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Inorganic nutrients and heavy metals in some wild edible plants consumed by rural communities in Northern Uganda: Implications for human health

Alfred Nyero[a,*], Innocent Achaye[a], Godwin Upoki Anywar[c], Geoffrey Maxwell Malinga[b]

[a] Department of Chemistry, Faculty of Science, Gulu University, P.O. Box 166, Gulu, Uganda
[b] Department of Biology, Faculty of Science, Gulu University, P.O. Box 166, Gulu, Uganda
[c] Department of Plant Sciences, Microbiology and Biotechnology, College of Natural Sciences, Makerere University, P.O. Box 7062, Kampala, Uganda

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ABSTRACT

For centuries, wild edible plant species have sustained local communities across Africa by supplementing households' diets in seasons of food shortage. Wild edible plants contain inorganic nutrients, which are essential for the proper functioning of organisms. However, their nutritional contents have not been well researched and are generally poorly understood. This study aimed to quantify the levels of inorganic micro-and macronutrients as well as heavy metals (Mg, Ca, K, Fe, Zn, Cd, Hg and Pb) in selected wild edible plants traditionally consumed among the Acholi communities in northern Uganda, and associated health risks of consuming them. The leaves and young stems of 12 wild edible plants, viz: *Acalypha rhomboidea, Asystacia gangetica, Crassocephalum sacrobasis, Crotalaria ochroleuca, Heterotis rotundifolia, Hibiscus cannabinus, Hibiscus* sp., *Hibiscus surattensis, Ipomoea eriocarpa, Maerua angolensis, Senna obtusifolia* and *Vigna membranacea* were air-dried and crushed to powder. The powders were then macerated using aqua regia solution and analyzed in triplicates using the Atomic Absorption Spectrophotometry (AAS). The target hazard quotient (THQ) of Pb was calculated for non-carcinogenic health risks. Mg, Ca, K, Fe, Zn and Pb were detectable in all the wild edible plants sampled. All inorganic nutrients (mg/100gdw), were below the Recommended Daily Allowance (RDA); Mg (9.4 ± 0.19 to 10.4 ± 0.15), Ca (119 ± 5.82 to 1265 ± 14.9), Fe (3.29 ± 0.02 to 11.2 ± 0.09), Zn (0.52 ± 0.02 to 2.36 ± 0.03). Hg and Cd were below detectable limits in all the samples tested. The content of Pb (0.69 ± 0.11 to1.22 ± 0.07) was higher than the CODEX and EU limits of 0.1 ppm (0.001 mg/g) but was below the recommended threshold of 1. The health risk assessment revealed no potential hazards both in children and adults. However, there is a need to study the bioavailability of Pb when the vegetables are consumed due to factors such as indigestion and antinutritional compounds.

* Corresponding author.
E-mail address: a.nyero@gu.ac.ug (A. Nyero).

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1. Introduction

Micronutrient deficiencies remain a significant global public health challenge. More than two billion people in the world suffer from micronutrient deficiencies. This is mainly due to the assimilation of diets that lack essential micronutrients, particularly vitamin A, iodine, iron and zinc [1–3]. The majority of these people live in low-to middle-income countries. The groups most vulnerable to micronutrient deficiencies are young children, pregnant women, lactating mothers and the elderly. This can be mainly attributed to their relatively substantial demand for vitamins and minerals and they are more susceptible to the negative outcome of deficiencies [4, 5]. For example, for a pregnant woman, micronutrient deficiencies have been linked to the altered length of gestation, and impaired foetal development and growth, which can lead to pregnancy loss, greater risk of dying during childbirth, and birth to a small or mentally impaired baby [6]. For a young child, micronutrient deficiencies increase the risk of dying due to infections and contribute to impaired physical and mental development.

The consumption of wild edible plants is seen as a sustainable solution to inorganic micronutrient deficiencies. Many communities, particularly in northern Uganda, consume wild edible plants [7–10]. Wild edible plants are essential in supplementing staple foods by supplying vitamins, minerals, phytochemicals and antioxidants. They have also been reported to be good sources of macro-and micronutrients or trace elements, including B, Cu, Fe, Mn, Mo, Zn, Na, K, Mg, Ca, N, S, and P [11–13]. Inorganic micronutrients are particularly needed in the body in small amounts to drive essential processes, including energy metabolism, nerve functions and muscle contraction [14]. Zinc plays a vital role in transmitting information within and between cells. Therefore, these food plants could help overcome macro-and micronutrient deficiencies since the local community easily accesses them cheaply. However, wild edible plants grow in natural environments. They are therefore vulnerable to contamination with heavy metals like Cd, Ag, Se, Fe, Mg, Zn, Cu, Mo, Pb, Hg and Ni from different sources, including soil and run-off water [15]. These wild edible plants take up the metals by absorbing them from contaminated soil, water and deposits on plant parts with high exposure to polluted air [16,17]. Nevertheless, given that wild edible plants are regularly and readily consumed in most rural areas because of their abundance, nutrient richness and potential health benefits, their continued consumption may pose severe health risks for the consumers [18,19]. Human exposure to toxic metals is a global environmental health burden today [20,21]. This is because heavy metals can bioaccumulate in living organisms and can be toxic at elevated levels [22,23]. For instance, Pb is one of the systemic environmental toxicants implicated in causing cancer, neurological and cardiac problems, kidney damage, and hemolytic anemia [24,25]. Pb has been used worldwide for centuries and is present in products such as car batteries, gasoline and paints leading to increased toxicity in humans [23]. In blood, Pb toxicity disrupts the functions of the digestive, circulatory, central nervous, respiratory and reproductive systems and everyday activities of enzymes [26]. Children are at a higher toxicity risk than adults because their body tissues are still young and susceptible to Pb contamination [27]. Another heavy metal of concern is Cd because it is mostly responsible for kidney and liver dysfunction, which is indicated by the passing of proteins in urine [28,29]. Long-term exposure to Cd may cause numerous types of cancer [30]. Knowledge of the inorganic nutrient content in food is needed, especially in the current dietary shift to fast foods, which lack the required nutrients for body health [31]. Consumption of heavy metals contaminated plants negates the benefits of eating such plants and results in heavy metal poisoning. Investigations of the heavy metals in wild edible plants are thus essential for environmental safety and for reducing the risks associated with their consumption. Hence, there is a need for continuous scientific assessment of the heavy metals in wild edible plants, especially those grown in urban areas with contaminations from industrial and domestic wastes [32]. Although certain heavy metals such as Co, Mn, Ni, Cu and Fe are essential components for various biological activities within the body, their elevated levels can cause numerous health consequences to humans. Thus, this study aimed to determine the contents of inorganic micro-and macronutrients and heavy metals in selected wild edible plants consumed in the Acholi sub-region.

2. Materials and methods

2.1. Collection and preparation of plant samples

Healthy leaves and young stems of twelve wild edible plants from two sub-counties in Omoro district within the Acholi sub-region of northern Uganda were collected using standard methods according to the World Health Organization guidelines on good agricultural and collection practices for medicinal plants [33]. The Acholi sub-region was severely affected by the war between Joseph's Kony's Lord Resistance Army and the Uganda People's defense forces from mid-1980's to 2006, where heavy weaponries were used [34]. The sampling sites were located far away from roads with heavy traffic or manufacturing industries. Samples of plant materials were randomly collected from between 20 and 30 individual plant species for subsequent analysis. These plants were *Acalypha rhomboidea* Raf., *Asystacia gangetica* (L.) T. Anderson, *Crassocephalum sacrobasis* (DC.) S. Moore, *Crotalaria ochroleuca* G.Don., *Heterotis rotundifolia* (Sm.) Jacq.-Fél, *Hibiscus cannabinus* L., *Hibiscus* sp., *Hibiscus surratensis* L., *Ipomoea eriocarpa* R.Br., *Maerua angolensis* DC., *Senna obtusifolia* (L.) Irwin & Barneby and *Vigna membranacea* A. Rich. Voucher specimens of the plant species were collected and taken to the Makerere University herbarium for identification. The plant samples were shade dried at room temperature for 5–10 days or until the parts were completely dried and subsequently dried in the oven at 100 °C to constant weight. The dried samples were grounded into a fine powder using an electric grinder.

2.2. Determination of inorganic nutrients and heavy metals in edible plants

The powder samples from each plant were used for the elemental assay using a standard procedure based on AOAC methods [35]. Eight inorganic elements were chosen because of their various roles in the human body's physiological and biochemical functions.

These elements were Mg, Ca, K, Fe, Pb, Zn, Hg, and Cd. Quantification tests for the elements were done in triplicate. About 2 g of powder sample was weighed into a clean boiling tube. Distilled water (5.0 ml) and concentrated nitric acid (25 ml) were added and mixed by shaking gently. The mixture was refluxed over a water bath at 90 °C for 4 h, cooled and 10 ml of 70% perchloric acid added. The tubes were refluxed over a water bath at the same temperature for 1 h and later cooled to room temperature. Concentrated hydrochloric acid (2 ml) was then added to the sample, made to 100 ml with distilled water and filtered. All glassware used in the analysis was washed, soaked in aqua regia for 2 h, then rinsed with deionised water and dried in the oven. All reagents used in this study were of analytical grade: hydrochloric acid 'AnalaR' (sp. gr. 1.18, BDH), nitric acid 'AnalaR' (sp. gr. 1.42, BDH), perchloric acid 'AnalaR' (sp. gr.1.70 BDH), stock solutions 1000 ppm (1 mg/g) (Sigma-Aldrich) of Mg, Ca, K, Fe, Pb, Zn, Hg and Cd were serially diluted to make standard solutions in the concentrations of 0.125, 0.25, 0.50, 1.00 ppm for calibration. To both standard and sample solutions,1% (w/v) lanthanum solution was added to overcome potential interferences. The samples were then analyzed using a graphite furnace flame Atomic Absorption Spectrophotometer (Shimatzu model AA-63000, Japan). The mineral concentrations were expressed as mg/100 g dry weight (dw) and compared with the Recommended Daily Allowances, RDA [33,36,37]. Two reference materials were used for the optimization of sample digestion: ERM-CC580 (Institute for Reference Materials and Measurements, IRMM, Belgium) estuarine sediment with the certified total mercury content of (132 ± 3) μg/g and ERM-CE464 tuna fish (IRMM, Belgium) with the certified total mercury content of (5.24 ± 0.10) μg/g as described in Bulska et al. [38].

2.3. Human health risk assessment

The heavy metals health risk assessment was done using the standard method [39,40]. The estimated daily intake (EDI) and target hazard quotient (THQ) were calculated to determine the potential effects of heavy metal contamination on the health of both children and adults.

2.3.1. Estimated daily intake

The estimated average daily intake, EDI (mg/kg body weight/day), represented an estimate of the daily exposure dose of pollutants/heavy metals that consumers might be exposed to through their diets. The EDI was calculated using the formula $= C \times CR \times IR/BW$ [41,42], Where C is the concentration of heavy metal, CR is the conversion factor (To convert the concentration of sample from dry weight to fresh weight values, a conversion factor of 0.2 was used based on the moisture content of fresh leaf (80%); IR is the average daily consumption which was considered as 0.3 kg/person/day [43], 0.17 kg/person/day [44] and 0.1 kg/person/day [45]. BW is the average body weight of consumers, which was estimated as 27 kg for children aged 6–9yrs [46] and 70.3 kg for adults [47, 48].

2.3.2. Target hazard quotient

The target hazard quotient (THQ) of each pollutant/heavy metal is an estimate of the non-carcinogenic health risk level [41,42] due to the consumption of wild edible plants. THQ refers to the ratio of mean daily dose of heavy metal to its reference dose. According to US EPA [49], and Zhang et al. [50], THQ and HI values > 1 indicate a potential adverse cancer effect, while values < 1 denote non-adverse cancer risk in consumers. To estimate the human health risk from consuming heavy metals/pollutants in food, the THQ was calculated using the following formula:

$$THQ = \frac{EDI}{RfD},$$

RfD is the daily intake reference dose (an estimate of the daily dosage to which the consumers may be continuously exposed over a

Table 1
Mean concentration of macro- and micro-nutrients in mg/100 g (dw) ± standard deviation.

Plant samples	Mg	Ca	Fe	K	Pb	Zn
Acalypha rhomboidea	10.23 ± 0.14^{cd}	1170.14 ± 17.00^{g}	8.21 ± 0.04^{h}	2268.20 ± 15.18^{f}	0.99 ± 0.11^{ab}	1.38 ± 0.01^{f}
Asystasia gangetica	10.42 ± 0.15^{d}	532.39 ± 25.76^{e}	11.20 ± 0.09^{j}	2180.15 ± 19.20^{f}	1.22 ± 0.07^{b}	1.82 ± 0.01^{h}
Crassoccephalum sacrobasis	9.83 ± 0.07^{ab}	150.12 ± 1.82^{a}	9.17 ± 0.03^{i}	3346.84 ± 486.86^{g}	0.98 ± 0.04^{ab}	2.36 ± 0.03^{i}
Crotalaria ochroleuca	10.05 ± 0.07^{bc}	122.18 ± 10.69^{a}	5.06 ± 0.03^{e}	839.48 ± 39.70^{bc}	1.77 ± 0.13^{c}	1.45 ± 0.01^{g}
Heterotis rotundifolia	9.68 ± 0.06^{a}	223.46 ± 9.19^{b}	6.13 ± 0.02^{f}	782.74 ± 4.90^{bc}	0.94 ± 0.03^{ab}	0.95 ± 0.01^{d}
Hibiscus cannabinus	9.48 ± 0.19^{a}	458.13 ± 20.47^{d}	4.31 ± 0.10^{c}	518.65 ± 2.92^{ab}	1.12 ± 0.25^{b}	0.98 ± 0.01^{d}
Hibiscus sp.	9.66 ± 0.11^{a}	576.40 ± 23.85^{e}	11.21 ± 0.08^{j}	532.28 ± 9.77^{ab}	0.87 ± 0.22^{ab}	0.73 ± 0.01^{c}
Hibiscus surattensis	10.23 ± 0.07^{cd}	835.88 ± 10.22^{f}	6.69 ± 0.03^{g}	288.37 ± 1.00^{a}	0.69 ± 0.11^{a}	0.55 ± 0.01^{d}
Ipomoea eriocarpa	9.81 ± 0.13^{ab}	118.51 ± 5.82^{a}	4.75 ± 0.04^{d}	1494.40 ± 14.92^{de}	1.19 ± 0.20^{b}	0.62 ± 0.02^{b}
Maerua angolensis	$10.11 \pm 0.20b^{cd}$	523.73 ± 46.63^{e}	3.82 ± 0.04^{b}	1554.60 ± 13.65^{e}	0.98 ± 0.05^{ab}	0.52 ± 0.02^{a}
Senna obtusifolia	9.77 ± 0.02^{ab}	1265.30 ± 14.94^{h}	3.29 ± 0.02^{a}	1112.13 ± 4.49^{cd}	0.87 ± 0.06^{ab}	1.34 ± 0.01^{f}
Vigna membranacea	10.28 ± 0.07^{cd}	351.60 ± 11.31^{c}	4.42 ± 0.09^{c}	$914.63 \pm 19.13b^{c}$	0.87 ± 0.02^{ab}	1.26 ± 0.01^{e}

All tabulated mean ± standard deviation (s.d) values were derived from triplicate sample tests. Turkeys test at 95% confidence level and statistical significance level was taken at $p < 0.05$. The superscript letters a, b, c, d, e, f, g, h, i shown in the table denote significant differences ($p < 0.05$). Mercury and cadmium were below detectable limits and omitted from table. A one-way ANOVA revealed that there was a statistically significant difference in mean inorganic components among the twelve wild edible plants: Mg [$F_{(11, 23)} = 17.73$, $p = 0.00$)]; Ca [$F_{(11, 23)} = 1088.94$, $p = 0.00$], Fe [$F_{(11,23)} = 7064.15$, $p = 0.00$], K [$F_{(11,23)} = 115.42$, $p = 0.00$], Pb [$F_{(11,23)} = 12.48$, $p = 0.00$], and Zn [$F_{(11,23)} = 4400.87$, $p = 0.00$].

lifetime without experiencing any harmful effects). RfD for Pb = 0.0035 mg/kg/day.

2.4. Statistical analysis

The data were analyzed using the statistical package for social sciences, SPSS version 26.0, and presented as mean ± standard deviation. Differences in inorganic nutrient and heavy metal contents among plant species were evaluated using analysis of variance (ANOVA) followed by Turkey Post-Hoc test as the multiple comparison procedure.

3. Results and discussion

Our findings on metal elements content of selected wild edible plant species (Table 1) show that Mg content varied between 10.42 ± 0.15 mg/100 g in *A. gangetica* to 9.48 ± 0.19 mg/100 g (dw) in *H. cannabinus.* These values are higher than the Mg values for *H. cannabinus* reported by Amagloh and Nyarko [51], which was 508.28 mg/kg. Magnesium concentration in the fresh weight of the wild edible plants was approximately uniform at 0.02 mg/g, according to our study. The daily intake of Mg in all the wild edible plants in this study for both adults and children was 2 mg (Table 2). This value is lower than the Reference Daily Allowance (RDA) for both children and adults. The assumption is that both adults and children eat at least 100 g of fresh vegetables daily. However, these edible plants are not the sole diet of the locals. Thus, other food items consumed contribute towards the realization of the RDA. The RDA values for Mg are (300–600 mg) for infants below 6 years, and (280–350 mg) adults. Magnesium is a cofactor in more than 300 enzyme systems that regulate diverse biochemical reactions in the body, including protein synthesis, muscle and nerve transmission, neuromuscular conduction, signal transduction, blood glucose control, and blood pressure regulation [52,53]. Magnesium also acts as a cofactor during RNA and DNA synthesis [54].

Calcium content varied between 1265.30 ± 14.94 mg/g in *S. obtusifolia* to 118.51 ± 5.82 mg/g in *I. eriocarpa*. Calcium content in fresh weight of vegetables ranges from 2.53 mg/g in *S. obtusifolia* to 0.24 in *I. eriocarpa* and *C. ochroleuca* (Table 2). Sudi et al. [55] reported Ca content of 2.64 ppm (2.64×10^{-3} mg/g), which is lower than the value in our findings. Again, this consumption does not meet children's and adults' daily requirements. The RDA values for Ca are 600–800 mg for infants below 6 years, and 800–1200 mg for adults. Calcium content in fresh weight (mg/100 g fw) of other conventional vegetables, for instance, cabbages vary from 32.1 ± 0.8 to 44.0 ± 1.4 mg/g [56]. Calcium salts provide rigidity to the skeleton and calcium ions play a role in many metabolic processes. It is essential for maintaining bones and teeth strong over a lifetime. It also ensures the proper functioning of muscles and nerves and helps blood clot processes [57]. Calcium is involved in vascular contraction, vasodilation, muscle functions, nerve transmission, intracellular signaling and hormonal secretion [58].

The potassium content varied between 3346.84 ± 486.86 mg/100 g (dw) in *C. sacrobasis* to 288.37 ± 1.04 mg (dw) in *H. surattensis*. Potassium content in fresh weight of vegetables ranges from 6.69 to 0.58 mg/100 g. The daily intake of K through eating 100 g of fresh wild edible plants for adults and children in this study ranged from 58 to 669 mg. This, again does not supply the RDA. The RDA values for K are 1600 mg for infants below six years and 3500 mg for adults (Table 2). Potassium plays an essential role in cell metabolism, participating in energy transduction, hormone secretion, and the regulation of protein and glycogen synthesis [37]. It also reduces the risk of blood pressure, stroke, and cardiovascular disease [59].

The iron content varied between 11.21 ± 0.08 mg/g in *Hibiscus* sp., and *A. gangetica* to 3.29 ± 0.02 mg/g in *S. obtusifolia*. Fe content in fresh weight of the 12 vegetables ranged from 0.02 to 0.01 mg/g. The daily intake of Fe through eating 100 g of fresh wild edible

Table 2
Macro-nutrients concentration of mineral nutrients mg/g for dry weight and fresh weight (dw and fw), daily intake (DI)* and percentage recommended daily allowance (%RDA) for Mg, Ca and K.

	Mg				Ca				K			
Sample	dw	fw	DI	%RDA	dw	fw	DI	%RDA	dw	fw	DI	%RDA
Acalypha rhomboidea	0.10	0.02	2.05	0.73	11.70	2.34	234.03	39.00	22.70	4.54	453.64	28.35
Asystasia gangetica	0.104	0.02	2.08	0.74	5.32	1.06	106.48	17.75	21.80	4.36	436.03	27.25
Crassoccephalum sacrobasis	0.098	0.02	1.97	0.70	1.50	0.30	30.02	5.00	33.50	6.69	669.37	41.84
Crotalaria ochroleuca	0.101	0.02	2.01	0.72	1.22	0.24	24.44	4.07	8.39	1.68	167.90	10.49
Heterotis rotundifolia	0.097	0.02	1.94	0.69	2.23	0.45	44.69	7.45	7.83	1.57	156.55	9.78
Hibiscus cannabinus	0.095	0.02	1.90	0.68	4.58	0.92	91.63	15.27	5.19	1.04	103.73	6.48
Hibiscus sp.	0.097	0.02	1.93	0.69	5.76	1.15	115.28	19.21	5.32	1.06	106.46	6.65
Hibiscus surattensis	0.102	0.02	2.05	0.73	8.36	1.67	167.18	27.86	2.88	0.58	57.67	3.60
Ipomoea eriocarpa	0.098	0.02	1.96	0.70	1.19	0.24	23.70	3.95	14.90	2.99	298.88	18.68
Maerua angolensis	0.101	0.02	2.02	0.72	5.24	1.05	104.75	17.46	15.60	3.11	310.92	19.43
Senna obtusifolia	0.098	0.02	1.95	0.70	12.65	2.53	253.06	42.18	11.10	2.22	222.43	13.90
Vigna membranacea	0.103	0.02	2.06	0.74	3.57	0.71	71.35	11.59	9.17	1.83	183.33	11.46

	RDA (mg/day)		
	Mg	Ca	K
Infants 3-6	300–600	600–800	1600
Pregnant/Lactating mothers	280	1200	3500
Post-menupose/men	350	800	3500

plants for adults and children ranged from 1 to 2 mg which is below the RDA. The RDA value for Fe was 10 mg for infants below three years and adults (Table 3). Iron is an essential mineral for oxygen transport and energy production and is a functional component of hemoglobin and myoglobin. Iron is a crucial part of cytochromes in the electron transport system during the biochemical process of energy production [60].

The zinc content varied between 2.36 ± 0.03 mg/100 g (dw) in *C. sacrobasis* to 0.52 ± 0.02 mg/100 g (dw) in *M. angolensis* (Table 3). Zinc concentration in fresh weight of vegetables ranges was highest in *C. sacrobasis* 0.005 mg. The daily intake of Zn in the wild edible plants for adults and children was 0.5 mg. The RDA values for Zn are 10 mg for infants below three years and adults, respectively. Zinc is an essential component of many enzymes participating in the synthesis and degradation of carbohydrates, lipids, proteins, and nucleic acids, as well as in the metabolism of other micronutrients [61].

The Pb concentration in the twelve vegetables varied from 1.77 ± 0.13 mg/g in *C. ochroleuca* to 0.87 ± 0.02 mg/g in *V. membranacea* (Table 4). These values are higher than 0.005–0.1 ppm (5.0 × 10-6–1 × 10-6 mg/g) reported in a study on vegetables in Jamaica [62] and the CODEX and EU limits of 0.1 mg/kg [63,64]. However, the THQ values were less than 1, implying that consumption of wild vegetables does not pose a long-term deleterious effect in children and adults. The high concentration of Pb in the edible wild plants could be due to soil contaminations from the metal residues resulting from the on-going irrational use of pesticides [65] or the use of heavy weapons during the 25 years of insurgency in the study area. Plant species in areas affected by military activities are known to accumulate heavy metals [66,67]. Another study conducted in Soroti (Eastern Uganda), an area similarly affected by armed insurrection, reported a high concentration of heavy metals in beef from cattle grazed within the area [68]. One major main limitation of our study was that we miss collecting data on the nature of the soil from which the samples were collected. This could have helped to pinpoint the sources and mechanisms by which the heavy metals entered the food chain.

4. Conclusions and recommendations

Wild edible plants consumed in the Acholi sub-region are rich in inorganic nutrients. However, the amount consumed by the community does not meet the RDA. None of the plants contained detectable levels of Hg or Cd. All the plants contained Pb which was higher than the CODEX and EU limits (0.1 ppm/1 × 10^{-4} mg/g). However, the THQ of Pb in all those plants falls below the limit to cause long-term adverse effects. Therefore, consuming these edible plants does not pose a health risk of public concern to the consumer. There is need to promote use of such edible plant through local community sensitization since their consumption can contribute to attaining the RDA which is important for healthy living. Further studies are needed to quantify other inorganic components such as Se, Mn, As, and estimate their bioavailability.

Data availability statement

Data included in article/supplementary material/referenced in article.

Additional information

No additional information is available for this paper.

Table 3
Micro-nutrients concentration of mineral nutrients mg/g for dry weight (dw)and fresh weight (fw), daily intake (DI)* and percentage recommended daily allowance (%RDA) for Fe and Zn in dry weight (dw) and fresh weight (fw).

	Fe				Zn			
Sample	dw	fw	DI	%RDA	dw	fw	DI	%RDA
Acalypha rhomboidea	0.08	0.02	1.64	16.41	0.01	0.003	0.28	2.76
Asystasia gangetica	0.11	0.02	2.24	22.40	0.02	0.004	0.36	3.64
Crassoccephalum sacrobasis	0.09	0.02	1.83	18.34	0.02	0.005	0.47	4.72
Crotalaria ochroleuca	0.05	0.01	1.01	10.13	0.01	0.003	0.29	2.90
Heterotis rotundifolia	0.06	0.01	1.23	12.26	0.01	0.002	0.19	1.89
Hibiscus cannabinus	0.04	0.01	0.86	8.61	0.01	0.002	0.20	1.96
Hibiscus sp.	0.11	0.02	2.24	22.41	0.01	0.001	0.15	1.46
Hibiscus surattensis	0.07	0.01	1.34	13.38	0.01	0.001	0.11	1.10
Ipomoea eriocarpa	0.05	0.01	0.95	9.50	0.01	0.001	0.12	1.23
Maerua angolensis	0.04	0.01	0.76	7.64	0.01	0.001	0.10	1.04
Senna obtusifolia	0.03	0.01	0.66	6.59	0.01	0.003	0.27	2.68
Vigna membranacea	0.04	0.01	0.89	8.87	0.01	0.002	0.25	2.48

		RDA (mg/day)
	Fe	Zn
Infants 3-6	10	10
Pregnancy/Lactating mothers	15	15–22
Post-menupose/men	10	12–15

Table 4
Target Hazard Quotient (THQ) values for Lead in the wild edible vegetables.

Sample	mg/g (dw)	mg/g (fw)	DI	EDI	Children	THQ	Adult	THQ
Acalypha rhomboidea	0.01	0.002	0.197	0.0004	2.59E-05	0.0065	5.50E-06	0.0014
Asystasia gangetica	0.01	0.002	0.244	0.0006	3.98E-05	0.01	8.50E-06	0.0021
Crassoccephalum sacrobasis	0.01	0.002	0.195	0.0004	2.54E-05	0.0063	5.40E-06	0.0014
Crotalaria ochroleuca	0.02	0.004	0.354	0.0013	8.34E-05	0.0208	1.80E-05	0.0045
Heterotis rotundifolia	0.01	0.002	0.188	0.0004	2.36E-05	0.0059	5.10E-06	0.0013
Hibiscus cannabinus	0.01	0.002	0.223	0.0005	3.32E-05	0.0083	7.10E-06	0.0018
Hibiscus sp.	0.01	0.002	0.174	0.0003	2.02E-05	0.005	4.30E-06	0.0011
Hibiscus surattensis	0.01	0.001	0.139	0.0002	1.28E-05	0.0032	2.70E-06	0.0007
Ipomoea eriocarpa	0.01	0.002	0.237	0.0006	3.75E-05	0.0094	8.00E-06	0.002
Maerua angolensis	0.01	0.002	0.195	0.0004	2.54E-05	0.0063	5.40E-06	0.0014
Senna obtusifolia	0.01	0.002	0.174	0.0003	2.02E-05	0.005	4.30E-06	0.0011
Vigna membranacea	0.01	0.002	0.17	0.0003	1.93E-05	0.0048	4.10E-06	0.001

Author contribution statement

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

Innocent Achaye: Conceived and designed the experiments; Analysed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Godwin Anywar Upoki, Geoffrey Maxwell Malinga: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Ethical approval

The study was reviewed and approved by the Gulu University Research Ethics Committee in compliance with the Nagoya Protocol on Access and Benefit Sharing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Abbreviations

AAS Atomic Absorption Spectrophotometer
SPSS statistical package for social sciences
USEPA United State Environmental Protection Agency
WHO World Health Organisation

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