Nutrient and bioactive compounds composition of the leaves and stems of Pandiaka heudelotii: A wild vegetable

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Abstract

The proximate, minerals, vitamins, amino acid, alkaloids, phytosterols, carotenoids, glycosides and saponins profiles of the leaves and stems of Pandiaka heudelotii were determined using standard methods. The leaves and stems had high contents (g/100g) of fibre (10.3–12.9) and carbohydrate (47.2–55.3); and moderate protein (4.4–9.8) and crude fat (6.7–10.2); respectively, equivalent to 41.1–51.6%, 15.7–17.8%, 8.8–19.6%, 10.3–15.7% of the corresponding daily values. They had high contents of iron, manganese, calcium, magnesium, potassium, selenium, vitamins C, E and B2, alkaloids, glycosides, carotenoids, saponins; and moderate phytosterol. Their proteins had high contents of essential amino acids (42.6–48.5%). Triacetonamine (57.20–60.13%), nicotiflorin (53.45–55.35%), carotene (49.95–51.94%), liquiritin (57.54–62.34%), and sitosterol (82.84–85.03%) were respectively, the most abundant alkaloids, glycosides, carotenoids, saponins and phytosterols detected. This result indicates that the leaves and stems are good sources of nutraceuticals and nutrients for human nutrition. It provides an insight into the nature of its bioactive components.

Keywords: Food science, Nutrition, Food analysis, Biochemistry
1. Introduction

Vegetables enrich and diversify the human diet. They are rich sources of fibre, mineral nutrients, vitamins, bioactive phytochemicals, and other compounds that support human health and nutrition (Radovich, 2011; Sinha et al., 2011). One of such vegetables that can be used as a source of nutrient and nutraceuticals is Pandiaka heudelotii. Pandiaka heudelotii is a wild vegetable, which belongs to the Amaranthaceae family (Ifeanacho et al., 2017). In southern Nigeria, the leaves of this plant are used as vegetables and boiled for tea (Ifeanacho et al., 2017). They are also used for the treatment of malaria.

Earlier, Ifeanacho et al. (2017) reported the profile of phenolic compounds in the leaves and stems of Pandiaka heudelotii. They reported that the leaves and stems had high contents of flavonoids and benzoic acid derivatives, and moderate contents of lignans and hydroxycinnamates. Presently, there is no information in the biochemical literature regarding the nutrients, allicins, alkaloids, phytosterols, carotenoids, glycosides and saponins compositions of the leaves and stems of this wild vegetable. Therefore, this study investigated the composition of these compounds in the leaves and stems of Pandiaka heudelotii with a view to providing information on their potential as sources of nutrients and nutraceuticals. The pharmacological significance of these bioactive constituents is also discussed herein.

2. Materials and methods

2.1. Collection of samples

Fresh samples of Pandiaka heudelotii were collected from within the Abuja Campus of University of Port Harcourt, Port Harcourt, Nigeria. They were identified and prepared as earlier reported by Ifeanacho et al. (2017).

2.2. Determination of nutrient profiles

2.2.1. Proximate analysis

A portion of the samples was used for proximate analysis, to determine (in triplicate) the moisture, crude protein, fat, ash, fibre and total carbohydrates, using standard methods. The moisture content was determined according to AOAC Official Method 967.03 (AOAC International, 2006). The ash content was determined according to AOAC Official Method 942.05 (AOAC International, 2006). The crude protein (% total nitrogen x 6.25) was determined by Kjeldhal method using AOAC Official
Method 2001.11 (AOAC International, 2006). Crude fat was determined according to AOAC Official Method 920.39 (AOAC International, 2006). The determination of the fibre content was based on AOAC Official Method 973.18 (AOAC International, 2006). Carbohydrate content was determined by difference (i.e. by subtracting the sum of all the other components from 100 g). Metabolizable energy value was calculated with Atwater factors 4, 9 and 4 for protein, fat and carbohydrate respectively (Ikewuchi et al., 2009).

2.2.2. Determination of mineral elements and phosphorus composition

Analysis of the mineral elements was carried out according to FAO fertilizer and plant nutrition bulletin 19 (Motsara and Roy, 2008). The samples were ashed and digested with nitric acid, before being analyzed with an atomic absorption spectrophotometer. Phosphorus was determined spectrophotometrically by the vanadium molybdate method (Motsara and Roy, 2008). The phosphorus content of the samples was converted to orthophosphates by digestion with a mixture of HNO₃ and HClO₄; and the resultant orthophosphates was made to react with molybdate and vanadate in Vanadomolybdate Reagent, to form a yellow-coloured vanadomolybdophosphoric complex whose intensity (which is directly proportional to the concentration of phosphorus present in the sample) was read at 420 nm in a spectrophotometer.

2.2.3. Determination of vitamin profile

The vitamin content was extracted by a combination of the methods of Association of Official Analytical Chemists (AOAC) Method 992.03, 992.04 and 992.26 (AOAC International, 2006). Chromatographic analysis was performed with an HP 6890 (Hewlett Packard, Wilmington, DE, USA) Series gas chromatograph equipped with a pulse flame photometric detector and a 30 m × 0.25 mm i.d. column coated with a 0.25 μm film of DB-5MS, and powered with HP ChemStation Rev. A09.01[1206] Software. Split injection (split ratio 20:1) was performed, with nitrogen as carrier gas at a flow rate of 1.0 m/s. The column temperature was maintained at 50 °C for 2 min after injection, and then ramped at 10 °C/min for 20 min, followed by another ramping at 15 °C/min for 4 min. The injection port and detector temperatures were 250 and 320 °C respectively. The hydrogen and compressed air pressures were 137.90 and 262.00 kPa. Calculations were based on analysis of standard mixtures and calculation of individual correction coefficients.
2.2.4. **Determination of per cent daily value (%DV)**

Per cent daily values (%DV) were determined by comparison to the appropriate daily values (Food and Drug Administration, 2013). It was calculated using the following formula.

\[
\text{Percent daily value (\%)} = \frac{\text{weight of the particular nutrient in 100 g of sample}}{\text{daily value}} \times 100
\]

2.2.5. **Determination of amino acid profile**

The extraction of the amino acids was carried out according to AOAC Method 982.30 (AOAC International, 2006). The sample was dried to a constant weight, defatted, hydrolysed, and concentrated to 1.0 mL. The concentrated hydrolysate was derivatised before being subjected to gas chromatography analysis on an HP 6890 (Hewlett Packard, Wilmington, DE, USA) Series gas chromatograph equipped with a pulse flame photometric detector and a 30 m $\times$ 0.25 mm i.d. column coated with a 0.25 μm film of HP-5 and powered with HP ChemStation Rev. A09.01[1206] Software. A split injection was adopted at a split ratio of 20:1. The carrier gas used was hydrogen at a flow rate of 1.0 mL/min. The inlet and detector temperatures were 250 and 320 °C. The column and compressed air pressures were respectively 137.90 and 241.32 kPa. The oven was programmed initially at 60 °C, ramped at 8 °C/min for 20 min, maintained for 2 min and then ramp again at 12 °C/min for 6 min, before maintaining for 2 min.

2.2.6. **Determination of digestible indispensable amino acid (DIAA) reference ratio and DIAA score**

The digestible indispensable amino acid (DIAA) reference ratio for each indispensable amino acid (IAA) in the test proteins were determined by comparing their amino acid composition as obtained in this study, with WHO reference protein patterns (FAO, 2013), according to the following equation.

\[
\text{Digestible IAA reference ratio} = \frac{\text{mg of a digestible indispensable amino acid in 1 g protein of the sample}}{\text{mg of same digestible indispensable amino acid in 1 g of reference protein}}
\]

The digestible IAA score (DIAAS) was determined by expressing the lowest DIAA reference ratio as a percentage (FAO, 2013); while the limiting amino acid was taken as the DIAA with the least DIAA ratio.
2.3. Evaluation of the phytochemical profile

2.3.1. General procedures

Gas chromatography was carried out at Multi Environmental Management Consultants Limited, Igbe Road, Ikorodu, Lagos, with a Hewlett Packard HP 6890, gas chromatograph, fitted with a flame ionization detector (except for allicins analysis, in which pulse flame photometric detector was used), and powered with HP Chemstation Rev. A09.01[1206] software, to identify and quantify compounds. Standards were from Sigma-Aldrich Co. and Lynnchem Biological Technology Co. Standard solutions were prepared in methanol for alkaloids and allicins; in acetone for carotenoids; in methylene chloride for phytosterols; and in ethanol for glycosides and saponins. The linearity of the dependence of response on concentration was verified by regression analysis. Identification was based on comparison of retention times and spectral data of the standards. Quantification was performed by creating calibration curves for each compound determined, using the standards.

2.3.2. Determination of alkaloids composition

The extraction of the alkaloids was carried out according to Ngounou et al. (2005). The resultant extract was subjected to gas chromatography on a DB-5MS column capillary of dimensions: 30 m × 0.25 mm ID × 0.25 μm film thickness. The inlet and detection temperatures were 250 and 320 °C. The equipment was run on split injection (20:1 split ratio), using nitrogen as carrier gas. The hydrogen and compressed air pressures were 193.05 and 262.00 kPa respectively. The oven temperature was run initially at 60 °C for 5 min, ramped at 10 °C/min for 20 min, and ramped again at 15 °C/min for 4 min.

2.3.3. Determination of saponins composition

The extraction of the saponins was carried out according Guo et al. (2009). The resultant extract was subjected to gas chromatography on a DB-225MS column capillary of dimensions: 30 m × 0.25 mm ID × 0.25 μm film thickness. The inlet and detection temperatures were 250 and 320 °C. The equipment was run on split injection (20:1 split ratio) using nitrogen as carrier gas. The hydrogen and compressed air pressures were 193.05 and 275.79 kPa respectively. The oven temperature was run initially at 60 °C for 5 min, ramped at 12 °C/min for 18 min, and ramped again at 15 °C/min for 5 min.

2.3.4. Determination of allicins composition

The allicins were extracted in accordance with Chehregani et al. (2007). The resultant extract was subjected to gas chromatography on an OV-101 column capillary of
dimensions: 30 m × 0.30 mm ID × 0.25 μm film thickness. The injection and detection temperatures were 250 and 320 °C. The equipment was run on split injection (20:1 split ratio), using helium as carrier gas at a pressure of 206.84 kPa. The hydrogen and compressed air pressures were 193.05 and 268.90 kPa respectively. The oven temperature was run initially at 80 °C for 5 min. The first ramping was at 10 °C/min for 5 min, maintained for 4 min; and the second ramping at 10 °C/min for 5 min, maintained for 4 min.

2.3.5. Determination of sterols composition

Extraction of oil was carried out according to AOAC method 999.02 (AOAC International, 2006), while the analysis of the sterols was carried out according to AOAC method 994.10 (AOAC International, 2006) and AOAC method 970.51 (AOAC International, 2006). The resultant extract, after saponification and removal of nonsaponifiables, was subjected to gas chromatography on a HP INNOWax column capillary of dimensions: 30 m × 0.25 mm ID × 0.25 μm film thickness. The inlet and detection temperatures were 250 and 320 °C. The equipment was run on split injection (20:1 split ratio), using nitrogen as carrier gas. The hydrogen and compressed air pressures were 151.68 and 241.32 kPa respectively. The oven temperature was run initially at 60 °C. It was then ramped at 10 °C/min for 20 min, maintained for 4 min; ramped again at 15 °C/min for 4 min, and maintained for 10 min.

2.3.6. Determination of carotenoids composition

The extraction of the carotenoids was carried out according to Takagi (1985). The resultant extract was subjected to gas chromatography on an AC-5 column capillary of dimensions: 30 m × 0.25 mm ID × 0.25 μm film thickness. Inlet and detection temperatures were 250 and 320 °C. The equipment was run on split injection (20:1 split ratio), with nitrogen as carrier gas. Hydrogen and compressed air pressures were 206.8 and 275.8 kPa respectively. Oven temperature was run initially at 60 °C, ramped at 10 °C/min for 20 min, maintained for 2 min; ramped again at 15 °C/min for 4 min and maintained for 4 min.

2.3.7. Determination of glycosides composition

The glycosides were extracted in accordance with Oluwaniyi and Ibiyemi (2007). The resultant extract was subjected to gas chromatography on an AC-5 column capillary of dimensions: 30 m × 0.25 mm ID × 0.25 μm film thickness. The inlet and detection temperatures were 250 and 320 °C. The equipment was run on split injection (20:1 split ratio) using nitrogen as carrier gas. The hydrogen and compressed air pressures were 193.05 and 275.79 kPa respectively. The oven temperature was run initially at 70 °C for 5 min, and ramped at 12 °C/min for 20 min.
2.3.8. Derivation of compositions per dry weight from the composition per wet weight

Compositions per dry weight of the parameters were derived from compositions per wet weight and vice versa, using the following formula (Ikewuchi et al., 2015).

\[
\text{Composition per dry weight (\%)} = \frac{\text{Composition per wet weight (\%)} \times 100}{\text{Dry matter content (\%)}}
\]

2.4. Statistical analysis

Means and standard deviations were calculated for three determinations. Means of the nutrient components were tested with student \( t \)-test and significance accepted at \( p < 0.05 \) probability levels.

3. Results and discussion

Table 1 shows the proximate composition and nutrient potential of the stems and leaves of Pandiaka heudelotii. The leaves had higher moisture \(( p < 0.0010)\), crude fat \(( p < 0.0152)\), and crude protein \(( p < 0.0005)\) contents and caloric value \(( p < 0.0234)\) than the stems, while the stems had higher carbohydrate \(( p < 0.0018)\), ash \(( p < 0.1111)\) and crude fibre \(( p < 0.0157)\) contents. They had moderate moisture levels, above which, the moisture would have been undesirable for their quality, since high moisture content increases water activity and the probability of microbial growth (Farah, 2012). Their protein and caloric contents were higher than those of cabbage, lettuce (green and red), amaranth leaves (U.S. Department of Agriculture, 2016a,b,c,d) and Tridax procumbens (Ikewuchi et al., 2009). Drying improved their protein content, therefore making the dried leaves a protein source with a protein content of 11% which is greater than the 10% cut-off (FAO, 2013). The ash, crude fat and total carbohydrate contents of the leaves of P. heudelotii were higher than those of Cnidoscolus aurifolia (Udo and Udo, 2016), cabbage, lettuce (green and red), amaranth leaves (U.S. Department of Agriculture, 2016a,b,c,d) and T. procumbens (Ikewuchi et al., 2009). The leaves had comparable fibre content to C. aurifolia (Udo and Udo, 2016). However, they had higher fibre than cabbage, green and red lettuce (U.S. Department of Agriculture, 2016a,b,c) and T. procumbens (Ikewuchi et al., 2009). According to Farah (2012), a high intake of dietary fibre has been positively associated with several beneficial physiologic and metabolic effects like lowering blood cholesterol and modulating the blood glucose and insulin responses.

In comparison to the daily values (Food and Drug Administration, 2013), a 100 g of the leaves can provide about 41.2–46.7% of daily value for crude fibre, 19.6–22.2% daily value for crude protein, 16.0–18.1% of daily value for caloric value, 15.7–17.8% of daily value for carbohydrate, 15.7–17.8% of daily value for crude
Table 1. Proximate composition (/100g) and nutrient potential (per cent daily value/100g) of the leaves and stems of *Pandiaka heudelotii*.

| Component       | Composition (g/100g) | Potential (per cent daily value/100g) |
|-----------------|----------------------|--------------------------------------|
|                 | Leaves | Stems | Leaves | Stems | Leaves | Stems | Leaves | Stems |
| Moisture        | 11.70 ± 0.243*       | -      | 8.20 ± 0.227 | -      | NA     | NA     | NA     | NA     |
| Dry matter      | 88.30 ± 0.243*       | 100.000 ± 0.000* | 91.80 ± 0.227 | 100.00 ± 0.000 | NA     | NA     | NA     | NA     |
| Ash             | 10.80 ± 0.617*       | 12.23 ± 0.699* | 12.25 ± 0.567 | 13.34 ± 0.617 | NA     | NA     | NA     | NA     |
| Crude fat       | 10.20 ± 0.657*       | 11.55 ± 0.744* | 6.70 ± 0.286  | 7.29 ± 0.311  | 15.69 ± 1.011* | 17.77 ± 1.145* | 10.30 ± 0.440 | 11.22 ± 0.479 |
| Crude protein   | 9.80 ± 0.171*        | 11.09 ± 0.194* | 4.40 ± 0.090  | 4.79 ± 0.098  | 19.60 ± 0.343* | 22.19 ± 0.388* | 8.80 ± 0.181  | 9.58 ± 0.197  |
| Carbohydrate    | 47.20 ± 0.861*       | 53.45 ± 0.975* | 55.25 ± 1.158 | 60.18 ± 1.261 | 15.73 ± 0.287* | 17.81 ± 0.325* | 18.41 ± 0.386 | 20.06 ± 0.420 |
| Crude fibre     | 10.30 ± 0.432*       | 11.66 ± 0.489* | 12.90 ± 0.238 | 14.05 ± 0.259 | 41.20 ± 1.726* | 46.65 ± 1.955* | 51.60 ± 0.951 | 56.20 ± 1.035 |
| Caloric value   | 319.80 ± 9.315*      | 362.17 ± 10.547* | 298.90 ± 2.690 | 325.59 ± 2.931 | 15.99 ± 0.466* | 18.10 ± 0.527* | 14.94 ± 0.135 | 16.28 ± 0.147 |

Values are means ± standard deviation of triplicate determinations. *P* < 0.05 compared to stems.

*The unit of Caloric value = kcal/100g; NA = not applicable.*
fat (Table 1). A 100 g of the stems can provide 51.6—56.2% of daily value for crude fibre, 18.4—20.1% of daily value for carbohydrate, 15.0—16.3% of daily value for caloric value, 10.3—11.2% of daily value crude fat and 8.8—9.6% of daily value for crude protein.

The leaves and stems of *P. heudelotii* had high contents of vitamins C, E and B2, although, the leaves had higher contents of these vitamins (Table 2). They had higher vitamin C than cabbage, lettuce (green and red), amaranth leaves (Venskutonis and Kraujalis, 2013; U.S. Department of Agriculture, 2016a,b,c,d) and *T. procumbens* (Ikewuchi and Ikewuchi, 2009a). They also had higher vitamin B2 than cabbage, lettuce (green and red), amaranth leaves (U.S. Department of Agriculture, 2016a,b,c,d) and *T. procumbens* (Ikewuchi and Ikewuchi, 2009a); but lower contents than amaranth seeds (Venskutonis and Kraujalis, 2013). The leaves had higher vitamin B3 than cabbage, green and red lettuce (U.S. Department of Agriculture, 2016a,b,c) and *T. procumbens* (Ikewuchi and Ikewuchi, 2009a); but lower contents than amaranth leaves and seeds (Venskutonis and Kraujalis, 2013; U.S. Department of Agriculture, 2016d). The leaves and stems had higher vitamin B1 than amaranth leaves (U.S. Department of Agriculture, 2016d) and *T. procumbens* (Ikewuchi and Ikewuchi, 2009a), but lower contents than cabbage, green and red lettuce (U.S. Department of Agriculture, 2016a,b,c). Their vitamins B6, B5, B9, A, E and K contents were lower than those of cabbage, lettuce (green and red) and amaranth leaves (U.S. Department of Agriculture, 2016a,b,c,d). When compared to the relevant daily values (Food and Drug Administration, 2013), a 100 g of the leaves can provide about 123.5%—139.9% of daily value for vitamin C, 319.2%—361.4% of daily value for vitamin E, and 16.7%—18.9% of daily value for vitamin B2. That of the stem is equivalent to 104.6%—113.9% of daily value for vitamin C, 200.1%—218.0% of daily value for vitamin E, and 11.3%—12.3% of daily value for vitamin B2.

The leaves and stems had high contents of calcium, iron, magnesium, manganese, potassium and selenium (Table 3). The leaves had higher copper ($p < 0.021$), phosphorus ($p < 0.019$), selenium ($p < 0.028$), sodium ($p < 0.010$) and zinc ($p < 0.014$); and lower calcium ($p < 0.016$), iron ($p < 0.031$), magnesium ($p < 0.012$), manganese ($p < 0.029$) and potassium ($p < 0.005$) contents than the stems. They both had higher manganese and phosphorus than lettuce (green and red), cabbage and amaranth leaves (U.S. Department of Agriculture, 2016a,b,c,d). They had higher calcium, magnesium and potassium than *C. aurifolia* leaves, cabbage, lettuce (green and red), amaranth leaves (Udo and Udo, 2016; U.S. Department of Agriculture, 2016a,b,c,d) and *T. procumbens* (Ikewuchi and Ikewuchi, 2009b). According to Kilgour (1985), to avoid hypertension from food sources, the ratio of sodium to potassium should be $\leq 1.67$. This study showed that the leaves and stems of *P. heudelotii* had low sodium to potassium ratios, and so may be very safe for consumption by hypertensive individuals. In addition, they had high calcium to phosphorus ratios. High dietary calcium/phosphorus ratio might have a positive influence on bone mass...
Table 2. Vitamin composition and potential of leaves and stems of *Pandiaka heudelotii*.

| Component | Concentration (mg/kg) |  |  |  |  |
|-----------|-----------------------|----------------------|----------------------|----------------------|----------------------|
|           | Leaves /fresh weight | Leaves /dry weight | Stems /fresh weight | Stems /dry weight | Per cent daily value/100 g | Leaves /fresh weight | Leaves /dry weight | Stems /fresh weight | Stems /dry weight |
| Vitamin B3 | 4.380220 | 4.960612 | 3.079010 | 3.354041 | 0.988400 | 1.119370 | 1.183690 | 1.289320 |
| Vitamin B6 | 0.197680 | 0.223873 | 0.236720 | 0.257865 | 0.988400 | 1.119370 | 1.183690 | 1.289320 |
| Vitamin C | 741.062900 | 839.255800 | 627.558600 | 683.615000 | 123.510000 | 139.876000 | 104.593000 | 113.936000 |
| Vitamin A | 0.013093 | 0.014828 | 0.014734 | 0.016050 | 0.087280 | 0.098840 | 0.098220 | 0.106990 |
| Vitamin B1 | 0.505763 | 0.572778 | 0.325199 | 0.354247 | 3.371750 | 3.818520 | 2.167990 | 2.361650 |
| Vitamin B2 | 2.837960 | 3.213998 | 1.915700 | 2.086819 | 16.693900 | 18.905900 | 11.268890 | 12.275400 |
| Vitamin D | 0.000334 | 0.000378 | 0.00021 | 0.00023 | 0.027830 | 0.031520 | 0.001770 | 0.001930 |
| Vitamin E | 0.287266 | 0.325330 | 0.180990 | 0.196176 | 319.153000 | 361.441000 | 200.080000 | 217.952000 |
| Vitamin B9 | 0.203796 | 0.230800 | 0.201742 | 0.219763 | 5.094900 | 5.769990 | 5.043550 | 5.494060 |
| Vitamin K | 0.003549 | 0.004019 | 0.002379 | 0.002592 | 0.443620 | 0.502400 | 0.297380 | 0.323950 |
| Vitamin B5 | 0.281392 | 0.318677 | 0.130562 | 0.142224 | 0.281390 | 0.318680 | 0.130560 | 0.142220 |
Table 3. Mineral nutrient composition and potential of leaves and stems of *Pandiaka heudelotii*.

| Component | Composition (mg/kg) | Potential (per cent daily value/100 g) |
|-----------|---------------------|----------------------------------------|
|           | Leaves /fresh weight | Leaves /dry weight | Stems /fresh weight | Stems /dry weight | Leaves /fresh weight | Leaves /dry weight | Stems /fresh weight | Stems /dry weight |
| Iron      | 64.8260 ± 0.8850     | 73.4156 ± 1.0023* | 81.7450 ± 0.7780 | 89.0468 ± 0.8475 | 36.0145 ± 0.4917* | 40.7865 ± 0.5568* | 45.4139 ± 0.4322 | 49.4705 ± 0.4708 |
| Copper    | 1.6130 ± 0.0880*     | 1.8267 ± 0.0997*  | 0.5140 ± 0.0150  | 0.5599 ± 0.0163  | 8.0650 ± 0.4400*  | 9.1336 ± 0.4938*  | 2.5700 ± 0.0750  | 2.7996 ± 0.0817  |
| Manganese | 46.9570 ± 0.4220*    | 53.1789 ± 0.4779* | 55.1840 ± 0.3210 | 60.1133 ± 0.3497 | 234.7850 ± 2.1100*| 265.8947 ± 2.3896*| 275.9200 ± 1.6050| 300.5664 ± 1.7484|
| Zinc      | 26.8350 ± 0.5210*    | 30.3907 ± 0.5900* | 8.3070 ± 0.3090  | 9.0490 ± 0.3366  | 17.8900 ± 0.3473* | 20.2605 ± 0.3933* | 5.5380 ± 0.2060  | 6.0327 ± 0.2244  |
| Calcium   | 34125.0400 ± 174.9800*| 38646.7044 ± 198.1653*| 39205.9000 ± 87.3000 | 42707.9521 ± 95.0980 | 460.5195 ± 2.0085*| 521.5396 ± 2.2746*| 544.1855 ± 1.0685| 592.7947 ± 1.1639|
| Magnesium | 18420.7800 ± 80.3400*| 20861.5855 ± 90.9853*| 21767.4200 ± 42.7500 | 23711.7865 ± 46.5686 | 426.336 ± 0.0391* | 29.8251 ± 0.0443* | 38.9016 ± 0.2559 | 42.3765 ± 0.2788 |
| Potassium | 9217.4580 ± 13.6870* | 10438.7973 ± 15.5006*| 13615.5600 ± 89.5600 | 14831.7647 ± 97.5599 | 6.1289 ± 0.0307*  | 1.2785 ± 0.0348*  | 0.7573 ± 0.0194 | 0.8250 ± 0.0211 |
| Sodium    | 270.9460 ± 7.3770*   | 306.8471 ± 8.3545* | 181.7640 ± 4.6670 | 198.0000 ± 5.0839 | 1.1289 ± 0.0307*  | 1.2785 ± 0.0348*  | 0.7573 ± 0.0194 | 0.8250 ± 0.0211 |
| Phosphorus| 982.1630 ± 7.0410*   | 1112.3024 ± 7.9740*| 926.4290 ± 3.6970 | 1009.1819 ± 4.0272 | 9.8216 ± 0.0704*  | 11.1230 ± 0.0797* | 9.2643 ± 0.0370 | 10.0918 ± 0.0403 |
| Selenium  | 0.0120 ± 0.0003*     | 0.0136 ± 0.0003*  | 0.0080 ± 0.0001  | 0.0087 ± 0.0001  | 1714.2850 ± 42.8550*| 1941.4326 ± 48.5334*| 1142.8550 ± 7.1450| 1244.9401 ± 7.7832|
| Sodium/   | 0.0294 ± 0.0008*     | 0.0294 ± 0.0008*  | 0.0133 ± 0.0003  | 0.0133 ± 0.0003  | NA               | NA               | NA               | NA               |
| phosphorus|                    |                    |                  |                  |                  |                  |                  |                  |
| ratio†    |                          |                      |                  |                  |                  |                  |                  |                  |
| Calcium/  | 34.7478 ± 0.4273*      | 34.7478 ± 0.4273*   | 42.3197 ± 0.0746 | 42.3197 ± 0.0746 | NA               | NA               | NA               | NA               |
| phosphorus|                      |                      |                  |                  |                  |                  |                  |                  |
| ratio†    |                          |                      |                  |                  |                  |                  |                  |                  |

Values are means ± standard deviation of triplicate determinations. *P < 0.05 compared to stems.
†These have no units. NA = not applicable.
(Lee et al., 2014). It allows for strong bone development because absorption of calcium under this condition would be maximal (Koshihara et al., 2005). According to Korkmaz et al. (2013), magnesium (a calcium channel blocker) is involved in many metabolic processes, like maintenance of cell membrane function, modulation of smooth muscle contraction and enzymatic activities. Studies have shown that magnesium is a neuroprotective agent; increases blood flow to tissues; plays a vital role in development and function of the eye; and in diabetic patients, decreases insulin resistance, enhances glycaemic control and prevents diabetic retinopathy (Korkmaz et al., 2013).

They also had higher iron and zinc contents than cabbage, lettuce (green and red), amaranth leaves (U.S. Department of Agriculture, 2016a,b,c,d) and T. procumbens (Ikewuchi and Ikewuchi, 2009b), but however, had lower contents than C. aurifolia leaves (Udo and Udo, 2016). They had higher selenium than cabbage and green lettuce (U.S. Department of Agriculture, 2016a,b); but only those of the leaves were higher than amaranth leaves (U.S. Department of Agriculture, 2016d). They however had lower selenium than red lettuce (U.S. Department of Agriculture, 2016c). Their copper were higher than those of cabbage, green and red lettuce (U.S. Department of Agriculture, 2016a,b,c); while only those of the leaves were higher than amaranth leaves (U.S. Department of Agriculture, 2016d). Comparison to relevant daily values (Food and Drug Administration, 2013), shows that a 100 g is equivalent to 234.8−265.9% (leaves) and 275.9−300.6% (stems) daily value for manganese; 1714.3−1941.4% (leaves) and 1142.9−1244.9% (stems) daily value for selenium; 341.3−386.5% (leaves) and 392.1−427.1% (stems) daily value for calcium; 460.5−521.5% (leaves) and 544.2−592.8% (stems) daily value for magnesium; 36.0−40.8% (leaves) and 45.4−49.5% (stems) daily value for iron; and 26.3−29.8% (leaves) and 38.9−42.4% (stems) daily value for potassium.

Amino acid profile, and DIAA reference ratios of the leaf and stem proteins are given in Tables 4 and 5. They are rich in essential amino acids, 48.5% for leaves and 42.6% for stems [especially isoleucine (in leaves and stems), aromatic amino acids (leaves), threonine (leaves and stems), leucine (leaves) and histidine (leaves)] and can meet the daily requirements (FAO, 2013) for essential amino acids (except leucine, in the case of the stem protein), for children (≥6 months), adolescents and adults. Compared to WHO reference protein patterns for infant (≤6 months), child (6 months−3 years), older child, adolescent, adult (FAO, 2013), the DIAAS of the leaf protein were 47.6, 57.6 and 68.4 respectively, with lysine as limiting amino acid. Those of the stem protein were 23.9, 34.7 and 37.6, with leucine as limiting amino acid. Every 100 g of these proteins contained 32.0 g (for leaves) and 23.9 g (for stems) of essential amino acids; 1.9 g (for leaves) and 1.5 g (stems) of sulphur-containing amino acids; and 6.5 g (leaves) and 4.0 g (stems) of aromatic amino acids (Table 4). The leaf protein can be used for supplementation of isoleucine, aromatic amino acids and threonine in diets of children (≥6 months),
adolescents and adults, and histidine and leucine in older children, adolescent and adults; while the stems can be used for isoleucine and threonine in children (≥6 months), adolescents and adults.

Compared to child (6 months—3 years) requirement protein pattern (FAO, 2013), the leaf protein has a digestible indispensable amino acid score, comparable to cooked peas, cooked kidney beans, cooked rice, cooked rolled oats; and higher digestible indispensable amino acid score than wheat bran, roasted peanuts, and rice protein concentrate (Rutherfurd et al., 2015).

The alkaloids, glycosides and carotenoids compositions of the leaves and stems of Pandiaka heudelotii is presented in Table 6a. The leaves (3309.6 mg/kg dry weight)
Table 5. Digestible indispensable amino acid (IAA) reference ratios of proteins from the leaves and stems of *Pandiaka heudelotii*.

| Amino acids                  | Amino acid composition from present study (mg/g protein) | Digestible Indispensable Amino Acid (IAA) reference ratio | Comparison to infant (birth to 6 months) requirement protein pattern | Comparison to child (6 months—3 years) requirement protein pattern | Comparison to older child, adolescent, adult requirement protein pattern |
|------------------------------|--------------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------|-----------------------------------------------------------------------|
|                              | Leaves | Stems  | Leaves | Stems  | Leaves | Stems  | Leaves | Stems  | Leaves | Stems  | Leaves | Stems  | Leaves | Stems  |
| Histidine                    | 19.184 | 11.006  | 0.914  | 0.524  | 0.959  | 0.550  | 1.199  | 0.688  |        |        |        |        |        |        |
| Isoleucine                   | 43.008 | 38.140  | 0.782  | 0.693  | 1.344  | 1.192  | 1.434  | 1.271  |        |        |        |        |        |        |
| Leucine                      | 64.955 | 22.907  | 0.677  | 0.239  | 0.984  | 0.347  | 1.065  | 0.376  |        |        |        |        |        |        |
| Lysine                       | 32.822 | 34.783  | 0.476  | 0.504  | 0.576  | 0.610  | 0.684  | 0.725  |        |        |        |        |        |        |
| Methionine + cysteine        | 19.141 | 15.107  | 0.580  | 0.458  | 0.709  | 0.560  | 0.832  | 0.657  |        |        |        |        |        |        |
| Phenylalanine + tyrosine     | 64.823 | 40.059  | 0.690  | 0.426  | 1.247  | 0.770  | 1.581  | 0.977  |        |        |        |        |        |        |
| Threonine                    | 37.790 | 37.909  | 0.859  | 0.862  | 1.219  | 1.223  | 1.512  | 1.516  |        |        |        |        |        |        |
| Valine                       | 38.721 | 39.123  | 0.704  | 0.711  | 0.900  | 0.910  | 0.968  | 0.978  |        |        |        |        |        |        |
Table 6a. Composition of phytochemicals isolated and detected in the leaves and stems of *Pandiaka heudelotii*.

| Compounds        | Leaves                          |                      |                      |                      |                      | Stems                          |                      |                      |
|------------------|---------------------------------|----------------------|----------------------|----------------------|----------------------|---------------------------------|----------------------|----------------------|
|                  | RT (min)                         | Composition (mg/kg)  |                      |                      |                      | RT (min)                        | Composition (mg/kg)  |                      |
|                  | /fresh weight                    | /dry weight          |                      |                      |                      | /fresh weight                  | /dry weight          |                      |
| Alkaloids        |                                 |                      |                      |                      |                      |                                 |                      |                      |
| Dopamine         | 7.689                            | 0.00000020           | 0.00000023           |                      | 7.715                | 0.00000020                     | 0.00000022           |
| 3-Methoxytyramine| 9.565                            | 0.02237450           | 0.02533918           |                      | 9.596                | 0.02018660                     | 0.02198976           |
| Triacetonamine   | 10.933                           | 1757.32480000        | 1900.17531100        |                      | 10.956               | 1264.13970000                  | 1377.05849700        |
| Thiarubrine A    | 11.333                           | 0.00000148           | 0.00000168           |                      | 11.357               | 0.00000147                     | 0.00000161           |
| Aporphine        | 11.478                           | 0.00000271           | 0.00000307           |                      | 11.502               | 0.00000264                     | 0.00000287           |
| Quinine          | 12.387                           | 466.60830000         | 528.43522080         |                      | 12.408               | 409.77370000                   | 446.37657950         |
| Acalyphin        | 13.771                           | 698.43130000         | 790.97542470         |                      | 13.791               | 536.22470000                   | 584.12276690         |
| Lycorine         | 14.796                           | 0.00000404           | 0.00000458           |                      | 14.795               | 0.00000431                     | 0.00000470           |
| Gelanthamine     | 15.464                           | 0.00000122           | 0.00000138           |                      | 15.484               | 0.00000181                     | 0.00000198           |
| **Total alkaloids content** |                      | 2922.38670000        | 3309.61121200        |                      | -                   | 2210.15840000                  | 2407.57956000        |
| Glycosides       |                                 |                      |                      |                      |                      |                                 |                      |                      |
| Linamarin        | 16.252                           | 0.00245385           | 0.00277899           |                      | 16.246               | 0.00123371                     | 0.00134391           |
| Lotaustralin     | 17.364                           | 0.0072481            | 0.0082085            |                      | 17.358               | 0.00040226                     | 0.00043819           |
| Prunasin         | 18.054                           | 0.07117660           | 0.08060770           |                      | 18.049               | 0.04066560                     | 0.04429804           |
| Indican          | 18.947                           | 0.01139200           | 0.01290147           |                      | 18.494               | 0.00701773                     | 0.00764459           |
| Dhurrin          | 18.592                           | 0.00125638           | 0.00142285           |                      | 18.662               | 0.00030929                     | 0.00033691           |
| Nicotiflorin     | 19.103                           | 564.48580000         | 639.28176670         |                      | 19.098               | 437.26660000                   | 476.32527230         |
| Amygdalin        | 19.520                           | 101.35280000         | 114.78233300         |                      | 19.515               | 65.88560000                    | 71.77080610          |
| Ouabain          | 20.471                           | 0.01012780           | 0.01146976           |                      | 20.595               | 0.00186416                     | 0.00203068           |
| Digitoxin        | 21.129                           | 0.00045487           | 0.00051514           |                      | 21.126               | 0.00035016                     | 0.00038144           |
| Digitalis        | 21.821                           | 0.00022305           | 0.00025260           |                      | 21.817               | 0.00017094                     | 0.00018621           |
| Digoxin          | 22.601                           | 0.0098648            | 0.01171179           |                      | 22.596               | 0.00746787                     | 0.00813494           |
| Clitorin         | 23.472                           | 222.38200000         | 251.84824460         |                      | 23.467               | 153.93800000                   | 167.68845320         |
| Mauritianin      | 23.968                           | 167.72810000         | 189.95258410         |                      | 23.964               | 132.87710000                   | 144.74629630         |
| **Total glycosides content** |                      | 1056.04740000        | 1195.97667000        |                      | -                   | 790.02010000                   | 860.58834420         |
| Carotenoids      |                                 |                      |                      |                      |                      |                                 |                      |                      |
| Malvidin         | 19.515                           | 0.00196500           | 0.00222600           |                      | 19.518               | 0.00123100                     | 0.00134100           |
| Beta-cryptoxanthin| 20.532                          | 0.11647800           | 0.13191200           |                      | 20.535               | 0.06703600                     | 0.07302400           |
| Lycopene         | 21.498                           | 0.0003100            | 0.0003500            |                      | 21.501               | 0.00001100                     | 0.00001200           |
| Carotene         | 22.597                           | 312.42140000         | 353.81812000         |                      | 22.599               | 247.67660000                   | 269.80021800         |
| Lutein           | 23.228                           | 120.57510000         | 136.55164200         |                      | 23.230               | 97.29698000                    | 105.98799600         |
| Xanthophyll      | 24.031                           | 43.93280000          | 49.75402000          |                      | 24.033               | 22.93570000                    | 24.98443200          |
| Anthera-xanthin  | 24.876                           | 27.46350000          | 31.10249200          |                      | 24.882               | 17.55660000                    | 19.12483700          |
| Asta-xanthin     | 25.610                           | 8.71534000           | 9.87014700           |                      | 25.615               | 4.63227000                     | 5.04604600           |

(continued on next page)
and stems (2407.6 mg/kg dw) had very high total alkaloids’ contents. Nine known alkaloids were detected including triacetanamine (60.13% in leaves; 57.20% in stems), acalyphin (23.90% in leaves; 24.26% in stems) and quinine (15.97% in leaves; 18.54% in stems). 3-Methoxytyramine, lycorine, aporphine, thiarubrine A, gelanthamine and dopamine constituted less than 0.001%.

The leaves and stems of *P. heudelotii* had lower total alkaloids contents than the leaves of *Tridax procumbens* (Ikewuchi et al., 2015). Amongst the alkaloids detected, triacetanamine (2,2,6,6-tetramethyl-4-keto piperidine), the most abundant, is known to be an anticonvulsive and antihypertensive compound (Navajas et al., 1994). Quinine, another alkaloids detected in the leaves and stems, has been reported to have analgesic, antiarrhythmic, anti-inflammatory, antimalarial, antioxidant, antipyretic and bacteriostatic activities (Krishnaveni et al., 2015).

As shown in Table 6a, the total glycosides’ contents of the leaves and stems of *Pandiana heudelotii* were 1196.0 mg/kg dw and 860.6 mg/kg dw, respectively. Thirteen known glycosides were detected including nicotiflorin (53.45% in leaves; 55.35% in stems), clitorin (21.06% in leaves; 19.49% in stems), mauritianin (15.88% in leaves; 16.82% in stems) and amygdalin (9.60% in leaves; 8.34% in stems). The remaining <0.01% consisted of prunasin, indican, ouabain, linamarin, digoxin, lotaustralin, digitoxin, dhurrin and digitalis.

The most abundant glycosides detected were nicotiflorin, clitorin, mauritianin and amygdalin. The pharmacological properties of nicotiflorin as reported in biochemical literature include analgesic, anthelmintic, anti-anaphylactic, antibacterial, antifungal, antihypertensive and neuroprotective activities (Li et al., 2006; Kumar, 2016). Clitorin has been reported to have antibacterial and antifungal activities (Kumar, 2016); while anti-carcinogenic, antifungal and gastroprotective activities have been reported for mauritianin (Leite et al., 2010; Kumar, 2016). Studies have reported that amygdalin has analgesic, anti-asthmatic, anti-atherogenic, anti-fibrotic, anti-hyperglycaemic, anti-inflammatory, antitumor, antitussive, antiulcer, broncho-protective, gastroprotective and immune regulatory effects (Song and Xu, 2014).
The leaves and stems had high contents of total carotenoids’ (708.3 mg/kg dw in leaves; 519.4 mg/kg dw in stems) (Table 6a). Ten known carotenoids were detected, including carotene (49.95% in leaves; 51.94% in stems), lutein (19.28% in leaves; 20.40% in stems), neoxanthin (11.98% in leaves; 12.25% in stems), viola-xanthin (5.96% in leaves; 5.93% in stems), xanthophyll (7.02% in leaves; 4.81% in stems), anthera-xanthin (4.39% in leaves; 3.68% in stems), asta-xanthin (1.39% in leaves; 0.97% in stems). The remainder (<0.1%) consisted of beta-cryptoxanthin, malvidin and lycopene.

The leaves and stems of *P. heudelotii* had higher carotene and lutein than cabbage (U.S. Department of Agriculture, 2016a), green lettuce (U.S. Department of Agriculture, 2016b) and red lettuce (U.S. Department of Agriculture, 2016c) and leaves of *T. procumbens* (Ikewuchi et al., 2015). They had higher neoxanthin, viola-xanthin and anthera-xanthin than the leaves of *T. procumbens* (Ikewuchi et al., 2015). They also had higher lycopene than cabbage (U.S. Department of Agriculture, 2016a), green lettuce (U.S. Department of Agriculture, 2016b) and red lettuce (U.S. Department of Agriculture, 2016c). Carotenes and lutein has anti-cancer activities (Dillard and German, 2000); while carotenes, in addition, have anti-oxidant and pro-vitamin A activities (Dillard and German, 2000).

The leaves and stems had high contents of total saponins’ (579.5 mg/kg dw in leaves; 306.7 mg/kg dw in stems) (Table 6b). Seven known saponins were detected, including liquiritin (57.54% in leaves; 62.34% in stems), liquiritigenin (37.21% in leaves; 33.72% in stems), isoliquiritigenin (5.25% in leaves; 3.94% in stems); with avenacin-A2, avenacin-B2, avenacin-A1 and avenacin-B1 making up less than 0.01%. Studies have shown that liquiritin, isoliquiritin and isoliquirigenin have anti-cancer effects, individually and in a combination of the three of them (Zhou and Ho, 2014). Isoliquiritin has anti-allergic, anti-depressive, antifungal and anti-inflammatory effects (Hong et al., 2017). Liquiritin has anti-cerebral ischemic, anti-depressive, anti-endothelial dysfunction, anti-melasma, anti-myocardial fibrotic, anti-Parkinsonian, bronchial-protective, cognition enhancing and neuroprotective effects (Hong et al., 2017).

The leaves and stems had moderate total phytosterols’ (105.6 mg/kg dw in leaves and 88.1 mg/kg dw in stems) and low total allicins’ (32.8 μg/kg dw in leaves and 27.8 μg/kg dw in stems) contents (Table 6b). Seven known phytosterols were detected consisting of sitosterol (85.03% in leaves and 82.84% in stems), stigmasterol (7.68% in leaves and 8.73% in stems), campesterol (6.19% in leaves and 7.17% in stems), 5-avenasterol (1.09% in leaves and 1.25% in stems); while the remainder (<0.01%) consisted of cholestanol, cholesterol and ergosterol. Three known allicins were detected, namely diallyl thiosulphinate (71.10% in leaves and 83.85% in stems), methyl allyl thiosulphinate (28.80% in leaves and 16.10% in stems) and allyl methyl thiosulphinate (0.11% in leaves and 0.04% in stems).
The leaves and stems of *P. heudelotii* had lower total phytosterol contents than cabbage (Piironen et al., 2003; U.S. Department of Agriculture, 2016a) and lettuce (Piironen et al., 2003). They had lower sitosterol than cabbage, but higher contents than lettuce (Piironen et al., 2003) and the leaves of *T. procumbens* (Ikewuchi et al., 2015). They also had lower stigmasterol than cabbage, lettuce (Piironen et al., 2003) and the leaves of *T. procumbens* (Ikewuchi et al., 2015). They had lower campesterol than cabbage and lettuce (Piironen et al., 2003). Their avenasterol contents were lower than that of lettuce (Piironen et al., 2003).

Studies have shown that beta-sitosterol possesses analgesic, angiogenic, antihelmintic, anti-arthritic, anti-atherosclerotic, anti-diabetic, anticancer, anti-hyperlipidaemic, anti-inflammatory, antimicrobial, anti-nociceptive, antioxidant,

| Compounds | Leaves | | | | Stems | | | |
|-----------|--------|--------|--------|--------|--------|--------|--------|--------|
|           | RT (min) | Composition (mg/kg) | | | | Composition (mg/kg) | | |
|           | /fresh weight | /dry weight | | | /fresh weight | /dry weight | | |
| Saponins  | Isoliquiritigenin | 18.490 | 26.871800 | 30.432390 | 18.492 | 11.080200 | 12.069935 |
|           | Liquiritigenin   | 19.511 | 190.403400 | 215.632390 | 19.514 | 94.921400 | 103.400218 |
|           | Liquiritin       | 20.618 | 294.456500 | 333.472820 | 20.783 | 175.501700 | 191.178322 |
|           | Avenacin-A1      | 21.813 | 0.000113 | 0.000128 | 21.815 | 0.000036 | 0.000039 |
|           | Avenacin-B1      | 23.185 | 0.000034 | 0.000038 | 23.110 | 0.000019 | 0.000021 |
|           | Avenacin-A2      | 24.776 | 0.006076 | 0.006881 | 24.786 | 0.001655 | 0.001803 |
|           | Avenacin-B2      | 26.276 | 0.003281 | 0.003716 | 26.282 | 0.000581 | 0.000633 |
|           | Total saponins content | - | 511.741200 | 579.548358 | - | 281.505500 | 306.650872 |
| Phytosterols | Cholesterol      | 19.385 | 0.003029 | 0.003430 | 19.384 | 0.0030246 | 0.003295 |
|           | Cholestanol      | 20.389 | 0.004897 | 0.005546 | 20.390 | 0.0047765 | 0.005203 |
|           | Ergosterol       | 21.425 | 0.002082 | 0.002357 | 21.429 | 0.0020757 | 0.002261 |
|           | Campesterol      | 22.303 | 5.771810 | 6.536591 | 22.303 | 5.8022300 | 6.320512 |
|           | Stigmasterol     | 23.068 | 7.159400 | 8.108041 | 23.061 | 7.0608400 | 7.691547 |
|           | 5-Avenasterol    | 24.011 | 1.012880 | 1.147089 | 24.009 | 1.0126400 | 1.103094 |
|           | Sitosterol       | 25.250 | 79.250400 | 89.751302 | 25.250 | 67.011000 | 72.996732 |
|           | Total phytosterol content | - | 93.204500 | 105.554360 | - | 80.896600 | 88.122658 |
| Allicins   | Diallyl thiosulphinate | 16.151 | 0.020606 | 0.023338 | 16.110 | 0.021378 | 0.023287 |
|           | Methyl allyl thiosulphinate | 17.086 | 0.008346 | 0.009452 | 16.980 | 0.004105 | 0.004471 |
|           | Allyl methyl thiosulphinate | 18.011 | 0.000031 | 0.000036 | 18.013 | 0.000011 | 0.000012 |
|           | Total allicins content | - | 0.028984 | 0.032824 | - | 0.025494 | 0.027771 |

RT = Retention time.

The leaves and stems of *P. heudelotii* had lower total phytosterol contents than cabbage (Piironen et al., 2003; U.S. Department of Agriculture, 2016a) and lettuce (Piironen et al., 2003). They had lower sitosterol than cabbage, but higher contents than lettuce (Piironen et al., 2003) and the leaves of *T. procumbens* (Ikewuchi et al., 2015). They also had lower stigmasterol than cabbage, lettuce (Piironen et al., 2003) and the leaves of *T. procumbens* (Ikewuchi et al., 2015) and campesterol than cabbage and lettuce (Piironen et al., 2003). Their avenasterol contents were lower than that of lettuce (Piironen et al., 2003). Studies have shown that beta-sitosterol possesses analgesic, angiogenic, antihelmintic, anti-arthritic, anti-atherosclerotic, anti-diabetic, anticancer, anti-hyperlipidaemic, anti-inflammatory, antimicrobial, anti-nociceptive, antioxidant,
antipyretic, immunomodulatory and neuroprotective activities (Dillard and German, 2000; Saeidnia et al., 2014). Stigmasterol has been reported to have pharmacological properties such as analgesic, anticonvulsant, anti-hypercholesterolaemic, anti-inflammatory, anti-mutagenic, anti-osteoarthritic, antioxidant, antitumor, hypoglycaemic and memory enhancing effects (Kaur et al., 2011; Saeidnia et al., 2014).

4. Conclusion

The above results show that the leaves and stems of *Pandiaka heudelotii* are good sources of macro- and micronutrients, and as such could contribute significantly to the human nutritional requirements and diet. It also shows that the leaves and stems of *Pandiaka heudelotii* contain a wide range of bioactive phytochemicals. The beneficial roles of these phytoconstituents can be harnessed in the human diet, making them veritable tools for nutritional therapy. This, therefore, highlights the potential of these leaves and stems as functional foods.

Declarations

**Author contribution Statement**

Jude C. Ikewuchi: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Catherine C. Ikewuchi: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Mercy O. Ifeanacho: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data.

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**Competing interest Statement**

The authors declare no conflict of interest.

**Additional information**

The chemical compounds studied in this article can be found in PubChem: Valine (PubChem CID: 6287); threonine (PubChem CID: 6288); isoleucine (PubChem...
CID: 38 6306); histidine (PubChem CID: 6274); alpha-tocopherol (PubChem CID: 14985); riboflavin 39 (PubChem CID: 493570); nicotinic acid (PubChem CID: 938); ascorbic acid (PubChem CID: 40 54670067); triacetonamine (PubChem CID: 13220); acalypbin (PubChem CID: 49787014); 41 quinine (PubChem CID: 3034034); nicotiflorin (PubChem CID: 5318767); clitorin 42 (PubChem CID: 11592917); mauritianin (PubChem CID: 44258751); amygdalin (PubChem 43 CID: 656516); carotene (PubChem CID: 5280489); lutein (PubChem CID: 126970006); 44 neoxanthin (PubChem CID: 5282217); viola-xanthin (PubChem CID: 448438); xanthophyll 3 45 (PubChem CID: 24728610); liquiritin (PubChem CID: 503737); liquritigenin (PubChem 46 CID: 114829); anthera-xanthin (PubChem CID: 5281223); isoliquiritigenin (PubChem CID: 47638278); sitosterol (PubChem CID: 222284); stigmasterol (PubChem CID: 5280794); 48 campesterol (PubChem CID: 173183).

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