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Nutritionally Essential Macro and Micro Minerals Contents of Fifteen Selected Leafy Wild and Semi-Wild Food Plants (WSWFPs) from Bunyoro-Kitara Kingdom, Uganda

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ABSTRACT

This paper presents the nutritionally essential macro (Ca, K, Mg, Na, P) and micro (Fe, Mn, Cu, Zn) minerals contents of fifteen selected leafy wild and semi-wild food plants (WSWFPs) from Bunyoro-Kitara Kingdom, Uganda. All the mineral assay were conducted using standard procedures. The results of the analyses were compared those of the conventionally well known and widely cultivated Brassica oleracea var capitata. L. (Alef.) - the common cabbage plant. Compared to the conventionally planted cabbage, most analysed WSWFPs were generally richer sources of macro and micro mineral elements. Ca contents were richer (373.50–518.43 mg/100g) in Asystasia mysorensis, Asystasia gangetica, Acalypha bipartita,Amaranthus spinosus, Bidens pilosa, Senna obtusifolia, Solanum nigrum, and Cleome hirta. While K concentrations were highest (365.64–714.14 mg/100g) in Amaranthus spinosus, Sonchus oleraceus, Basella alba, Asystasia gangetica, Asystasia mysorensis and Cleome hirta. Mg content was more abundant (235.90–421.70 mg/100g) in Asystasia gangetica, Asystasia mysorensis, Bidens pilosa, Senna obtusifolia, and Solanum nigrum. Na content was highest (234.15–355.75 mg/100g) in Senna obtusifolia, Bidens pilosa, Vernonia amygdalina, and Sonchus oleraceus. P was more abound (237.78–505.38 mg/100g) in Asystasia gangetica, Bidens pilosa, Asystasia mysorensis, and Senna obtusifolia. Fe content was highest (10.77–30.03 mg/100g) in Acalypha bipartita, Corchorus trilocularis, Asystasia gangetica, Bidens pilosa, Asystasia mysorensis, Senna obtusifolia, and Vernonia amygdalina. Mn was more plentiful (5.74–32.75 mg/100) in Vernonia amygdalina, Asystasia mysorensis, Asystasia gangetica, Bidens pilosa, Cleome hirta and Senna obtusifolia. Cu content was more concentrated (2.32–8.81 mg/100g) in Bidens pilosa, Vernonia amygdalina, Asystasia mysorensis, Asystasia gangetica, and Senna obtusifolia. Zn was more abundant (6.48–11.43 mg/100g) in Senna obtusifolia, Bidens pilosa, Vernonia amygdalina, Asystasia gangetica, Amaranthus spinosus and Asystasia mysorensis. These findings therefore suggest that a routine diet comprising of WSWFPs can definitely assure a relief from some of the major and minor mineral deficiencies often faced by the poor households.

Keywords: Essential macro-elements, essential micro-elements, wild food plants, wild edible plants, Uganda.

INTRODUCTION

Wild and semi-wild food plants (WSWFPs) are all are wild or semi-cultivated plants endowed with one or more parts that can be used for food if harvested or gathered at the appropriate stage of growth and properly prepared [1, 2]. Today, there is a growing interest in the mineral contents of these categories of foods plants. Besides, their potential to meet household food and income has been widely recognized to have security [3, 4]. To apprehend the situation, interests have been centralized on the exploitation, quantification and utilization of food plants, especially the vegetables [5]. Indeed, wild vegetables, growing wildly in various regions of the world, have been used for several purposes since ancient times [6]. Wild leafy vegetable preparations include the raw salad, widely known all over the world, in partially or completely cooked or fried forms. Ugandan cuisine has a wide range of choice among the leafy vegetables (wild, semi-wild and conventionally cultivated). In most Ugandan households, the inclusion of a leafy vegetable preparation in daily diet is an accepted practice. These green leafy vegetables are inexpensive, are easily and quickly cooked, and are rich in several nutrients, such as vitamins, minerals, proteins, and others.

There are available reports [7] that pinpoint green leafy plants as good sources of macro and micro minerals essentially for our nutrition. Human, as well as animal, studies originally showed that optimal intake of elements, such as sodium, potassium, magnesium, calcium, manganese, copper, zinc, and iodine, could reduce individual risk factors, including those related to cardiovascular disease [8-10]. Throughout the world, there is increasing interest in the importance of dietary minerals in the prevention of several diseases. Minerals are of critical importance in the diet, even though they comprise only 4–6% of the human body. Major minerals are those required in amounts greater than 100 mg per day and they represent 1% or less of body weight. These include calcium, phosphorus, magnesium, sulfur, potassium, chloride, and sodium. Trace minerals are essential in much smaller amounts, less than 100 mg per day, and make up less than 0.01% of body weight. Essential trace elements are zinc, iron, silicon, manganese, copper, fluoride, iodine, and chromium. The major minerals serve as structural components of tissues and function in cellular and basal metabolism and water and acid–base balance [11-13].

Several studies have been carried out on green vegetables, but there are limited studies on mineral contents of wild and semi-wild leafy food plants Uganda. The aim of this study was to determine the nutritionally essential macro (Ca, K, Mg, Na, P) and micro (Fe, Mn, Cu, Zn) minerals contents of fifteen selected leafy wild and semi-wild food plants (WSWFPs) from Bunyoro-Kitara Kingdom, Uganda. It was hypothesised that there are were no significant differences in the levels of nutritionally essential macro (Ca, K, Mg, Na, P) and micro (Fe, Mn, Cu, Zn) elements contents of the selected leafy WSWFPs compared to the conventionally well known and widely cultivated *Brassica oleracea var capitata.* L. (Alef.) -the common cabbage plant.

MATERIALS AND METHODS

Sample collection

Field samples of the selected leafy WSWFPs for nutritional analyses were collected from Mutunda and Kiryandongo sub-counties of Kibanda County in Bunyoro-Kitara Kingdom. The validity and usefulness of plant nutritional analysis depends largely on obtaining a reliable sample. If the samples taken are not representative, then all the careful and costly work put into subsequent analysis would be a wasted effort because the result would be less valid [14]. A minimum of 15-25 plants should be sampled in order to obtain a statistically significant number of plant tissues needed for analysis [15]. Field inventory (field walk) with key informants was undertaken to collect plant samples of the 15 studied leafy WSWFPs for laboratory analysis. The selection of the 15 species for nutrient content analysis were undertaken on the basis of SWOT (Strength, Weakness, Opportunities and Threats) analysis considering occurrence of the plant in natural habitats, market value, scanty information available on nutrient content, and the extent of anthropogenic pressure on species.

In addition to the 15 selected leafy WSWFPs, samples of the common cabbage plant- *Brassica oleracea var capitata*. L. (Alef.) was also collected from the same region and analysed for comparison purposes. Each plant sample was taken from a minimum of 15 plants found within a radius of about 1 km, with the exception of *Hibiscus acetosella* where samples were collected from 13 plants. Only the frequently harvested edible plant parts were collected in plastic bags labelled with sample numbers, date, code of locations, plant part, and analysis to be conducted. About 500 grams of each plant material were collected in order to have an adequate amount of plant material for the analysis.

Laboratory and analytical procedures

The laboratory and analytical procedures for nutritional analysis was limited to the portion of the plant normally consumed as prepared by local communities. All plant materials were dried in an oven with a fan at 65 °C for 24

hours using the AOAC [16] air oven method No. 14.003 and then ground for chemical analysis. All samples were analysed in triplicate.

Potassium (K) and Sodium (Na)

Na and K concentrations were determined using the Flame Emission Photometer (Jenway, model PFP7, U.K.) using NaCl and KCl to prepare the standards [17]. 0.3 g of oven dried (65 ^{0}C) ground plant samples were weighed in to a labelled dry and clean digestion tubes and 4.4 ml of the digestion mixture (0.42 g of selenium (Se) powder, 14 g of $Li_2SO_4.H_2O$, 350 ml of 30% H_2O_2 and 420 ml of H_2SO_4) was added to each tube, and also to reagent blanks for each batch of the samples. These were digested at 360 °C for 3 hours until the solution were colourless. After cooling, the tubes were topped up with 25 ml of distilled water, filtered, and later made up 50 ml with distilled water. These were kept for analysis. 1000 mg/l (ppm) stock solutions of Na and K were prepared by weighing 2.541 g of NaCl and 1.907 g of KCl analytical grade reagents respectively. These were then dissolved in distilled water to make 1-litre solutions respectively. Working Na and K solutions (100 ppm each) were prepared by diluting 20 ml of the respective stock solutions to 200 ml.

A seven-step standard series (0.0, 0.5, 1.0, 2.0, 3.0, 4.0 and 5 ppm Na; and 0, 1, 2, 4, 6, 8, 10 ppm K) were prepared by pipetting respective ml of working solutions in 100 ml flasks and adding 3 ml of 1N H_2SO_4 to each flask before topping up to 100 ml level by distilled water. Two (2) ml of the wet-digested sample solutions were pipetted into a 50 ml volumetric flask and made to the mark with distilled water. The solutions were sprayed starting with the standards, followed by the samples and the blanks directly into the flame of flame emission photometer (wavelength at 766.5 nm). Respective amount of the K and Na present in the samples were read off from the calibration curves of absorbance against K and Na concentrations and calculated as follows: Concentration (mg/l) = [(a – b) x v x f]/(1000 x w x1000). Where a is the concentration of K or Na in the digest; b is the concentration of the blank digest; w is the Wt. of the sample; v is the vol. of the digest solution; and f is the dilution factor. The concentrations were later computed to mg/100g of edible plant portion.

Phosphorus (P)

P was determined spectrophotometrically (absorbance at a wavelength of 880nm) using Spectronic 20D+ Spectrophotometer model (USA). Twelve (12 g) of ammonium molybdate were dissolved in 100 ml of warm distilled water and then cooled. 0.291 g of antimony potassium tartrate was separately dissolved in 100 ml of distilled water. Both solutions were made to 2 litres with distilled water. The mixtures were shaken thoroughly to ensure proper mixing. Ascorbic acid reducing reagent was prepared by dissolving 2.108 g of ascorbic acid into 400 ml of ammonium molybdate/antimony potassium tartrate. Working standard solutions of 0.1, 0.2, 0.4, 0.6 and 0.8-ppm concentrations were prepared. 0.5 ml aliquots of the working standard solutions were transferred to a 25 ml volumetric flask and diluted with distilled water followed by 5 mls of the ascorbic acid reducing reagent. The mixture was made to the mark with distilled water and mixed thoroughly. The mixture was left to stand for 40 minutes prior to absorbance reading on a spectrophotometer. Similar procedures were followed to take absorbance reading of the samples. Calibration curves of absorbance against concentration were plotted using the working standard solutions. Phosphorus concentrations (ppm) in the samples were read from the calibration curve using the previously obtained sample absorbencies. The phosphorus concentrations in the samples were then computed to mg/100 g of the edible plant portion.

Calcium (Ca), Iron (Fe), Magnesium (Mg), Manganese (Mn), Copper (Cu) and Zinc (Zn)

Ca, Fe, Mg, Mn, Cu, and Zn were determined by Atomic Absorption Spectrometry (Perkin Elmer 2380 AA - auto wavelength scan model, USA and Varian SpectrAA 220 FS- A fully automated double beam system, Australia). 0.3 g of finely ground and oven dried (65 °C) plant samples were weighed into a clean digestion tubes and 2.5 ml of digestion mixtures (7.2 g salicyclic acid, 3.5 g selenium powder, 100 ml of conc. H_2SO_4) and allowed to react at room temperature for 2 hours. Two separate blanks included in each batch of measurement. The tubes were heated in the block digester for 1 hour at 110 °C, allowed to cool after which three successive portions of H_2O_2 were added, waiting at least 10 seconds between additions. The tubes were returned to the block digester and the temperature adjusted to 330 °C. The mixtures were heated until the colour turned colours (sometimes light-yellow for some samples), cooled to room temperature, and transferred to 50 ml volumetric flasks and made up to the mark with deionised water.

Working standard solutions were prepared for each element from the stock solutions. A seven-step standard series were prepared from respective standard working solution of each element. Air-acetylene flame was used for atomization of Ca, Mg, Cu, Fe, Mn and Zn). Standard series, diluted samples and the blanks were then aspirated into the Atomic Absorption Spectrometer (AAS) calibrated for each element measurement (Ca at 239.8 nm, Cu at 324.7 nm, Fe at 248.3 nm, Mg at 202.6 nm, Mn at 248.3 nm, Zn at 213.9 nm) and the absorbencies and the concentration

of each element in the sample solutions was read directly from the machine in milligrams per litre (mg/l). The concentrations of these elements in the samples were later computed to mg/100g of edible plant portion.

Statistical data analysis
The mineral contents of the analysed 15 leafy WSWFPs were compared to those of the common cabbage (*Brassica oleracea var capitata*) using ANOVA [18] at 5% level of significance in MINITAB statistical software.

RESULTS

Nutritionally essential Macro (Ca, K, Mg, Na, P) mineral contents
The nutritionally essential macro (Ca, K, Mg, Na, P) mineral contents of the 15 selected leafy WSWFPs are summarized in Table 1. All the mean values of the triplicate analyses were significantly ($P < 0.05$) different from those of the corresponding cabbage. Calcium (Ca) content ranged from as low as 35.28 ± 1.28 mg (*Sonchus oleraceus*) to as a high as 518.43 ± 1.10 mg (*Asystasia mysorensis*). Apart from *Sonchus oleraceus*, all other leafy WSWFPs had significantly ($P < 0.05$) higher Ca content compared to cabbage (52.17 ± 1.06 mg). In addition to *Asystasia mysorensis*, other richest sources of Ca were the leaves of *Asystasia gangetica* (502.70 ± 1.71 mg), *Acalypha bipartita*(499.44 ± 1.96 mg), *Amaranthus spinosus* (410.40 ± 0.54 mg), *Bidens pilosa* (408.73 ± 0.66 mg) and *Senna obtusifolia* (406.50 ±1.10 mg).

Potassium (K) contents varied from 5.23 ± 0.33 mg (*Vernonia amygdalina*) to 714.14 ± 0.46 mg (*Amaranthus spinosus*). Most of the leafy WSWFPs had significantly ($P < 0.05$) higher mean K values compared to common cabbage (241.6 ± 1.52 mg). The richest sources of K were *Sonchus oleraceus* (576.68 ± 0.69 mg), *Basella alba* (494.27 ± 0.70 mg), *Asystasia gangetica* (466.08 ± 0.40 mg), and *Asystasia mysorensis* (423.72 ± 0.22 mg). Apart from *Vigna unguiculata* (13.48 ± 0.30 mg), all the other leafy WSWFPs had significantly ($P < 0.05$) higher P contents compared to the cabbage (36.83 ± 0.54 mg). The richest sources of P were *Asystasia gangetica* (505.38 ±1.34 mg), *Bidens pilosa* (492.92 ± 1.53 mg), *Asystasia mysorensis* (477.88 ± 0.64 mg) and *Senna obtusifolia* (237.78 ± 3.11 mg).

Sodium (Na) contents of the leafy WSWFPs ranged from 3.27 ± 0.44 mg (*Solanum nigrum*) to 355.75 ± 1.81 (*Senna obtusifolia*). With exceptions of *Solanum nigrum* and *Acalypha bipartita*(13.70 ± 0.46 mg), all the other leafy WSWFPs had significantly ($P < 0.05$) higher Na contents compared to the cabbage (16.20 ± 0.41 mg). In addition to *Senna obtusifolia*, other rich sources of Na included *Bidens pilosa* (279.97 ± 2.03 mg), *Vernonia amygdalina* (236.60 ± 1.07 mg) and *Sonchus oleraceus* (234.15 ± 1.58 mg). All the leafy WSWFPs except *Crotalaria ochroleuca* (3.63 ± 0.15 mg) had significantly ($P < 0.05$) higher Magnesium (Mg) contents compared to the cabbage (16.91 ± 0.39 mg). *Asystasia gangetica* (421.70 ± 1.07 mg), *Asystasia mysorensis* (393.70 ± 0.23 mg), *Bidens pilosa* (313.33 ± 1.39 mg), *Senna obtusifolia* (253.74 ± 0.89 mg), *Solanum nigrum* (235.90 ± 1.53 mg) were the richest sources of Mg.

Nutritionally essential Micro (Fe, Mn, Cu, Zn) mineral contents
Like in macro minerals, the mean values of the micro (Fe, Mn, Cu, Zn) mineral contents of the 15 analysed leafy WSWFPs were generally different and in most case significantly ($P < 0.05$) higher than those of the corresponding cabbage (Table 2). All the leafy WSWFPs had significantly ($P < 0.05$) higher iron (Fe) contents compared to the common cabbage (0.61 ± 0.02 mg). *Acalypha bipartita*(30.03 ± 0.55 mg), *Corchorus trilocularis* (18.92 ± 0.51 mg), *Asystasia gangetica* (18.34 ± 0.99 mg), *Bidens pilosa* (17.44 ± 0.26 mg), *Asystasia mysorensis* (13.40 ± 0.32 mg), and *Senna obtusifolia* (13.33 ± 1.39 mg) were the richest in Fe contents. Zinc (Zn) contents of the leafy WSWFPs varied from 0.08 ± 0.01 mg (*Solanum nigrum*) to 11.43 ± 0.37 mg (*Senna obtusifolia*). Apart from *Solanum nigrum*, all other leafy WSWFPs had significantly ($P < 0.05$) higher Zn contents compared to common cabbage (0.21 ± 0.02 mg). The richest sources of zinc were *Senna obtusifolia* (11.43 ± 0.37 mg), *Bidens pilosa* L (10.50 ± 0.40 mg), *Vernonia amygdalina* (9.4 ± 0.40 mg), and *Asystasia gangetica* (8.23 ± 0.18 mg).

Copper (Cu) contents of the leafy WSWFPs varied from 0.08 ± 0.01 mg (*Vigna unguiculata*) to 8.81 ± 0.16 mg (*Bidens pilosa*). Nine of the leafy WSWFPs had significantly ($P < 0.05$) lower Cu contents compared to that of the cabbage (2.04 ± 0.04 mg). Aside from *Bidens pilosa*, the richest sources of copper were *Vernonia amygdalina* (5.33 ± 0.37 mg), *Asystasia mysorensis* (4.20 ± 0.32 mg), *Asystasia gangetica* (3.72 ± 0.19 mg), and *Senna obtusifolia* (2.32 ± 0.16 mg) whose mean Cu content was not significantly ($P < 0.05$) different from that of common cabbage. Manganese (Mn) contents of the leafy WSWFPs ranged from as low as 0.64 ± 0.03 mg (*Basella alba*) to as high as 32.75 ± 1.25 mg (*Vernonia amygdalina*), with all mean values significantly higher than that of common cabbage (0.19 ± 0.03 mg). In addition to *Vernonia amygdalina*, other good leafy sources of Mn included *Asystasia mysorensis* (11.37 ± 0.35 mg), *Asystasia gangetica* (10.63 ± 0.43 mg), *Bidens pilosa* (9.62 ± 0.22 mg), *Cleome hirta* (6.27 ± 0.26mg), and *Senna obtusifolia* (5.74 ± 0.18 mg).

Table 1 Essential macro mineral contents of leafy WSWFPs compared to cabbage.

Species	Macro-mineral elements (Mean composition per 100 gram edible portion ±SEM)				
	Ca (mg)	K (mg)	P (mg)	Na (mg)	Mg (mg)
*Acalypha bipartita*Müll. Arg.	499.44 (1.96)	272.37 (1.34)	103.85 (1.23)	13.70 (0.46)	58.37 (0.38)
Amaranthus spinosus L.	410.40 (0.54)	714.14 (0.46)	88.22 (1.00)	27.26 (0.77)	65.44 (1.38)
Asystasia gangetica (L.) T.Anders.	502.70 (1.71)	466.08 (0.40)	505.38 (1.34)	43.10 (0.40)	421.70 (1.07)
Asystasia mysorensis (Roth) T.Anders.	518.43 (1.10)	423.72 (0.22)	477.88 (0.64)	39.77 (0.96)	393.70 (0.23)
Basella alba L.	119.60 (1.10)	494.27 (0.70)	55.67 (0.65)	18.33 (0.64)	59.37 (2.04)
Bidens pilosa L.	408.73 (0.66)	278.98 (0.48)	492.92 (1.53)	279.97 (2.03)	313.33 (1.39)
Cleome hirta (Klotzsch) Oliv.	373.50 (1.04)	390.62 (0.80)	15.83 (0.32)	27.37 (0.96)	79.74 (1.20)
Corchorus trilocularis L.	311.37 (1.04)	132.77 (0.71)	83.82 (0.84)	34.33 (0.46)	53.00 (1.40)
Crotalaria ochroleuca G.Don	243.57 (0.52)	166.94 (0.18)	69.44 (0.53)	29.30 (0.82)	3.63 (0.15)
Hibiscus acetosella Welw. *ex* Hiern	239.60 (0.53)	204.30 (0.32)	101.30 (1.00)	53.78 (0.19)	73.33 (1.30)
Senna obtusifolia (L.) Irwin & Barneby	406.50 (1.10)	101.67 (0.76)	237.78 (3.11)	355.75 (1.81)	253.74 (0.89)
Solanum nigrum L.	397.07 (1.70)	53.58 (0.31)	77.34 (0.96)	3.27 (0.44)	235.90 (1.53)
Sonchus oleraceus L.	35.28 (1.28)	576.68 (0.69)	63.64 (0.98)	234.15 (1.58)	72.00 (0.70)
Vernonia amygdalina Del.	163.63 (1.71)	5.23 (0.33)	75.78 (0.67)	236.60 (1.07)	25.18 (1.63)
Vigna unguiculata (L.) Walp.	127.54 (0.29)	98.63 (0.31)	13.48 (0.30)	23.34 (0.38)	57.08 (0.79)
Brassica oleracea var capitata. L. (Alef.) (Common cabbage)	52.17 (1.06)	241.6 (1.52)	36.83 (0.54)	16.20 (0.41)	16.91 (0.39)

Means are of three measurements. Bracketed are the standard errors of the mean. All means in column are significantly different from those of the corresponding cabbage in that column (P < 0.05). All measurements in mg/100 gram of edible portion.

Table 2 Nutritionally essential micro (Fe, Mn, Cu, Zn) mineral contents of selected leafy WSWFPs compared to cabbage.

Species	Micro-mineral elements (Mean composition per 100 gram edible portion ±SEM)			
	Fe (mg)	Zn (mg)	Cu (mg)	Mn (mg)
*Acalypha bipartita*Müll. Arg.	30.03 (0.55)	1.20 (0.27)	1.42 (1.14)	2.48 (0.06)
Amaranthus spinosus L.	4.25 (0.13)	7.51 (0.26)	1.58 (0.16)	1.14 (0.01)
Asystasia gangetica (L.) T.Anders.	18.34 (0.99)	8.23 (0.18)	3.72 (0.19)	10.63 (0.43)
Asystasia mysorensis (Roth) T.Anders.	13.40 (0.32)	6.48 (0.22)	4.20 (0.32)	11.37 (0.35)
Basella alba L.	2.13 (0.20)	0.93 (0.15)	1.17 (0.92)	0.64 (0.03)
Bidens pilosa L.	17.44 (0.26)	10.50 (0.40)	8.81 (0.16)	9.62 (0.22)
Cleome hirta (Klotzsch) Oliv.	8.67 (0.61)	1.77 (0.09)	1.15 (0.13)	6.27 (0.26)
Corchorus trilocularis L.	18.92 (0.51)	5.74 (0.18)	0.52 (0.05)	1.75 (0.05)
Crotalaria ochroleuca G.Don	3.47 (0.50)	3.33 (0.26)	ND	1.02 (0.14)
Hibiscus acetosella Welw. *ex* Hiern	5.28 (0.74)	0.62 (0.04)	0.41 (0.27)	ND
Senna obtusifolia (L.) Irwin & Barneby	13.33 (1.39)	11.43 (0.37)	2.32 (0.16)[a]	5.74 (0.18)
Solanum nigrum L.	8.68 (0.25)	0.08 (0.01)	0.13 (0.01)	1.64 (0.17)
Sonchus oleraceus L.	4.35 (0.42)	0.70 (0.03)	0.45 (0.03)	1.33 (0.07)
Vernonia amygdalina Del.	10.77 (0.87)	9.4 (0.40)	5.33 (0.37)	32.75 (1.25)
Vigna unguiculata (L.) Walp.	3.47 (0.15)	0.72 (0.04)	0.08 (0.01)	ND
Brassica oleracea var capitata. L. (Alef.) (Common cabbage)	0.61 (0.02)	0.21 (0.02)	2.04 (0.04)[a]	0.19 (0.03)

Means are of three measurements. Bracketed are the standard errors of the mean. Means in the same column followed by the same superscript letter are not significantly different from those of the corresponding cabbage (P > 0.05). All measurements are in mg/100 gram of edible portion. ND = Not Detected.

DISCUSSION

Essential macro (Ca, K, Mg, Na, P) mineral contents the WSWFPs consumed

The concentration of macro minerals (Ca, K, Mg, Na and P) from the analysed leafy WSWFPs ranged of 3.27–714.14 mg/100 g, with most WSWFPs either at par or even superior to the conventional and widely cultivated common cabbage plant compared with. Calcium (Ca) is essential for healthy bones, muscles, nerves, teeth and blood (Charles, 1992). It also required for the absorption of dietary vitamin B, synthesis of the neurotransmitter acetylcholine, and activation of enzymes such as the pancreatic lipase [19]. The recommended daily allowance of Ca for children is between 500 and 1000 mg and for adults 800 mg. To achieve a Ca level of nearly one percent of the total diet would be rather difficult. Concentrations of Ca in the analysed leafy WSWFPs are in the range of 35.28–518.43 mg/100g. The leafy *Asystasia mysorensis*, *Asystasia gangetica*, *Acalypha bipartita*, *Amaranthus spinosus*, *Bidens pilosa*, *Senna obtusifolia*, *Solanum nigrum* and *Cleome hirta* are the richest in Ca (373.50–857.94 mg/100g) and their consumption can contribute greatly to the RDA.

Concentration of potassium (K) in the leafy WSWFPs analysed ranged from 5.23 to 714.14 mg/100g. K is one of the most abundant elements in WSWFPs. Potassium is accumulated within human cells by the action of the Na^+, K^+-ATPase (sodium pump). The regulation of such metal ion flows, especially of K and Na, is crucial to life and is most clearly exemplified by the ionic movements that occur in nerve cells during excitation and transmission of the action potential [20]. K is an activator of some enzymes, in particular co-enzyme for normal growth and muscle function

[21]. Our findings indicate that most leafy WSWFPs are not deficient in potassium. Consumption of *Amaranthus spinosus*, *Sonchus oleraceus*, *Basella alba*, *Asystasia gangetica*, *Asystasia mysorensis* and *Cleome hirta*, which are the richest in K (365.64–714.14 mg/100g), might help in the case of potassium deficiency.

Magnesium (Mg) is an important electrolyte also responsible for proper nerve and muscle function. It plays an important role in regulating the neuromuscular activity of the heart. Where Ca stimulates the muscles, Mg is used to relax the muscles. It also works as co-factor in more than 300 metabolic reactions [22]. It aids the formation of bone and teeth and assists the absorption of Ca and K. It assists the parathyroid gland to process vitamin D, and a shortage here can cause absorption problems with calcium. With exception of *Crotalaria ochroleuca*, all other leafy WSWFPs analysed, presented higher levels of Mg compared to the conventionally cultivated common cabbage plant. The concentration of Mg ranged from 3.63 to 421.70 mg/100g. Mg has an RDA of 420 mg for men, 320 mg for women and 240 mg for children (Institute of Medicine, Food and Nutrition Board, 1997). Incorporation of *Asystasia gangetica*, *Asystasia mysorensis*, *Bidens pilosa*, *Senna obtusifolia* and *Solanum nigrum*, which are rich in Mg (235.90–421.70 mg/100g), could contribute substantially to RDA.

Sodium (Na) plays an important role in the maintenance of acid–base equilibrium and of osmotic pressure of body fluids [23]. It also assists nerve impulse initiation and muscle contraction. WSWFPs were more superior in sodium contents than the corresponding conventional cabbage food plant compared with. The concentration of Na ranged from 3.27 to 355.75 mg/100g. Na has an RDA of 1500 mg for a healthy living [24]. Therefore, consumption of WSWFPs such as *Senna obtusifolia*, *Bidens pilosa*, *Vernonia amygdalina* and *Sonchus oleraceus*, which are richer in Na contents (234.15–355.75 mg/100g), could nonetheless help supplement the dietary intake of Na.

Phosphorus (P) is involved in bone and teeth formation as well as metabolism, kidney function, cell growth and heart muscle contraction. It does not only help in conversion of food to energy but also in vitamin utilisation particularly with the B-vitamins [25]. P concentrations in most of the analysed WSWFPs were superior to that of the cabbage that was analysed as well. Given that the recommended daily allowance for P is 700 mg for normal adult life, inclusion of leafy WSWFPs like *Asystasia gangetica*, *Bidens pilosa*, *Asystasia mysorensis*, and *Senna obtusifolia*, which are rich in P contents (237.78–505.38 mg/100g) compared to the cultivated cabbage plant, could help supplement RDA of P intake.

Essential micro (Fe, Mn, Cu, Zn) mineral contents of WSWFPs consumed

Iron (Fe) is an essential microelement for haemoglobin formation, normal functioning of the central nervous system, and oxidation of carbohydrate, protein and fats [26]. It is also a cofactor bound to several non-heme iron enzymes required for the proper functioning of cells [23]. Its deficiency, according to World Health Organisation (WHO) report in 2005, affects about 3.7 billion people out of which about 2 billion people are anaemic [27]. Like other minerals, the concentration of Fe in many WSWFPs analysed in this study are much higher compared those in conventional food crops used for comparison. Given that RDA for Fe is 18 mg [28], consumption of WSWFPs such as *Acalypha bipartita*, *Corchorus trilocularis*, and *Asystasia gangetica*, which are very rich in Fe contents (18.34–30.03 mg/100g) could meet the daily Fe requirements of an adult. Similarly, use of the species like *Bidens pilosa*, *Asystasia mysorensis*, and *Senna obtusifolia*, *Vernonia amygdalina* that are considerably high in Fe contents (10.77–17.44 mg/100g) could substantially contribute to Fe recommended daily intake.

Manganese (Mn) plays important role in metabolism of vitamin B1 and vitamin E, activation of various enzymes such as decarboxylases, hydrolases, kinases, and transferases; which are important for proper digestion and utilization of foods [29]. Mn also acts as a catalyst in the breakdown of fats and cholesterol, and it is necessary for normal skeletal development and maintains sex hormone production [29]. Its deficiency can cause poor reproductive performance, growth retardation, congenital malformations in the offspring, abnormal formation of bone and cartilage, and impaired glucose [29]. The present study shows that many WSWFPs are important sources of Mn compared to conventionally cultivated cabbage plant that was also analysed for comparison. When compared with 2–4 mg set as RDA for Mn [30], consumption of most leafy WSWFPs such as *Vernonia amygdalina*, *Asystasia mysorensis*, *Asystasia gangetica*, *Bidens pilosa*, *Cleome hirta* and *Senna obtusifolia*, which are very rich in Mn content (5.74–32.75 mg/100g) would supply all the recommended daily intake of Mn. Additionally, utilization of tender leaves of *Acalypha bipartita* (2.85 ± 0.05 mg/100g) in the diet could also substantially meet part of the required daily intake of Mn.

Copper (Cu) is an essential nutrient involved in the absorption, storage and metabolism of iron. It helps in the oxidation of vitamin C and works with vitamin C to form elastin, a chief component of the elastin muscle fibres throughout the body [31]. It aids in the formation of red blood cells, transport of oxygen in the blood stream, supply of the body's tissues with oxygen, bone formation and its maintenance. Besides, it assists the thyroid gland in balancing and secreting hormones [31]. Findings from this study show that most WSWFPs are valuable sources of

Cu compared to conventional food plants analysed for comparison. The RDA for Cu is 2–4 mg [30], implying that consumption of leafy WSWFPs such as *Bidens pilosa*, *Vernonia amygdalina*, *Asystasia mysorensis*, *Asystasia gangetica*, and *Senna obtusifolia*, which are quite rich in Cu contents (2.32–8.81 mg/100g) could meet the recommended daily intake of Cu for a healthy life.

Zinc (Zn) is an antioxidant nutrient necessary for protein synthesis, wound healing and vital for the development of the reproductive organs, prostate functions and male hormone activity [32]. It is necessary for a healthy immune system, and is useful in fighting skin problems such as acne, boils and sore throats. It maintains the body's alkaline balance, helps in normal tissue function and aids in the digestion and metabolism of phosphorus [32]. Compared to cabbage, sesame and the common mangoes, all WSWFPs analysed in this study are better sources of Zn. RDA for Zn is 11 mg for adult life [28], so most WSWFPs like *Senna obtusifolia*, *Bidens pilosa*, *Vernonia amygdalina*, *Asystasia gangetica*, *Amaranthus spinosus* and *Asystasia mysorensis* which are rich in Zn contents (6.48–11.43 mg/100g) would greatly supplement the recommended daily intake of Zn.

CONCLUSIONS

Compared to the conventionally planted cabbage, most leafy WSWFPs were generally richer sources of macro and micro- mineral elements. Ca contents were richer (373.50–518.43 mg/100g) in *Asystasia mysorensis*, *Asystasia gangetica*, *Acalypha bipartita*,*Amaranthus spinosus*, *Bidens pilosa*, *Senna obtusifolia*, *Solanum nigrum*, and *Cleome hirta*. While K concentrations were highest (365.64–714.14 mg/100g) in *Amaranthus spinosus*, *Sonchus oleraceus*, *Basella alba*, *Asystasia gangetica*, *Asystasia mysorensis* and *Cleome hirta*. Mg content was more abundant (235.90–421.70 mg/100g) in *Asystasia gangetica*, *Asystasia mysorensis*, *Bidens pilosa*, *Senna obtusifolia*, and *Solanum nigrum*. Na content was highest (234.15–355.75 mg/100g) in *Senna obtusifolia*, *Bidens pilosa*, *Vernonia amygdalina*, and *Sonchus oleraceus*. P was more abound (237.78–505.38 mg/100g) in *Asystasia gangetica*, *Bidens pilosa*, *Asystasia mysorensis*, and *Senna obtusifolia*. Fe content was highest (10.77–30.03 mg/100g) in *Acalypha bipartita*, *Corchorus trilocularis*, *Asystasia gangetica*, *Bidens pilosa*, *Asystasia mysorensis*, *Senna obtusifolia*, and *Vernonia amygdalina*. Mn was more plentiful (5.74–32.75 mg/100) in *Vernonia amygdalina*, *Asystasia mysorensis*, *Asystasia gangetica*, *Bidens pilosa*, *Cleome hirta* and *Senna obtusifolia*. Cu content was more concentrated (2.32–8.81 mg/100g) in *Bidens pilosa*, *Vernonia amygdalina*, *Asystasia mysorensis*, *Asystasia gangetica*, and *Senna obtusifolia*. Zn was more abundant (6.48–11.43 mg/100g) in *Senna obtusifolia*, *Bidens pilosa*, *Vernonia amygdalina*, *Asystasia gangetica*, *Amaranthus spinosus* and *Asystasia mysorensis*.

These findings therefore suggest that a routine diet comprising of WSWFPs can definitely assure a relief from some of the major and minor mineral deficiencies often faced by the poor households. As such, there is a need for policy-makers and technocrats both at the local (districts, counties, sub-counties, parishes, villages) and national levels (e.g. Ministry of Agriculture, Animal Industry, and Fisheries) to create policies, by-laws or any other avenues for mainstreaming the management of some of the nutrient-rich WSWFPs into existing the farming systems and any the programs (e.g. Plan for Modernisation of Agriculture).

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