

Micronutrient composition of *Bidens pilosa* growing in three Extension Planning Areas of Rumphi district, Malawi

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DOI: <https://doi.org/10.51244/IJRSI.2026.1315PH00166>

Received: 20 August 2026; Accepted: 25 August 2026; Published: 05 September 2026

ABSTRACT

Micronutrient deficiencies are currently a public health concern in Malawi affecting preschool children, school aged children, adolescent girls and women of reproductive age. Dietary diversification offers an opportunity in addressing micronutrient deficiencies in Rumphi, Malawi. Incorporation of cheap readily available food might be a sustainable way of addressing micronutrient deficiencies in Rumphi district. *Bidens pilosa*, is an underutilized indigenous dark green vegetable growing wild as a weed in Malawi. The plant is easily accessible and readily available in Rumphi. The study was done to explore its micronutrient content and to compare the micronutrient values with other locally consumed vegetables in Malawi. *Bidens pilosa* leaf samples were collected from three Extension Planning Areas (EPAs) of Rumphi district. Moisture, ash, iron, zinc, copper, calcium, magnesium, sodium and potassium content determination were done on the samples. Statistical Package for the Social Sciences version 20 was used to analyze data where means were separated using Tukey's post Hoc test. No significant differences ($p > 0.05$) were found in moisture, iron, zinc, copper, magnesium and potassium contents among samples from the three EPAs. Significant differences ($p < 0.05$) were observed in ash, calcium, sodium and vitamin C. Micronutrient values found by the study compared greatly with other commonly consumed vegetables in Malawi. *Bidens pilosa* was also found to be a good contributor towards Dietary Reference Intakes for children, adolescent girls and women of reproductive age. These findings highlight the potential of *Bidens pilosa* as a cheap, readily available source of micronutrients in Rumphi, Malawi which can be incorporated in the dietary diversification interventions in addressing micronutrient deficiencies.

Keywords: *Bidens pilosa*, micronutrient, underutilization, Malawi, micronutrient deficiency

INTRODUCTION

Micronutrient deficiencies are still a public health concern in Malawi. According to the Malawi micronutrient survey key indicators report, prevalence of iron deficiency is at 22%, 5%, 35% and 39% for preschool children, school aged children, adolescent girls and women of reproductive age respectively. Further to that zinc deficiency (60%) seem to be more prevalent among preschool children. Vitamin A prevalence is at 4% for preschoolers and 1% for school aged children (National Statistical Office, 2016). Malnutrition in Malawi is driven by dietary inadequacies, food insecurity, climate variability and socio economic disparities (Simwanza et al., 2023).

Micronutrient deficiencies like zinc and vitamin A, can lead to irreversible consequences like physical and cognitive capacity, blindness, stunting, low work capacity, mental retardation, learning disabilities (Sanghvi et al., 2007). On the other hand, deficiency of minerals iron and zinc and vitamins A, D and B₁₂ during pregnancy can lead to negative maternal consequences like increased susceptibility to infections, poor wound healing, anemia, night blindness, neural tube defects and maternal mortality. Nutritional deficiencies affecting child

growth and development by leading to delayed development, reduced cognitive development, might affect economic development. Malnutrition might be a barrier to the attainment of the Malawi 2063 agenda since the human capital might be affected (Malawi Government, 2020). These micronutrient deficiencies in developing countries may be addressed by the underutilized vegetables which grows wildly in most areas (Issa et al., 2022)

Interventions like supplementation, food fortification, school feeding programs, community based nutrition education, are being done in Malawi but micronutrient deficiencies persist (Jomaa et al., 2011). Dietary diversification is another intervention in addressing micronutrient deficiencies. Incorporating foods like vegetables, staples, fruits, animal proteins and fortified staples can significantly improve nutrient intake (Miller & Welch, 2013). Inclusion of indigenous leafy vegetables in the diet as natural and inexpensive sources of some vitamins and minerals could prevent micronutrient deficiencies (Njume et al., 2014).

The indigenous/traditional leafy vegetables can play an important role in alleviating hunger and malnutrition in Sub Saharan Africa. However, they are neglected in research (Van Rensburg et al., 2004). Indigenous/traditional leafy vegetables are reported to be rich sources of essential micronutrients such as beta carotene, folic acid, vitamin C, calcium, iron, zinc, selenium, copper, and potassium (Shayanowako et al., 2021; Van Rensburg et al., 2004). Therefore, indigenous/traditional leafy vegetables are found to be a sustainable way of alleviating micronutrient deficiencies. Indigenous vegetables play a key role in addressing malnutrition challenges mainly micronutrient deficiencies which are major nutritional challenges in Sub-Saharan Africa (Etcheverry et al., 2012).

Bidens pilosa is an indigenous dark green wild vegetable originated from America which grows freely as a weed in Malawi. This plant is widely distributed in Malawi, found in abundance during the rainy season (November to April) and it is categorized as one of the important traditional vegetables in Malawi (Chagomoka et al., 2013). It is characterized as a neglected and underutilized leaf vegetable (Oloyede et al., 2023). Plants like *Bidens pilosa* are neglected despite their rich mineral content which are beneficial for human health and prevention of diseases. *Bidens pilosa* young leaves are usually harvested for consumption. Community members usually prefer harvesting younger leaves because they are not bitter compared to mature ones. Usually, *Bidens pilosa* leaves are boiled then tomatoes, salt, onion and groundnut flour are added. This is consumed as a side dish to *nsima* (Malawi staple food). Sometimes during preparation of *Bidens pilosa* water is discarded to reduce the bitterness. This is usually done when mature leaves have been harvested for consumption. This plant is a culturally accepted food in Malawi without any reported taboo associated with it.

Neglected and underutilized species play a major role in alleviating nutritional problems and poverty (Oloyede et al., 2023). Most of these crops are not cultivated but grow in the wild where they are well adapted to harsh environmental conditions (Matenge et al., 2012). *Bidens pilosa* have a remarkable recovery rate after exposure to a prolonged drought and has the ability to thrive in minimally nutritive soils (Njume et al., 2014; Shayanowako et al., 2021). This plant is resilient, its seeds can be viable for 3 to 4 years, it is fast growing, it prefers full sun to moderately dry soil, it requires minimal agriculture techniques for cultivation, it has a nature of hardiness, it also has the ability to thrive in any environment and explosive reproductive potential (Arthur et al., 2012; Bartolome et al., 2013). These characteristics enables *Bidens pilosa* to grow in harsh environmental conditions and may be promoted as a climate smart food in drought prone areas. Neglected and underutilized species build resilient food systems by among other factors, requiring fewer resources for production, adapting to climate variability and change, reducing reliance on a handful of major crops and boosting local nutrition and livelihoods (Mabhaudhi et al., 2019; Ndlovu et al., 2024). *Bidens pilosa* utilization contributes to localized food systems, knowledge sharing and food medicine integration thereby strengthening food sovereignty. Previous reports have indicated contributions of *Bidens pilosa* towards local livelihoods through income generating activities like selling, use as livestock or fish feed and medicine (Lee et al., 2026). Several studies have explored this plant in Malawi for its nutrient composition and found that it contains substantive amount of micronutrients (Chatepa and Masamba, 2020).

Micronutrient deficiencies are most common in the low resource communities in rural areas where diet consist mostly of the starches and less of the micronutrient rich sources. In Rumphi district, Malawi most people live in rural area and rely on smallholder agriculture for their food supply. Mainly these people rely on maize which is

the staple food. Dominant role of maize in the African diet can lead to malnutrition and vitamin deficiency diseases (Halilu et al.,2016). Therefore, this study was conducted to determine the potential of *Bidens pilosa* as an underutilized plant towards prevention of micronutrient deficiencies specifically by determining its micronutrient content compared with other locally consumed vegetables and to determine how much it contributes towards the dietary reference intakes of selected micronutrient vulnerable groups in Malawi.

MATERIALS AND METHODS

Study design and study area

A cross-sectional design was used where sample collection was done once. The study was conducted in Rumphi district, Malawi (Figure 1). Rumphi has 4560 sq. km land area, with a total population of 229,161 people, and majority (90.2%) of these people live in rural areas (National Statistics Office, 2019). Rumphi district has three distinct climatic zones, namely, lakeshore, lowland and plateau zones (Government of Malawi, 2022). It lies at latitude – 10.80292 S and longitude 33.80524 E. In Malawi, district agriculture offices are administratively and agroecologically subdivided into EPAs. These EPAs work directly with farming families and coordinates extension services at the grassroot level in sections composed of several villages (Masangano et al.,2016). The study was conducted in Chiweta, Mhuju and Ntchenachena Extension Planning Area (EPA), representing lakeshore, lowland and plateau climatic zones, respectively.

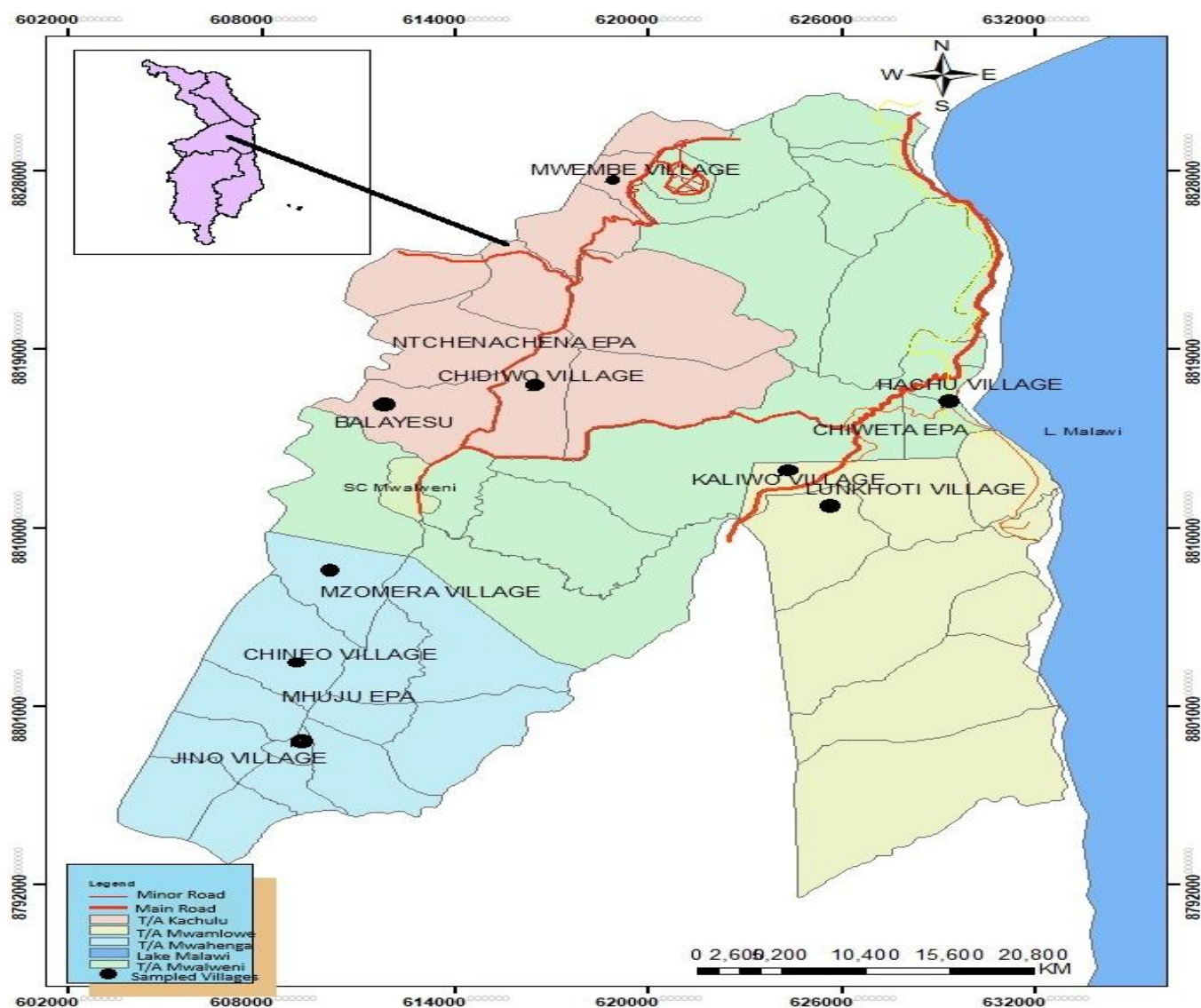


Figure 1: Map of part of Rumphi district, Malawi, showing the study villages in black dots

Data collection

Data was collected in December 2024, after approval by the Mzuzu University Ethics Committee (MZUNIREC) in Malawi with a reference number MZUNIREC/DOR/24/74. In each sampled village, local leaders were consulted to request consent for sample collection in their respective areas. Community members were also involved to guide where *Bidens pilosa* was growing. Two trained research assistants were involved in the sample collection. The young shoots of the plants were collected for mineral analysis. The plant leaves were used for the chemical analysis since it is the leaves which are used for consumption. The samples were labeled and packed in plastic bags and put it cooler box to maintain the freshness.

Sample collection

Samples were collected in all the participating villages in December 2024. A total of twenty seven 500g samples were collected from the three sampled EPAs. From Each EPA, three villages were sampled and, in each village, three samples were collected from three sampling areas in the wild making a total of 27 samples altogether. After the samples were collected there were identified and authenticated by a botanist from the National Herbarium and Botanic Gardens of Malawi, Mzuzu office.

Sample preparation

After the samples were collected, they were graded, where all impurities were removed.

Determination of minerals

Mineral determination comprised of four steps; moisture determination, ashing, ash treatment and analysis of samples on atomic absorption spectrophotometer (AAS). Moisture and ash determination was done according to AOAC (2005) while mineral analysis was done according to AOAC (2016). All Chemicals and reagents were purchased from Lab enterprise in Malawi and were of analytical grade.

Moisture determination

Each sample was weighed (1g) accurately on an analytical balance (Adam PW 214 serial number AE6801369) in triplicate. The samples were dried in an electric air oven (Scientific series 9000, model number 920, serial number 11958) at $105 \pm 5^\circ\text{C}$ for 12 hours to constant weight and cooled in a desiccator. After cooling the samples were weighed on an analytical balance. Moisture content was expressed as;

$$\text{Moisture (\%)} = \frac{(A-B)}{W} \times 100\%$$

Where A = weight of crucible plus sample (g) before drying

B = weight of crucible plus dry sample (g)

W= weight of sample (g)

Determination of Ash content

After moisture determination, the crucible containing dry sample was placed in a muffle furnace (Carbolite CWF 1200) and the sample was ashed at 650°C for 6 hours. Then the sample was cooled in a desiccator and later weighed on an analytical balance. Ash content was expressed as a percentage weight by weight (%w/w) as follows;

$$\text{Ash (\%)} = \frac{(X-y)}{w} \times 100\%$$

Where X = weight of crucible plus ash (g)

Y = weight of empty crucible (g)

W = Weight of sample before oven drying (g)

Treatment of ash

Hydrochloric acid (6M) was pipetted (7ml) into the crucible containing ash, then placed on a hot plate and heated to almost dryness. The sample was cooled and 10 ml of 3M hydrochloric acid was pipetted into the sample with crucible and boiled for about two minutes. The sample was then cooled in a desiccator and filtered quantitatively in a 100ml volumetric flask. The solution was diluted to the 100ml mark with distilled water. The volumetric flask was stoppered and shaken thoroughly to ensure a homogeneous solution.

Sample analysis on atomic absorption spectrophotometer

A calibration curve (0, 0.5, 1.0, 1.5, 2.0 mg/l) of each element was prepared from 100mg/l solution. The standards, samples and sample blanks were analyzed on Agilent 240FS Atomic Absorption Spectrophotometer. The following equation was used to calculate the mineral content.

$$\text{Mineral content (mg/100g)} = a - b * \left(\frac{V}{10W} \right)$$

where W is the weight (g) of the sample, V is the volume (mL) of extract (filtered sample), and a and b are concentrations (mg/L) of a sample solution and blank, respectively

Determination of vitamin C

Vitamin C content of *Bidens pilosa* leaves was determined using visual titration method employing the use of 2,6-dichloroindophenol dye (AOAC, 2006). An extract (20.00mL) of leaf+ $H_3PO_4:CH_3-COOH$; 1:1 homogenized in an electric blender (Charles Ross & Son Company, USA) was placed into three Erlenmeyer flasks (250mL) and was titrated to the end point using standardized 2,6-dichloroindophenol solution. A rose-pink color that persisted for over 5 seconds indicated the titration end point. Three blank titrations were carried out using the reagents only. The amount of vitamin C present in *Bidens pilosa* leaves was then calculated using the following:

$$\text{Vitamin C (mg/100g)} = (X - B) * \left(\frac{F}{E} \right) * \left(\frac{V}{Y} \right) * 100$$

Where X is the average sample titre volume (mL), B is the titre volume (mL) for the blank titration, F is mg ascorbic acid equivalent to 1.0mL of indophenol solution, E is mass (g) of sample from which vitamin C was extracted, V is the volume (mL) of the initial assay solution, and Y is the volume (mL) of the aliquot used in titration.

Data analysis

The nutrient content data were entered and analyzed using Statistical Package for the Social Sciences (SPSS) IBM version 20. Means and standard deviations were generated at 95% confidence interval level. Means were compared using Tukey's post Hoc test at 5% level of significance.

RESULTS AND DISCUSSION

There were no significant differences ($p > 0.05$) in moisture, iron, zinc, copper, magnesium, and potassium contents amongst the leaf samples from the three EPAs of Rumphidistrict (Table 1). However significant differences ($p < 0.05$) were observed in ash, calcium, sodium and vitamin C contents amongst the samples from the three EPAs. *Bidens pilosa* was found to have high potassium content and low copper content across the samples from the three EPAs. High moisture content of the samples was also observed across the samples.

Table 1: Micronutrient composition of *Bidens pilosa* growing in three EPAs of Rumphi district

EPAs Nutrients	Chiweta	Mhuju	Ntchenachena	Mean for all EPAs
Moisture*	82.8 ± 2.43 ^a	80.8 ± 0.99 ^a	80.9 ± 3.40 ^a	81.5 ± 2.56
Ash *	2.0 ± 0.30 ^{ab}	2.3 ± 0.32 ^a	1.8 ± 0.27 ^b	2.0 ± 0.33
Iron	39.8 ± 16.03 ^a	41.8 ± 25.67 ^a	23.5 ± 9.88 ^a	35.0 ± 19.53
Zinc	1.0 ± 0.08 ^a	1.1 ± 0.11 ^a	1.0 ± 0.17 ^a	1.1 ± 0.13
Copper	0.4 ± 0.2 ^a	0.4 ± 0.09 ^a	0.4 ± 0.10 ^a	0.4 ± 0.14
Calcium	1468.4±438.90 ^a	1056.9±240.37 ^b	783.5±225.82 ^b	1103.0±418.38
Magnesium	205.0 ± 32.09 ^a	184.7 ± 29.30 ^a	174.4 ± 49.05 ^a	188.0 ± 38.59
Sodium	148.7 ± 19.34 ^a	104.7 ± 33.96 ^b	120.0 ± 27.64 ^{ab}	124.4 ± 32.40
Potassium	2153.49±355.33 ^a	2238.11±262.6 ^a	2373.61±466.37 ^a	2255.07±368.14
Vitamin C	25.70 ± 11.26 ^a	32.98 ± 15.56 ^a	56.54 ± 29.04 ^b	38.65 ± 23.89

Data represent mean values ± standard deviation of three samples analyzed in triplicate each. Differences in moisture, ash and mineral contents were tested according to one - way ANOVA followed by Tukey's post Hoc test. Values on the same row with different superscripts are significantly different ($p < 0.05$). Values are mg/100g except * which is g/100g

Moisture content of the samples was similar, because the samples were collected and treated for moisture in a similar condition. However, high moisture content of the samples (around 80g/100g) was expected because leafy vegetables shape is maintained by water (Mampholo et al., 2016). Significant differences among the ash content observed signaled the differences in the mineral composition among the samples from three EPAs. The ash content of plants refers to the amount of the mineral elements present or a measure of mineral composition (Ullah et al., 2017). Significant differences observed in calcium, sodium and vitamin C could be due to amount of nutrient in the soil and differences in the ecological settings, since the samples were collected from the wild. The sampled EPAs represented three different ecological sites. These ecological sites might have had an influence to some of the mineral contents. According to Government of Malawi (2022), lowland climatic zone has very deep soils with alluvial sediments, plateau climatic zones have very deep, well-drained alluvial soils and lakeshore has cambisols and fluvisols soils. In terms of rainfall the mean maximum and minimum temperatures are 24°C and 11°C respectively in the plateau areas, and 18°C and 36°C in the lakeshore areas. The rainfall distribution is mostly influenced by the topography and proximity to Lake Malawi. The highest rainfalls are experienced in the high-altitude areas in plateaus in the range of 1500mm – 2000mm with the lowest rainfall experienced in the low-lying areas and rain shadow areas. Rainfall at the lakeshore areas is higher than on the low plateau within the same range of 2000mm – 2500mm.

Agro ecological zones might bring variations in microclimate, soil type, organic matter content, temperature, and rainfall, which might affect plant growth and maturation affecting the chemical composition traits (Abazinab et al., 2024). Wood et al. (2018) reported that soil organic matter is significantly related to crop nutrient composition. Their study further found that protein content was related to organic matter nitrogen while zinc was related to organic matter carbon in wheat. Another study by Hallman et al. (2024) found that higher soil organic matter led to greater water retention, and leaf nitrogen, phosphorous and potassium in most plant tissues. In addition, differences in soil pH in the agro ecological zones bring nutrient variations. Soil pH might increase the availability of nutrients like zinc, copper, iron and decreases availability of manganese (Pilbeam et al., 2016). Further to that pH can also result in differences in the relative micronutrient uptake (Darch, et al., 2022). Different climatic zones also differ in temperatures. Plant metabolism and related nutrient requirements may change and transpiration rates and their associated water uptake alter considerably under low temperature conditions (Mercado et al., 1997). On the other hand, heat stress often decreases root nutrient uptake thereby affecting nutrient quality (Giri et al., 2017). Further to this plant age and growth stage might contribute to nutrient variations. Some nutrients decrease while others increase with age. Sani et al. (2023) found that zinc, iron and copper decreased with age whilst calcium and magnesium increased with age. Their study further concluded that most minerals and vitamin content decrease with an increase in growth period making young leaves more

nutritious than matured ones. In line with this, the current study analyzed young leaves for micronutrient composition.

Further to this, the differences in environmental conditions where the samples are collected affect its nutrient content and composition (Yiblet & Adamu, 2023). However, this study did not attempt to measure the soil samples to determine the differences in soils since the aim of the study was to collect the samples in their natural wild habitat. Calcium content of *Bidens pilosa* might be affected by presence of a shade. Plants growing under a shade tend to have higher calcium content (Kimambo et al., 2013). Some of these samples collected in the current study were growing under shades in the wild.

Overall *Bidens pilosa* samples were found to have higher values of potassium and calcium and lower values of zinc and copper. Dark green leafy vegetables are good sources of calcium (Boukari et al., 2001). Therefore, this plant can be categorized as a readily available inexpensive good source of potassium and calcium in resource poor areas like Malawi, where malnutrition is widespread and people cannot afford fish or meat as their potassium and calcium source (Bwembya et al., 2014). High calcium levels of *Bidens pilosa* has also been reported by Odhav et al. (2007). In terms of zinc this plant is a poor source hence it cannot be considered as a good source of zinc in the diet. Vegetables and fruits have much lower concentrations of zinc due to their high water content (Gibson, 1994). Lower zinc levels of *Bidens pilosa* has also been previously reported (Muchuweti et al., 2008).

Iron levels reported in the study are similar to those reported by Issa et al. (2022) and higher than those reported by Xuan and Khanh (2016). However, *Bidens pilosa* is a plant which provide non heme iron, which has a lower bioavailability compared to animal sources. Apart from this, vegetables contain phenolic compounds and phytates which inhibit iron absorption (Brune et al., 1989). Previous studies have reported, phenolics 130.4(mg GAE/g), flavonoids 50.9 (mg QE/g), tannins (588.84 mg GAE/g) and 2288 mg/100g of oxalic acid (Mashinini et al., 2023; Chatepa and Masamba, 2020). Iron, phytate, oxalate and tannins can inhibit calcium absorption (Wongdee et al., 2019). Phytic acid affect bio accessibility of zinc with varying impacts depending on the zinc source (Rock et al., 2025). Tannins reduce iron bioavailability before absorption through formation of insoluble antinutritional mineral complexes (Bohn et al., 2008).

On the other hand, the presence of a substantive amount of vitamin C in the sampled *Bidens pilosa* could promote non heme iron absorption of the plant. Vitamin C enhances iron absorption via prevention of the formation of insoluble and unabsorbable iron compounds and the reduction of ferric to ferrous iron, a requirement for iron uptake into the mucosal cells (Hallberg et al., 1989). Traditional processing methods can also affect micronutrient and antinutrient composition in a plant. The traditional processing method used in the study area is cooking by boiling. This method has been found to associate with better retention of iron, zinc, copper, calcium, magnesium and beta carotene and a greater reduction of anti-nutrients in most vegetables (Issa et al., 2019).

Mineral content of *Bidens pilosa* compared with other commonly consumed vegetables in Malawi

Common types of exotic and indigenous vegetables in Malawi include cabbage, Chinese cabbage, rape, mustard, amaranths, okra (Nzima et al., 2024; Chagomoka et al., 2013). Mineral content of *Bidens pilosa* found in the study (Table 1) was compared with mineral contents of other common type of vegetables consumed in Malawi. The comparison was based on mineral values taken from the Malawi Food Composition table (MAFOODS, 2019). Calcium content obtained in the study was higher than the reported calcium contents of Chinese cabbage, cabbage and jute mallow while lower than amaranths vegetables (Table 2). In terms of iron values found by the study, were higher than those reported in the food composition table for Chinese cabbage, rape and jute mallow leaves while lower than pumpkin leaves and amaranths vegetables. *Bidens pilosa* magnesium values obtained by the study were lower than most magnesium contents of commonly consumed vegetables reported in the food composition table (Table 2). Highest potassium and sodium content of *Bidens pilosa* was determined by the study compared with the reported values of all the commonly consumed vegetables values. Zinc and copper values obtained in the study were lower compared with the other commonly consumed vegetables. However, *Bidens pilosa* vitamin C content was higher than the reported values of cabbage and pumpkin leaf however it

was lower than values of rape and amaranths vegetables. From this comparison *Bidens pilosa* compares greatly with other commonly consumed vegetables and it is a good source of some micronutrients compared to other commonly consumed vegetables in Malawi. The evidence suggests that *Bidens pilosa* can be a valuable vegetable source of micronutrients in the Malawian diet which consist of 99.9% vegetables consumption amongst households (National Statistical Office, 2026).

Bidens pilosa is eaten as a side dish vegetable to complement *nsima* which is a staple food in Malawi. Micronutrients from *Bidens pilosa* will complement the carbohydrate rich *nsima* which is low in vitamins and minerals. Further to that *Bidens pilosa* will bring diversity and variety to the diets. *Bidens pilosa* could easily be integrated into the diet in the study area, since vegetables are the main component of diet mainly in the rural areas, due to their readily availability and cheapness. Cheapness and easy to access, would help households in the study area to reduce stress of food costs. Currently Malawi is experiencing rising cost of food, causing food shortages (National Statistical Office, 2026). *Bidens pilosa* can be integral part of rural diets particularly during scarcity (Daum et al., 2022). Since *Bidens pilosa* is readily available it will contribute to food availability and accessibility for the community members. Therefore, providing as a sustainable source of food in the community contributing towards food security.

Table 2: Comparison of the mineral content values generated by the study to reported mineral content of commonly consumed vegetables in Malawi (MAFOODS, 2019).

Vegetable	Calcium	Iron	Magnesium	Potassium	Sodium	Zinc	Copper	Vit C
<i>Bidens pilosa</i> *	1103.0	35	188	2255.1	124.4	1.1	0.4	38.7
Cabbage	1019	41.3	424	167	28	3.5	2.03	29
Chinese cabbage	84	0.3	15	167	9	0.6	0.06	38
Rape	1990	30.8	425	296	40	5.9	0.73	60
Pumpkin leaf	1980	131.7	726	230	6	4.1	0.97	23
Amaranths	2350	66.7	1350	602	13	5.28	1.02	45
Jute mallow	495	8.1	77	580	8	0.58	0.24	38

Values are mineral content presented in mg/100g adapted from the MAFOODS (2019) except * which are mineral contents obtained by the current study

Percentage contributions of the mineral values determined by the study towards the dietary reference intakes of young children, adolescent girls and women of reproductive age in Malawi

The *Bidens pilosa* mineral values determined by the study per 100g were compared with the Dietary Reference Intakes (DRI) per day for three micronutrient vulnerable groups in Malawi namely; children, adolescent girls and women of reproductive age (Table 3). The DRIs which were used for comparison were taken from Institute of Medicine (US) Panel on Micronutrients (2001), Institute of Medicine (2000), National academies of Sciences, Engineering and Medicine, Health and Medicine Division, Food and Nutrition Board (2019) and Institute of Medicine (2011). *Bidens pilosa* micronutrient values were found to be above the DRI of iron, magnesium, vitamin C, potassium, copper and calcium for children 1 to 3 years old, however they were lower than the zinc and sodium dietary reference intakes (Table 3). For adolescent girls, 100g of *Bidens pilosa* highly contributed to DRI of iron, potassium and calcium. However, its contribution towards DRI of Sodium is lower (8%). On the other hand, 100g of *Bidens pilosa* contributed to more than 100% DRI of iron, potassium and calcium for women of reproductive age. However, it's percent contributions to zinc and sodium DRIs are low. Looking across the three vulnerable groups stated, *Bidens pilosa* is a good source of iron and potassium and a poor source of zinc and sodium to these vulnerable groups. With these findings *Bidens pilosa* might be incorporated in the dietary diversification interventions where it can provide a valuable source of micronutrients amongst the vulnerable groups in the prevention of the micronutrient deficiencies. Notably low sodium contribution of *Bidens pilosa* towards the DRI is important since high sodium containing foods might bring adverse health effects. Similar results were found by Bwembya et al. (2014).

Table 3: Dietary reference intakes and percentage contribution of *Biden pilosa* mineral values towards dietary reference intakes of three vulnerable groups in Malawi

	Children 1 to 3 years	Adolescent girls 14 to 18 years	Women of reproductive age
Iron	7 (500%)	15 (233%)	18 (194%)
Zinc	3 (37%)	9 (12.2%)	8 (14%)
Magnesium	80 (235%)	360 (52%)	310 (61%)
Sodium	800 (15%)	1,500 (8%)	1,500 (8%)
Copper	0.34 (118%)	0.89 (45%)	0.9 (44%)
Vitamin C	15 (258%)	65 (60%)	75 (52%)
Potassium	2000 (113%)	2300 (98%)	2600 (87%)
Calcium	700 (158%)	1300 (85%)	1000 (110%)

Values show dietary reference intakes adapted from Institute of Medicine (US) Panel on Micronutrients (2001), Institute of Medicine (2000), National academies of Sciences, Engineering and Medicine, Health and Medicine Division, Food and Nutrition Board (2019) and Institute of Medicine (2011). In brackets shows per 100g *Bidens pilosa* percentage contribution towards the dietary reference intake values of the vulnerable groups.

Alignment of the study findings with the Malawi 2063 agenda and the Sustainable Development Goals (particularly SDG 2, Zero Hunger and SDG 3, Good Health and Well-being)

Bidens pilosa is a cheap, readily available plant in the study area. Therefore, it will provide as a nutritious food for poor people and vulnerable groups like children and pregnant women as their source of micronutrients in their diet. This might help to reduce some of the micronutrient deficiencies present in the study area thereby contributing to SDG 2 (United Nations, 2015). Further to that reduction of malnutrition will contribute towards the ending of preventable deaths of under 5 children and women of reproductive age therefore contributing to SDG number 3(United Nations, 2015).

Malawi 2063 agenda (Malawi Government, 2020), with a vision of “an inclusively wealthy and self – reliant nation” has an enabler number 5, which is about human capital development. It states that having a health population plays a pivotal role in the transformation of the economy. However, micro nutrient deficiencies affect cognitive development which further affects the human capacity. The results of this study show that *Bidens pilosa* is a good source of some micronutrients, and if incorporated in the diet it might help in the reduction of some micronutrient deficiencies and improve cognitive development which in return will improve human capacity. Further to that utilization of *Bidens pilosa* could improve livelihoods and resilience within rural households. Readily availability of this plant will also promote access to and consumption of diverse diets among young children and pregnant women. All of these will result in having health individuals who can contribute towards the achievement of Malawi 2063 agenda.

Novelty of findings

Most studies of *Bidens pilosa* in Malawi have concentrated in the central and southern regions of Malawi, only a few have been done in the northern region. However, this study has concentrated in Rumphi district which is in northern region of Malawi. In addition, this study brings new knowledge on the micronutrient composition of *Bidens pilosa* growing in three distinct ecological zones of Rumphi district and add knowledge on the comparisons which exist across these ecological zones. Further to that, the study brings direct comparison of *Bidens pilosa* nutrient values with the Malawi Food Composition Table for commonly consumed vegetables in Malawi. The current study also calculated the percentage contributions of *Bidens pilosa* micronutrient content to Dietary Reference Intakes for specific vulnerable groups in Malawi.

CONCLUSION

Based on the results from this study, it is shown that *Bidens pilosa* sampled from three EPAs of Rumphi district, contain iron, zinc, magnesium, sodium, copper, potassium, calcium and vitamin C. Some of the minerals of *Bidens pilosa* sampled from the three EPAs differ significantly. The different environmental conditions where samples were collected affected some mineral contents amongst the *Bidens pilosa* samples. This plant can be used as a cheaper alternative source of micronutrients since it is widely distributed plant, culturally acceptable and readily available growing freely in the maize fields or in the wild of the study area. It can also be concluded that *Bidens pilosa* compares well with other vegetable options which are commonly consumed in Malawi and can add value in the diet of micronutrient deficient vulnerable groups in Malawi. These characteristics put *Bidens pilosa* highly amongst the other vegetables and it can be used in dietary diversification strategies towards addressing micronutrient deficiencies which are still a public health concern in Malawi. However, it has to be noted that samples were analyzed whilst raw while consumption involves processing which includes cooking. Cooking and preservation methods might affect the final mineral contents consumed since some minerals are lost during the processes. Therefore, when interpreting the results nutrient losses due to food preparation have to be taken into consideration.

Limitations

The study was conducted only during one season therefore, further studies might be done on other seasons to compare the results. The study also concentrated in a single district which might limit the application of the results. Soil analysis was also not done to determine the soil characteristics. In addition, bioavailability of the micronutrients was also not done.

Recommendation

Future research should include soil analysis and environmental monitoring to understand better the drivers of nutrient variation. Further studies might be done in other Malawian districts to understand further the nutrient value of *Bidens pilosa*. Another study could also be done to look at bioavailability of the determined micronutrients to evaluate their contributions towards human nutrition. In addition to that further studies could also be done on processing methods which promote bioavailability of nutrients. Other studies could also be done on consumer acceptance of *Bidens pilosa* to determine how best it can be incorporated in the diet. Intervention studies can also be recommended to determine the impact of this plant consumption towards nutritional status of people.

Funding for the study

This study was made possible by the financial support of The African Centre of Excellence in Neglected and Underutilized Biodiversity (ACENUB) under Mzuzu University (MZUNI), Malawi

Data Availability

The data that supports the findings are provided within the manuscript. Additional details supporting the findings may be provided upon request from the corresponding author.

Ethics Approval

The study was granted ethical approval by the Mzuzu University Research Ethics Committee (reference number MZUNIREC/DOR/24/74). In each study area, the village chief was consulted for sample collection in their area

Competing interests

The authors declare that there are no competing conflicts of interest.

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