

Total phenolic content (TPC) was determined according to the Folin-Ciocalteau method (Kujala et al., 2000; Singleton et al., 1999), using gallic acid as a standard. About 0.5g of the sample was weighed, dissolved in 100ml distilled water in a 100ml volumetric flask and swirled for about 30 minutes and filtered. 2ml of the filtrate was pipetted into a test tube. A stock solution of Gallic acid (100ppm) was prepared and out of it, dilutions of 5ppm, 10ppm, 20ppm, 40ppm, 50ppm were prepared. From the dilutions, 2ml each was pipetted into different labelled test tubes and 1000µl of 20% sodium carbonate (Na_2CO3) added to dilutions and sample filtrated. 20µl of Folin-Ciocalteau was added to each test and the resultant reaction mixtures were incubated for 30 minutes at room temperature. Absorbance was measured spectro-photometrically at 760nm using a UVVIS Spectrophotometer. From the calibration curve (Fig. 4), the total phenol content was calculated and expressed as Gallic Acid Equivalent (GAE) in mg per gramme, subsequently converted to milligrams per kilogram.

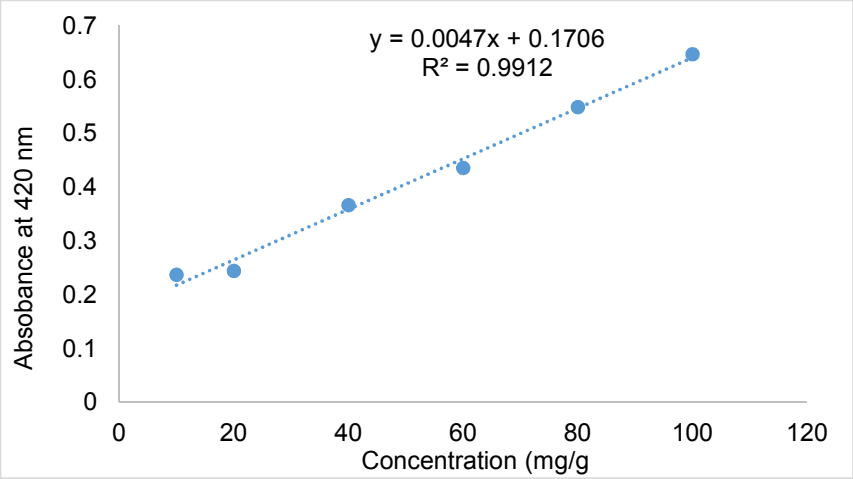

Fig. 3. Graph of absorbance and y is the quercetin equivalent

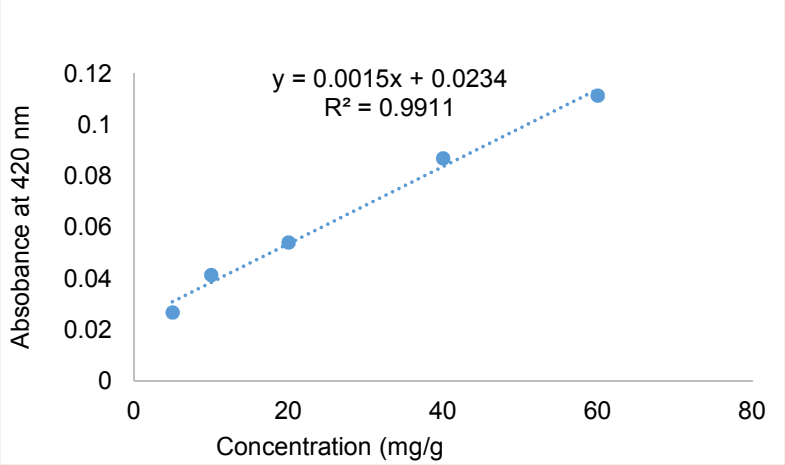

Fig. 4. Total phenol calibration curve

2.7 Antioxidant Activity (Radical Scavenging Activity)

About 0.5g of powdered sample was weighed into a 15 ml centrifuge tube, extracted with 10 ml distilled water and centrifuged at 10,000rpm for 15 minutes. A 6.4 ml reaction mixture was obtained containing 0.2 ml sample, 0.2 ml distilled water and 6 ml of 0.004% DPPH (1,1-diphenyl-2-picrylhydrazyl) in tubes and shaken by hand. Test sample was kept for 30 minutes at room temperature in the dark. Absorbance of reaction mixture was read and blanked at 517 nm.The reaction mixture lacking sample developed the most intense colour. The colour decreased with increasing volume of extract added.

The ability to scavenge the DPPH was calculated as:

DPPH radical scavenging activity (% of Inhibition) = [1 - (As/A0)] × 100,

where:
AS- Absorbance of sample,
Ao- Absorbance of DPPH solution diluted to same volume of distilled water.
Distilled water was used as blank.

2.8 Data Analysis

Each treatment (variety) samples were analysed in triplicates and the average values recorded with standard deviations (SD). The data was then processed in Microsoft Excel to display the results illustratively in tables and histograms.

3. RESULTS AND DISCUSSION

3.1 Proximate Estimation

The proximate values of the nutrient, moisture and ash content of leaves of five varieties of sweet potato tested (Table 1), show that the crops are very nutritious. Leaves of the AW variety, for instance, recorded the highest protein (6.17± 0.43%) and carbohydrates (8.61 ± 0.32%) content of all. The spread of the mean protein and carbohydrate contents, as indicated by the standard deviation(SD) values in both cases, of 0.43 and 0.32 respectively, are wide. The lowest protein (4.11 ± 0.04%) and carbohydrate (5.72 ± 0.04%) contents occurred in leaves of AO and RL varieties respectively. The mean protein content range of 4.11% to 6.17% falls within the findings of 3.02 % to 7.38% in sweet potato vines by Gupta et al. [19], in Rajasthan.On the other hand, the range of protein recorded here is much lower than the range of 26.37% to 37.06% reported in Tanzania [20]. The protein of sweet potato leaves, according to Mwanri et al. [20], are rich in the amino acids lysine and tryptophan, which are deficient in grains. Sweet potato leaves, therefore, can augment the amino acid requirement of people in developing countries whose main diet is on grains and where animal protein is not readily affordable tolow income earners. This will reduce deficiency malnutrition in these specific amino acids and promote public health in those areas.

Comparing these mean nutrient content values of the leaves of the AW variety with those of the root tubers of the same variety that Ayimbire et al. [16] found recently (protein, 3.82%; total carbohydrate, 15.80%), one marvels at the richness of the leaves in nutrients, even more than the root tubers! Ayeleso et al. [4] also reported more protein content in leaves (24.90 mg/Kg) than in root tubers (15.70 mg/Kg), corroborating this finding. Yet, sweet potatoes are usually cultivated for the use of the latter, discarding the leaves with only a few cultures using them for food [7,21,24]. Ayeleso et al. [4], however, recorded more carbohydrates in root tubers (201.20 mg/Kg) than in leaves (88.20 mg/Kg) of sweet potatoes, contrasting differently from this results. The level of carbohydrate in the current findings are much lower than in the work of Mwanri et al. [20] in Tanzania (17.76 to 41.62%).

The content of crude fibre is generally high in the leaves of all the varieties, ranging from1.42 ± 0.50% in AO to 2.42 ± 0.18% in the OF variety. Like the protein content, the carbohydrate contents of the leaves are much higher than the range of 0.11% to 1.77% in root tubers that Ayimbire et al. [16] recorded earlier on the same varieties of sweet potato.On the other hand, the fibre content found here is much lower than that found by Mwanri et al. [20] of 16.01 to 21.48%.According to Ayeleso et al. [4], the high fibre content of sweet potatoes in addition to other roughage forming components account for some of the nutraceutical properties of the crop including mitigation of cancer of the colon. The proportion of fat in all the leaves of the five sweet potato varieties is similar, averaging 2,096 ± 0.046%, the lowest being 1.89 ± 0.10% in RL with the highest of 2.25 ± 0.06% in AO. Comparing with the findings of fat content in root

tubers of the same varieties of1.74 to 4.84% [16], the lower fat content in the leaves makes them appear to be even safer for consumption by people who are recommended to be on low fat diets. The high amounts of protein, carbohydrate and crude fibre coupled with the low fat content make leaves of the five varieties of sweet potato not only nutritious but also healthy food. The fat contained in sweet potatoes has been reported to be unsaturated [4], thus further making it suitable for consumption as it is devoid of health problems like hypertension, which are associated with low density lipoprotein (LDL) cholesterol. On the other hand, in Tanzania, a higher fat content of 3.11 to 3.27% has been reported in the leaves of sweet potatoes [20].

Leaves of all the varieties are saturated with water to an average of83.504 ±0.098%, with the minimum being 80.75 ±0.07% in AW and maximum of 85.63 ±0.12% in AO. This is slightly lower than the finding of 85.63 to 86.28% by Mwanri et al. [20]. This is in keeping with the fact that transpiration pulls water to the leaves for evaporation while photosynthesis produces additional water which is also stored in the leaves. High water content may be advantageous when the fresh leaves are eaten by human in combination with other foods or are fed to animals as fodder, given that the body requires adequate water for normal functioning. However, lots of water in the leaves may reduce their taste when they are eaten raw [16].

On the average, the leaves of all the varieties recorded low ash content (2.300% ±0.028). The RL variety had the lowest content of 2.00 ±0.00% of ash as the RS one contained the highest ash content (2.51±0.09%). Ingabire and Vasanthakaalam [9] associated high moisture content with a low proportion of ash, which seems to fall in line with the current results. However, the ash levels in this work is much lower than that of 12.87 to 20.41% reported in Tanzania [20] which also recorded high levels of water (85.63 to 86.28%).

3.2 Concentration of Minerals

The leaves of the five sweet potato varieties were found to be generally rich in the minerals Fe, Ca, K, Zn, Mn and Mg which were tested for (Table 2). Leaves of the two orange flesh varieties, OF and AO, had the highest and higher concentrations of the minor nutrient iron (Fe) of 2,020.41 and 467.11 mg/Kg respectively, than the white flesh ones. Those of the RS variety recorded the lowest concentration of Fe (33.73 mg/Kg).These results are comparable with other workers' findings in literature. The range of152.20 to 174.80 mg/kg of Fe that Mwanri et al. [20] determined in Tanzania, for instance, falls within that of the current finding, albeit their highest value is much lower than the present highest concentration. Thereport by Awol [36] in South- west of Ethiopia (738.81 mg/Kg) is also similar in Fe content while that of9.70 mg/Kg by Ayeleso et al. [4] is much lower. The work of Ayeleso et al. [4] also revealed that, of the six minerals they examined, sweet potato leaves contained higher concentrations of many minerals than root tubers in five of them, sodium being the exception, as illustrated in Table 2.

The record of 111.00 to 199.00 mg/Kg of Fe in sweet potato leaves reported by Suárez et al. [7] is also within the levels found in the current work.

Fe is animportant constituent of haemoglobin in the red blood cells and myoglobin in muscle tissue as well as in developing foetus, which functions in the collection of oxygen from inspired air and its subsequent transportation to the cells of the body for metabolism. High content of Fe in sweet potato leaves means the latter can serve as a rich source of Fe for people especially vulnerable groups like pregnant women and children, thereby reducing their risk of experiencing anaemia.

Table 1. Results of proximate estimation of leaves of five sweet potato varieties for nutrient, ash and moisture content expressed in percentage (%)

SPV	Protein	Fat	Crude fibre	Carbo-hydrate	Ash	Moisture
RL	5.94±0.12	2.25±0.06	1.69±0.01	5.72±0.04	2.00±0.00	84.10±0.02
RS	4.26±0.09	2.15±0.01	1.72±0.07	6.52±0.19	2.51±0.09	84.56±0.18
AW	6.17±0.43	2.06±0.05	1.66±0.02	8.61±0.32	2.43±0.01	80.75±0.07
AO	4.11±0.04	1.89±0.10	1.42±0.50	6.24±0.23	2.13±0.03	85.63±0.12
OF	4.84±0.08	2.13±0.01	2.42±0.18	8.12±0.19	2.43±0.01	82.48±0.10

Meaning of abbreviations: SPV = Sweet Potato Variety, AW = Agric white, AO = Agric orange flesh, RS = Red Skin, RL = Red local, OF = Orange flesh

Table 2. Concentration of minerals (mg/Kg) inleavesand root tubers of sweet potatoes

Mineral	Leaves	Root tubers
Calcium	780.00	300.00
Iron	9.70	6.10
Magnesium	700.00	250.00
Phosphorus	810.00	470.00
Potassium	5080.00	3370.00
Sodium	550.00	60.00

Source: Ayeleso et al. [4]

The concentration of calcium (Ca) was highest (488.03 mg/Kg) in leaves of the AW variety with the lowest (271.34 mg/Kg) occurring in the AO variety. The white flesh varieties (AW, RS and RL) are found to contain more Ca than the orange flesh ones (AO and OF), which is in contrast to the concentration of Fe (Table 3). The range of values here are much lower than those recorded by Mwanri et al. [20] in Tanzania (34,570.00 to 42,550.00 mg/Kg), Awol [36] in South- west of Ethiopia (3,201.25 mg/Kg) andSuárez et al. [7] recently (13,188.00 to 14,074.00 mg/Kg). Ca is a major mineral needed in the formation of bone and teeth. Eating sweet potato leaves which are rich sources of Ca will therefore help ameliorate health issues relating to bones and teeth.

The highest (1,019.17 mg/Kg) and lowest (201.96 mg/Kg) concentrations of potassium (K) occurred in OF and RS respectively, following a similar trend as the content of Fe. Comparing the current values of K content with what others found shows that the sweet potato leaves grown here are not as rich in K as those grown elsewhere. For instance, in South- west of Ethiopia, Awol [36] found 36,088.54 mg/Kg of K. Suárez et al. [7] recorded between 19,638.00 and 33,417.00mg/kg of K while Ayeleso et al. [4] reported 5,080.00 mg/kg of the element. Given that K is essential in the Na/K pump operating in cells, especially of the nervous system, consuming sweet potato leaves rich in both Na and K could have health benefits. According to Awol [36], K is needed for the proper functioning of body cells and has been found to reduce high blood pressure and its related problems.

In general, only leaves of the RS variety contain appreciable level of zinc (Zn) of 88.52 mg/Kg). Zn concentration in the other varieties range from a maximum of 27.21 mg/Kg in AW to a minimum of 15.10 mg/Kg in the AO variety. The content of Zn, like that of Ca, is lowest in the orange flesh varieties. The concentration of Zn found in this study is similar to the range of 32.00 to 33.00 mg/Kg recorded recently by Suárez et al. [7].

The concentration of Manganese was found inappreciable quantities in only three varieties, with an average of 53.057 mg/Kg. The mineral was not detected in two varieties (RS and AO).The current varieties contain less Mn than the range of 63.10 to 99.00 mg/Kg found elsewhere recently [7]. Awol [36] also recorded a higher concentration (95.90 mg/Kg) of Mn than what was recorded here and observed that the relevance of the mineral in the body is due to its association with the body enzymes.

Magnesium (Mg) is the element that occurred in the leaves of the five sweet potato varieties in highest concentration of all the minerals tested for, with an average concentration of 7,991.024 mg/Kg. The maximum concentration of 11,241.20 mg/Kg was found in the OF variety with the minimum of 747.55 mg/Kg recorded in the RS variety. Other earlier workers also recorded appreciable concentrations of Mg. Awol [36] observed 1,187.50 mg/Kg, Suárez et al. [7] recorded a range of 4,550.00 to 5,130.00 mg/Kg.

Table 3. Results of determination of concentration of minerals (mg/Kg) in leaves of five sweet potato varieties

SPV	Fe	Ca	K	Zn	Mn	Mg
RL	81.25	453.67	877.75	23.52	50.61	10,079.50
RS	33.73	420.76	201.96	88.52	BDL	747.55
AW	88.06	488.03	894.34	27.21	56.08	10,161.30
AO	467.11	271.34	853.9	15.1	BDL	7,725.57
OF	2020.41	385.41	1019.17	21.69	52.48	11,241.20

Meaning of abbreviations on table: SPV = Sweet Potato Variety, AW = Agric white, AO = Agric orange flesh, RS = Red Skin, RL = Red local, OF = Orange flesh

In general, the concentrations of the minerals Fe, Ca and Zn appear to follow the flesh colour pattern (white or orange flesh) of the sweet potato varieties whereas those of K, Mn and Mg do not.

3.3 Content of Phytochemicals

Leaves of the sweet potato varieties investigated were found to contain phytochemicals such as total phenol, flavonoids, total and beta carotenes as illustrated in Figs. 5 to 8. These phytochemicals influence the physiology of the human body in diverse ways including their antioxidant inhibition of the activities of free radicals and reactive oxygen species in the body.

3.3.1 Total phenols content (TPC)

Fig. 5 shows that the AW and AO varieties had the lowest content of total phenol of201.32 ± 8.84 mg/Kg while the OF one contained the highest concentration of874.81 ±95.86 mg/Kg. The increasing order of concentration of total phenol in leaves of the five sweet potato varieties is AO<AW<RS<RL<OF. Other earlier workers have recorded excessively higher concentrations of total phenol than the current study: Suárez et al. [7] documented total polyphenol content in leaves of different sweet potato varietiesranging between 60,000 mg/Kg dw and 91,000 mg/Kg dwas Dinu et al. [6], found total polyphenolic content in the leaves of two sweet potato varieties to be 2,500 mg/Kg and 2,200 mg/Kg. Zhang et al. [37], stated their finding of total Phenolic content of sweet potato leaves as 112,980 ± 4,140 mg/Kg whereas Abong et al. [8], reported a span of phenolic content from 44,960,000 to 68,010,000 mg/Kg, extremely higher than recorded in this study.

3.3.2 Content of flavonoids

With an average of 4,915 ± 166 mg/Kg, the concentration of flavonoids in all five varieties in the current study are similar. This is illustrated in Fig. 6 which shows that the lowest concentration occurred in the OF variety(4,185 ±96 mg/kg) as the highest of 5,941 ± 496 mg/Kg, was found in the RS variety. Recently, total Flavonoid was found to be 56,870 mg rutin equivalent/Kg dried extract in leaves of sweet potato [37] as well as a range from 4,0970,000 to 73,160,000 mg/Kg [8]. According to Kim et al. [38], cited in Egamberdieva, [5], flavonoids can reduce the development of cancers in humans.

3.3.3 Concentration of total and beta carotenes

From Fig. 7, it is seen that the concentration of total carotene in the five varieties of sweet potato decreases in the order RL>RS>AW>AO>OF. The RL variety contains 124.22 ± 10.00 mg/Kg while the OF one possessed 49.39 ± 2.00 mg/Kg of total carotene. The content pattern of total carotene in the sweet potato leaves (Fig. 8) is similar to that of beta carotene RL> RS> AW> OF> AO, with the RL variety containing 4.56± 0.03 mg/Kg and the AO variety having the lowest concentration of 1.57 ± 0.53mg/Kg. Thus, leaves of the orange flesh varieties contained the lowest concentrations of both total and beta carotenes.

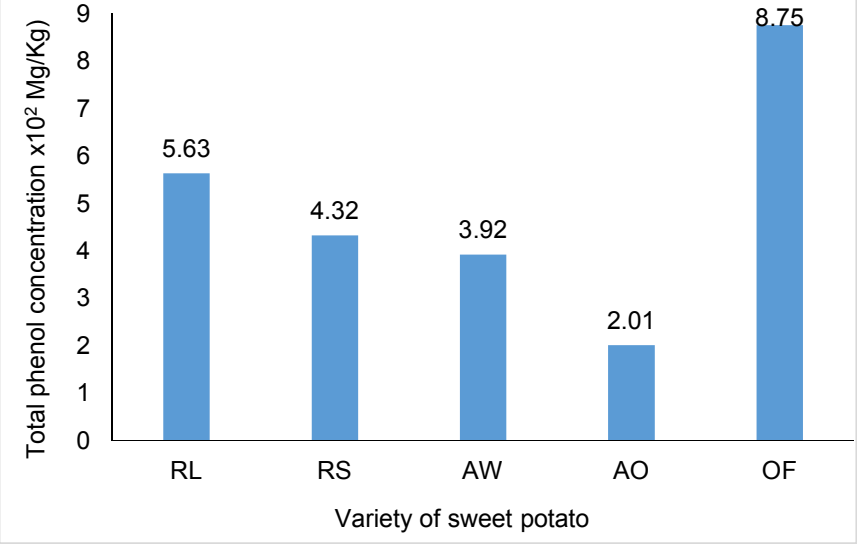

Fig. 5. Concentration of total phenol (mg/Kg) in five varieties of sweet potato

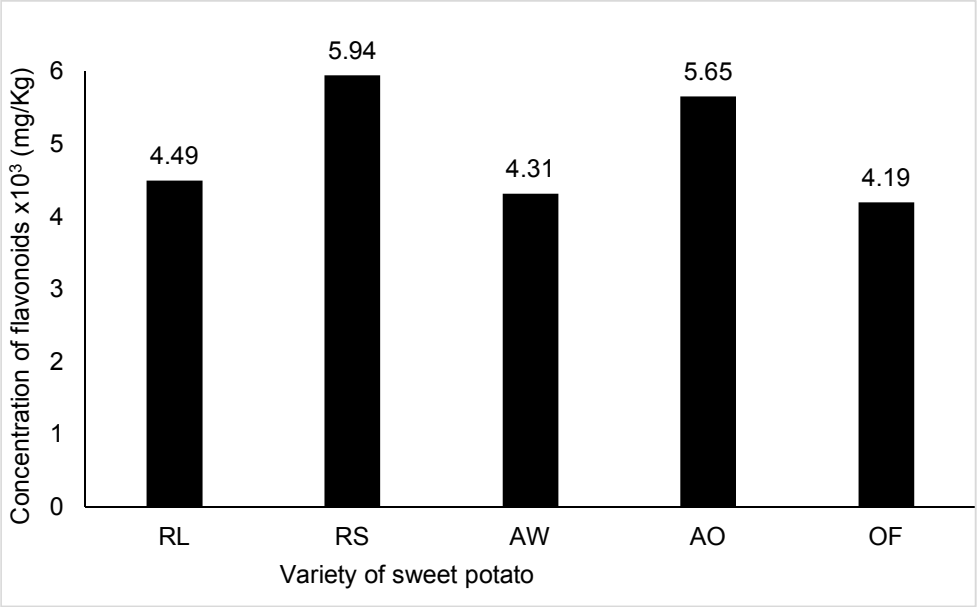

Fig. 6. Concentration of flavonoids x10^3 (mg/Kg)in five varieties of sweet potato.

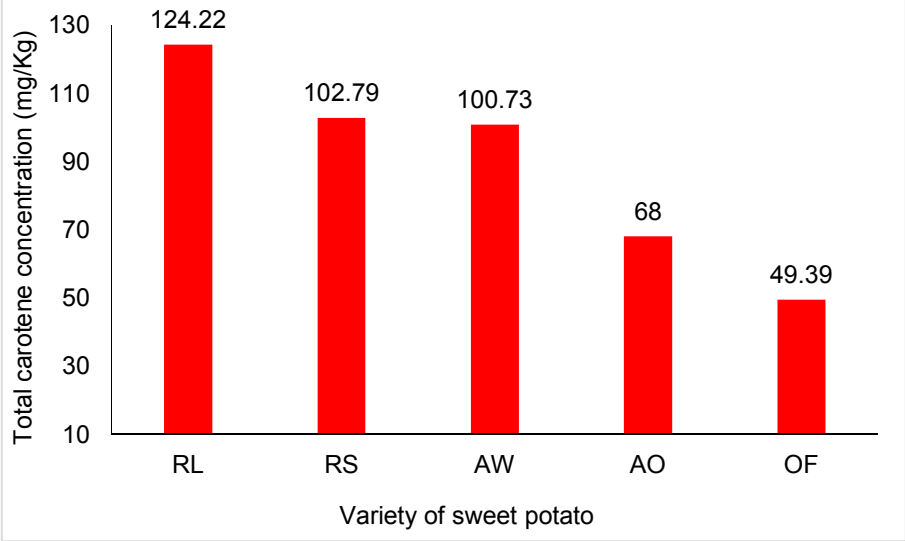

Fig. 7. Concentration of total carotenes (mg/Kg)in five varieties of sweet potato.

Other earlier workers documented a carotenoid concentration ranges in sweet potato leaf extracts of 4,418.00 to 5,332 mg/Kg [20], which is much higher than in the current findings, and 238,000 to 250,500 mg/Kg [6]. Recently, Abong et al. [8], published a range of cis β-carotene from 22,400.00 to 47,800 mg/kg while trans β-carotene spanned from 133,300 to 280,700 mg/Kg. Differences in strain of sweet potato as well as soil conditions are said to account for such differences in nutrient and phytochemical content [4,9-10,13,22-23,26]. It may also partly be due to differences in methodology.

3.3.4 Antioxidation capabilities

Fig. 9 illustrates that the capacity of phytochemicals in the sweet potato varieties to scavenge and inhibit free radicals as well as reactive oxygen species [using the DPPH (1,1-diphenyl-2-picrylhydrazyl) assay] was highest in the of variety (510,731.82 ± 1233.60mg/Kg) but

lowest in the RS one (378663.78 ± 9899.55 mg/Kg). Thus the antioxidation capabilities of the five sweet potato varieties increase in the order RS<AO<RL<AW<OF. In their investigation, Suárez et al. [7] reported an antioxidation capability of (DPPH:74,000.00 ± 1000. Mg VcE/ Kgdw) which much lower than in the current finding.On the other hand, Abong et al. [8] stated an antioxidant activity from 38273.00 mg/K g to 47076.00 mg/Kg, which also is lower than is recorded in this work. According to Ayeleso et al. [4], beta carotene and anthocyanin are responsible for the antioxidation properties of sweet potato. Dinu et al. [6], estimated the correlation of phytochemicals to antioxidation, recording r^2 = 0.53 between total polyphenols and antioxidant activity as well as r^2 = 0.84 between reducing sugar and antioxidant activity, thus establishing a link between phytochemicals and antioxidant activity.

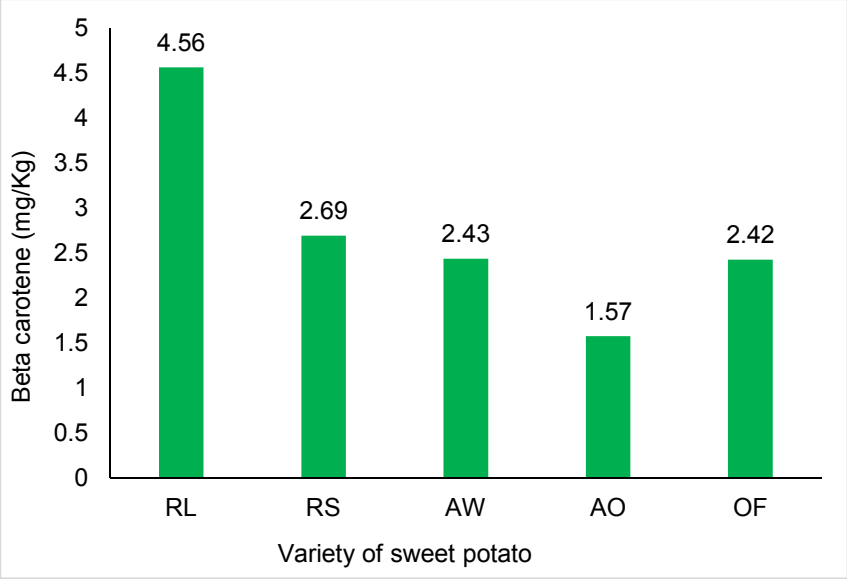

Fig. 8. Concentration of Beta carotenes (mg/Kg) in five varieties of sweet potato

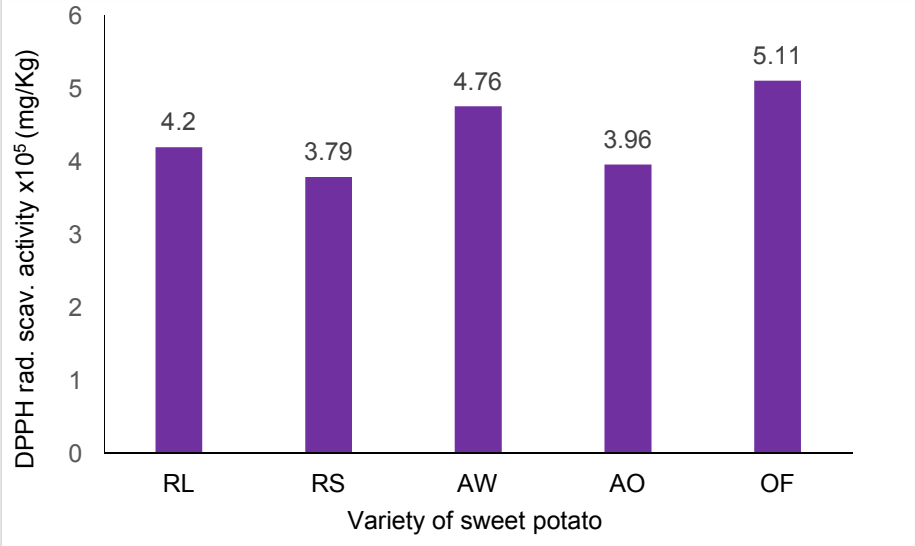

Fig. 9. Antioxidant scavenging activity of five varieties of sweet potato

Various human diseases, for instance, abnormal cell and tissue growth, heart diseases and diseases of the nervous system, are caused by the presence and activities of harmful charged elements or compounds usually referred to as free radicals, reactive oxygen species, etc. in the body cells. Certain naturally occurring chemicals in plants; phytochemicals, have the capacity to neutralize or remove these dangerous charged particles from the cells of the body. The result is the reduction or even elimination of these diseases and the improvement of public health. Studies have confirmed the content of considerable amounts of these phytochemicals in sweet potato leaves [2-8,20,38-40]. Informed by these findings and the link between phytochemicals and the amelioration of various health conditions, many have reached the conclusion that sweet potato is one of the nutraceutical crops. All five varieties of sweet potato in this work have high antioxidation capacity and can thus be deemed to have health benefits in consequence.

4. CONCLUSION

Leaves of the five sweet potato varieties studied are rich in diverse nutrients and phytochemicals. The AW variety recorded the highest protein and carbohydrates content of all while the highest content of crude fibre occurred in the OF variety. The two orange flesh varieties, had the highest (OF) and higher (AO) concentrations of the minor nutrient iron (Fe). Magnesium (Mg) is the element that occurred in highest concentration of all the minerals tested for. The high nutrient, mineral and phytochemical content encourages the growth and consumption of both leaves and root tubers of sweet potatoes as a cheaper means of reducing malnutrition and enhancing good public health. It is therefore, essential for more investigations to establish the nutrient content and nutraceutical capabilities of both roots and leaves of the different varieties of sweet potato in the different environments so as to equip the general public with appropriate information to guide dieting choices.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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