



Assessment of the Nutritional Value of Selected Wild Leafy Vegetables Growing in the Roma Valley, Lesotho

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Authors' contributions

This work was carried out in collaboration among all the authors. Author EBT designed the study, wrote the protocols, managed the literature searches and edited the draft manuscript. Author TN managed the analysis and wrote the first draft of the manuscript. Author SM contributed to the discussion section and literatures searches on the biochemistry of the macro and microminerals, proof read the draft manuscript and performed the statistical analysis. All the authors read and approved the final manuscript.

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ABSTRACT

Objective: The study aimed at determining the nutrient content of nine selected wild leafy vegetables growing in Roma Valley of Lesotho as a means to achieve food security, improve nutritional and dietary diversity and address malnutrition in rural communities.

Methodology: The vegetables were analysed for proximate composition, and Ca, Mg, Na, P, K, Fe, Mn, Se, Cu and Zn and vitamin C. Analyses were carried out using standard methods.

Results: The proximate analysis revealed a high in moisture (81.15 - 92.23%) statistically similar ($p < 0.05$), some were rich in protein, vitamin C, Cu, Mn, K and Fe. *Chenopodium album* has the highest protein (31.53 ± 8.65 mg/100 g) fresh weight (FW); and *Rorripa nudiscula* (51.4% of RDA). *Chenopodium album* and *Rorripa nudiscula* were rich in Ca, 1598.21 ± 15.25 mg/100 g FW and 1508.50 ± 25.40 mg/100 g FW and in Mg, 505.14 ± 35.55 mg/100 g FW and 525.18 mg/100 g FW respectively. The vegetables were rich in K, but low in Na, with Na-to-K ratio < 1.0 , indicating that the vegetables could be ideal source of balanced sodium and potassium intake in diet. The

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vegetables were rich in Cu with ranging from 114.4% of RDA in *Hypochoeris radicata* to 342.2% of RDA in *Chenopodium album*. Fe was abundant in *Rorripa nudiscula* 251.7% of RDA and *Chenopodium album* 187.8% of the RDA. Mn was abundant in *Amaranthus cruentus* 557.8% of the RDA, in *Chenopodium album* or 245.7% of the RDA, in *Rorripa nudiscula*, 205.5% of RDA, *Amaranthus thunbergii* (130.9% of RDA), moderate amounts in *Amaranthus caudatus* (1.94±0.36 mg/100 g FW or 84.4%) and *Amaranthus spinosus* (83.5% of RDA). The content of Se was moderate: *Rorripa nudiscula* (38.3% of RDA), *Amaranthus thunbergii* (20.50±0.27 µg/100 g FW, 37.3% of RDA), *Amaranthus spinosus* (34.0% of RDA) and *Lactuca serriola* (20.7% of RDA). Zn was high in *Chenopodium album* (117.3% of RDA) moderate in *Rorripa nudiscula* (35.6% of RDA) *Lactuca serriola* (23.9% of RDA), *Amaranthus spinosus* (19.6% of RDA), *Amaranthus caudatus* (15.9% of RDA). Most of the nutrient were statistically similar at $p < 0.5$.

Conclusion: The nutrient composition indicated that the vegetables could be good source of minerals and vitamin C and could be incorporated in rural household diets to improve nutrition, address malnutrition and food insecurity.

Keywords: Wild leafy; Amaranthus; micronutrients; vegetables; carbohydrates; macronutrients.

1. INTRODUCTION

There are hundreds of herbaceous plants that have their natural habitats in sub-Saharan Africa and are consumed primarily as vegetables in many countries in the region [1]. These wild leafy vegetables have been part of the food systems in sub-Saharan African communities for generations and form a vital component of diets and are indispensable ingredients in soups and sauces [2]. Generally, these wild leafy vegetables have higher protein content than cultivated leafy vegetables [3]. Some of these vegetables contain non-nutritive bioactive compounds such as phytates and oxalates, which have been shown to have health protecting and enhancing properties [4]. Recent studies have shown that some green leafy vegetables also contain bioactive phytochemicals that have been linked to protection against cardiovascular and degenerative diseases [5].

The search for new and unconventional sources of nutrients in developing countries has attracted a great interest, because of the threat to food security as a result of rapidly growing populations and dwindling agricultural land, unpredictable weather patterns and poor crop yield. [6]. In rural Lesotho vegetables are a valuable source of dietary minerals, proteins and roughage [2]. The many wild leafy vegetables known in Lesotho [7], only a few are exploited for their nutritional value and health benefits due to lack of the appropriate information and the perception among urban consumers that wild vegetables are food for the poor, low-income groups [8].

The promotion of the production and consumption of these wild leafy vegetables

require knowledge of the nutrients content and health benefits relative to the traditional vegetables on the market. This understanding motivated the current study, which was aimed at determining the nutrient content of selected wild leafy vegetables and evaluating their nutritional potential. The study focused on nine wild vegetables growing in the Roma Valley of Lesotho and widely consumed among the rural communities. Five species were selected from the Amaranthaceae, which are drought resistant and grow well in harsh conditions, four other species from the Chenopodiaceae, Asteraceae and Brassicaceae known to be rich in protein, dietary fibre, minerals, vitamins, and antioxidants [9]. The selected vegetables were *Amaranthus caudatus*, *Amaranthus cruentus*, *Amaranthus hybridus*, *Amaranthus spinosus*, *Amaranthus thunbergii*, *Chenopodium album*, *Rorripa nudiscula*, *Lactuca serriola* and *Hypochoeris radicata*. The results of the study could be valuable source of information on local wild plant food resources that could improve the national food profile as affordable nutrient dense food resources and as a motivation for their promotion and acceptance among the urban population [10].

2. MATERIALS AND METHODS

2.1 Sample Collection and Processing

The wild vegetables were randomly collected from cultivated and non-cultivated fields from different locations in the Roma Valley area of Lesotho Latitude: -29°26' 28.79" S Longitude: 27° 42' 17.39" E). The samples were placed in black plastic bags and transported to the laboratory for processing the same day. The vegetables studied are listed in Table 1.

Table 1. Characteristics of the of the selected indigenous leafy vegetables

Species	Family	Local (Sesotho) name	Common names
<i>Amaranthus caudatus</i>	Amaranthaceae	<i>Theepe</i>	Foxtail amaranth, love-lies bleeding, Tassel flower
<i>Amaranthus cruentus</i>	Amaranthaceae	<i>Theepe</i>	Red amaranth, purple amaranth; blood amaranth
<i>Amaranthus hybridus</i>	Amaranthaceae	<i>Theepe-ea-bokone</i>	Cape pigweed, cock's comb, common amaranth
<i>Amaranthus spinosus</i>	Amaranthaceae	<i>Theepe</i>	Spiny pigweed, thorny pigweed, spiny amaranth
<i>Amaranthus thunbergii</i>	Amaranthaceae	<i>Theepe</i>	Wild spinach; red pigweed, small pigweed
<i>Chenopodium album</i>	Chenopodiaceae	<i>Seruo</i>	Lambs quarters; pigweed, white goose foot
<i>Hypochoeris radicata</i>	Asteraceae	<i>Pheeo-la-khoho</i>	Flat weed; cat's ear, hairy wild lettuce, false dandelion
<i>Lactuca serriola</i>	Asteraceae	<i>Leshoabe</i>	Prickly lettuce; wild lettuce. milk thistle
<i>Rorippa nudiscula</i>	Brassicaceae	<i>Papasane</i>	Creeping yellow cress Watercress

The edible parts, i.e. the leaves and young tender stems of each collected plant were combined to form a composite sample, which was used for the analysis. The samples were soaked in tap water for 30 min. and washed thoroughly with tap water and rinsed with distilled deionized water to eliminate any contamination with nitrates, nitrites, chlorides and trace elements that might have been present in the tap water. The residual moisture on the leaves was evaporated at room temperature. The fresh samples were blanched to reduce the numbers of any contaminating microorganisms and to preserve colour, flavour and nutritional value. The blanched samples were put into Ziploc plastic bags and stored at 4°C until required for analysis.

2.2 Sample Preparation and Analysis

The proximate analyses of all the selected vegetable samples were determined. The parameters determined were moisture, ash, crude fat, protein, dietary fibre, carbohydrates and vitamin C according to the AOAC methods [11]. The moisture content and vitamin C were determined on the same day of collection using fresh samples to minimize losses. The protein content determined by the Kjeldahl method was calculated using the conversion factor of 6.25. [12]. Dietary carbohydrate was determined by direct analysis, which gives the sum of the weights in grammes of monosaccharides, disaccharides, oligosaccharides and

polysaccharides, excluding fibre [11]. The minerals calcium, (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe), copper (Cu), manganese (Mn), selenium (Se) and zinc (Zn) were determined using inductively coupled plasma atomic absorption spectrophotometer (Varian ICP-AES-220 FS). Wet digestion was preferred to avoid partial volatilization of Se and Fe. A 1.0 g of the sample oven-dried at 35°C was accurately weighed and carefully digested in nitric acid (70%) until clarity was achieved. After cooling, 3 mL of water was added and heating resumed for a further 10 min. Finally, the solution was cooled to room temperature, filtered to remove any suspended particles and the filtrate was diluted to 100 mL with deionized water [13].

The phosphorous (P) content of the vegetable samples was determined as the blue phosphomolybdate complex [14] using HACH DR 2800 spectrophotometer. The values for the contents of the various nutrients were compared with the recommended daily allowances (RDA).

2.3 Statistical Analysis

The data for each vegetable species (n=3) were statistically analysed by the Tukey multiple comparisons test using one-way analysis of variance (ANOVA) to determine if the mean values for the nutrients for each of the vegetable species were significantly different from each other. Levels of significance were set at p<0.05.

The statistical analyses were carried out using the statistical package SPSS 16.0 version 23.0.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of the Vegetables

Macronutrients, which are needed in larger quantities normally include water, carbohydrates, fat and protein and are also called energy-providing nutrients, except for water. The results of the proximate analysis of the selected vegetables showed some variation in the composition of protein, total fat, carbohydrates, dietary fibre, moisture and energy shown in Table 2 using the ANOVA Tukey multiple comparisons analysis at significance difference level set at ($p < 0.05$).

The moisture content of the vegetables ranged between 81.2 ± 4.7 g/100 g and 92.2 ± 8.3 g/100 g of fresh weight (FW) and was statistically similar among all the vegetables. The range of moisture content agreed with previously reported values from other regions of Africa [15,16]. *Lactuca serriola* had the highest moisture content of 92.2 ± 8.3 g/100 g FW and *Amaranthus cruentus* with the lowest moisture content of 81.2 ± 4.7 g/100 g FW and *Amaranthus cruentus* with the lowest moisture content of 81.2 ± 4.7 g/100 g FW (Table 2). The amount of moisture in a food substance is very important in terms of its quality, stability, processing and storage methods. The moisture content of food influences the shelf life, as it enhances the activity of water-soluble enzymes, coenzymes and inorganic co-factors, which play a major role in the hydrolysis reactions and biochemical processes such as bacterial growth that leads to the deterioration of foods [17]. The high moisture content implies that the vegetables should be stored in refrigerators, which is not common among the rural households. In general, there is correlation between the moisture content of a food substance and the rate of its deterioration, which depends on the proportion of water present in the food substance that is available for hydrolytic processes [18]. The moisture content was high for all the vegetables species studied and this could provide for greater activity of water soluble enzymes, coenzymes and inorganic cofactors essential for the metabolic activities in these vegetables. However, the moisture content alone is not enough to conclude that these green leafy vegetables would have a shorter shelf life. It requires additional information on the intrinsic

characteristics of these vegetables such as pH, redox potential, nutrients, biological structures and antimicrobial constituents as well as extrinsic factors such as temperature, relative humidity and presence of competitor microorganisms [19].

Amino acids are an important component of every cell in the body and needed in the diet for growth and development in children and to help in the repair of cells and the building of new cells, in the synthesis of enzymes, hormones and other substances in the body [20]. Amino acids, which are the building blocks of proteins are grouped into three categories of essential, non-essential and conditional amino acids. Essential amino acids cannot be synthesized in the body and hence have to be supplied by food [21]. The protein content of the vegetables are shown in Table 2. which are within the range 3.14 ± 0.31 mg/100 g FW (0.006% of the RDA) to 31.5 ± 8.7 mg/100 g FW (0.06% of the RDA) which were very low relative to the RDA values of 46 g for adult women and 56 g for adult men [22]. *Chenopodium album* had the highest protein content of 31.537 ± 8.7 mg/100 g FW. The lowest protein content was found in *Amaranthus hybridus* and *Lactuca serriola* with values of 3.82 ± 0.53 mg/100 g FW (0.007% of the RDA) and 3.14 ± 0.31 mg/100 g FW (0.006% of the RDA) respectively. These values for protein content were comparable to reported values, and in some cases higher while similar values have been reported elsewhere [23]. Inadequate protein intake retards growth and development in children [24], leads to muscle wasting, brittle hair and nails, oedema on hands, feet, poor wound healing etc. [25]. The values indicated that these leafy vegetables contain moderate amounts of protein. However, since these vegetables are readily available and some are available throughout the year, they may be a good source of protein to supplement the diet in the poor rural communities where malnutrition remains a major public health problem in Lesotho, especially among children under the age of five years [26].

The results of the study showed that the wild vegetables contained low amounts of dietary fibre, less than 1% of the RDA [22], which varied from the lowest value of 4.52 ± 1.83 mg/100 g for *Hypochoeris radicata* to the highest value of 45.52 ± 1.83 mg/100 g FW for *Amaranthus thunbergii*, constituting 0.01% and 0.12% of the RDA for dietary fibre respectively. A generous intake of dietary fibre provides many health benefits as it plays an important role in the physiological and metabolic activities in the body.

Dietary fibre is probably best known for its ability to prevent or relieve constipation and normalize bowel movements [26]. The consumption of a diet rich in fibre seems to enhance the functioning of the immune system may help prevent the fluctuations in blood glucose levels [27], assists weight loss [68] lowering the concentration of blood cholesterol and may be useful for diabetic patients because of the multiple effects on cardiovascular risk factors [28], lowers blood pressure [29] and protects from some gastrointestinal disorders [30]. On the other hand deficiency of dietary fibre may lead to constipation, diabetes, obesity [31] and cardiovascular diseases [32]. Among the vegetables, *Amaranthus thunbergii* and *Amaranthus hybridus* could be a good source of dietary fibre with the content of 45.51 ± 8.36 and 21.15 ± 4.85 of the RDA respectively, while the rest of the vegetables could be a supplementary source of dietary fibre.

All the nine vegetables studied were low in fat with values in the range from 0.75 ± 0.08 mg/100 g FW for *Amaranthus cruentus* to 23.70 ± 4.25 mg/100 g FW for *Amaranthus hybridus*. The values were all less than 1% of the RDA [22] hence they would not contribute to the fat intake in the diet. Dietary fat is very essential for humans since fat is as an energy reserve, and fats together with carbohydrates and proteins are the sources of energy in the human diet. Fats enhance the bioaccessibility and absorption of hydrophobic nutrients such as carotenoids, lycopene present in vegetables, fat-soluble vitamins A, D, E and K in diet, which have been shown to help prevent heart disease and cancer [33]. Fatty acids, the building blocks of many important substances in the body, are essential to cell membranes, maintaining a regular heartbeat, providing an anti-inflammatory function, regulating cholesterol and contributing to brain and eye development in a developing baby and are also involved in many physiological functions [34].

Carbohydrates are of special importance because they are the primary energy source in the human body. Carbohydrates, proteins and fats are the three macronutrients that provide energy to the body. Besides energy production, carbohydrates function as energy store, building macromolecules, sparing proteins and assisting in lipid metabolism [35]. The carbohydrate content of the screened vegetables ranged from 3.58 ± 1.05 mg/100 g FW for *Rorripa nudiscula* to

68.25 ± 2.14 mg/100 g FW for *Chenopodium album*. Dietary carbohydrates are not only an energy source, but also have important impact on the maintenance of human health [36]. Besides, carbohydrates provide the basic materials for the construction of nearly all cell membranes in the body. Green leafy vegetables as a healthy source of carbohydrates also provide other nutrients like minerals, fibre, proteins and a host of phytonutrients. The carbohydrate content of the vegetables was negligible; all are less than 0.01% of the RDA [22].

The amount of total ash of vegetables is an indication of mineral content, though the total ash values in terms of nutritional value are not as important as the values of the individual mineral elements. The ash content of the wild vegetables used in the study varied widely. *Amaranthus cruentus* gave the lowest amount of ash (1.56 ± 0.45 mg/100 g FW), while *Amaranthus spinosus* had the highest ash content of 21.08 ± 5.25 mg/100 g FW. These observed relatively high values of total ash were indicative of higher mineral content, a fact that was consistent with the observed high amounts of different minerals in *Amaranthus spinosus* and *Chenopodium album* which also gave the highest total ash values among the vegetables screened (Table 2). The vegetables *Amaranthus spinosus* and *Chenopodium album* could be a good source of mineral nutrients for human nutrition.

The energy content in terms of calorific value varies over a wide range. *Lactuca serriola* had the lowest energy content of 45.85 ± 5.21 kcal/100 g FW and *Hypochoeris radicata* had the highest energy content of 420.34 ± 35.20 kcal/100 g FW. The *Amaranthus* species had relatively higher energy content among the vegetables studied, but still lower than the RDA [22]. The energy content of foods depends on the amount of carbohydrates, fats and protein present in the foods, which are the major sources of energy in foods [37]. Energy is vital in the maintenance of the human body; it is required for all processes in the body, digestion and absorption of nutrients, mental, energy, physical functions, basal metabolism, muscle metabolism, and physical functions. The energy released by a particular food is a vital parameter in human nutrition; excess intake of foods with high energy density has been accepted as the cause of many chronic diseases, such as obesity and cardiovascular diseases [38].

3.2 Macrominerals

Minerals are indispensable in the maintenance of life as their functions are numerous and either quite broad or highly specific in the metabolism and homeostasis of the body [39]. Since the minerals cannot be biosynthesized, the only source is foods that contain these minerals [40]. The data from the analysis for content of the five major macrominerals, analysed using the ANOVA Tukey multiple comparisons analysis with significance difference defined at ($p < 0.05$) are presented in Table 3.

Calcium (Ca) is a major essential mineral for the human body. The Ca content in the vegetables was highest in *Chenopodium album* (1598.2 ± 15.25 mg/100 g FW) and lowest in *Rorripa nudiscula* (1508.5 ± 25.40 mg/100 g FW). Calcium is the major constituent of bones and teeth, regulates the function of muscles and nerves, the clotting of blood and activates a variety of enzymes including ATPases, which are have fundamental roles in energy production, harnessing and conservation, active transport and pH homeostasis [41]. The amount Ca in *Chenopodium album* and *Rorripa nudiscula* were 133% and 126% of the RDA respectively [42]. These vegetables could meet the daily requirements for this mineral. However, some anti-nutrients like phytates and oxalates found in plant foods, which make minerals non-bioavailable [43] if present in considerable amounts, may lower the bioavailability of Ca.

The content of magnesium (Mg) in the wild vegetables was within the range 525.1 ± 12.5 mg/100 g FW and 12.85 ± 5.74 mg/100 g FW (Table 3). *Rorripa nudiscula* and *Chenopodium album* had the highest Mg content of 525.1 ± 12.5 mg/100 g FW and 505.14 ± 38.55 mg/100 g FW, which translate into 125% and 120% of the RDA respectively, while *Lactuta serriola* had the lowest Mg content of 12.85 ± 5.74 mg/100 g FW (3% of RDA) [42]. Magnesium is an essential mineral present in all human tissues and has both physiological and biochemical functions. It is involved in more than 300 enzyme systems in the body and many fundamental biochemical processes like the synthesis of nucleic acids and energy production [44]. It is a component of bones and teeth and it is an active component of many enzymes systems in the human body [45]. In terms of the Mg content, *Chenopodium album* and *Rorripa nudiscula* are a good source of the mineral to meet the daily recommended requirements [46].

The macrominerals, potassium (K) and sodium (Na) with other macrominerals Ca, Mg and P are essential for a variety of physiological and metabolic processes in the human body, which include activity of enzymes, energy production, the formation and composition of bones and teeth and the formation of ATP [47]. The two minerals K and Na regulate the osmotic pressure of body fluids balance and blood pressure. Potassium enhances the removal of excess sodium from the body and is important in managing high blood pressure as it helps lower blood pressure [48]. The sodium content of the vegetables was relatively low, within the range of 10.85 ± 2.15 mg/100 g FW and 75.20 ± 8.32 mg/100 g FW, except for *Amaranthus cruentus* (Table 3) while the content of K was relatively high in the range of 345.47 ± 45.16 mg/100 g FW to 3415.80 ± 43.25 mg/100 g FW, but was below the RDA [22,49]. The relative proportions of Na to K in the human body is crucial for the functioning of the cardiovascular system. It has been reported that a Na:K ratio < 1.0 is essential to maintain cardiovascular health [59]. A high K content with low Na content was observed for all, except for *Amaranthus cruentus* resulting in a Na:K ratio < 1.0 , which could be a good source of nutrients for people with hypertension. Dark green vegetables have been identified as good sources of potassium hence the promotion of consumption of foods that are naturally high in potassium as another way of reducing the Na:K ratio of the diet, as high sodium intake is a major public health problem. The observed low Na:K ratio suggested that these wild vegetables are a good source of balanced sodium and potassium intake [50]. The promotion of consumption of these wild vegetables with the exception of *Amaranthus cruentus* could therefore enhance the maintenance of good cardiovascular health due to the low Na:K ratio.

The phosphorus (P) content for all the analysed wild leafy vegetables varied widely from 2.25 ± 0.76 mg/100 g FW for *Hypochoeris radicata* and 85.5 ± 25.4 mg/100 g FW for *Amaranthus cruentus*. The *Amaranthus* species, except for *Amaranthus caudatus*, had a higher P content than all the other wild vegetables in the study. The range of P content in the wild vegetables was close to reported values [51], though constituting only 5% of the RDA [42]. The role of P in human nutrition is two-fold; structural and biochemical. It is essential for healthy bone and tooth structure and it is a major constituent of phospholipids which constitute cell membranes.

Table 2. Proximate composition of selected wild vegetables per 100 g fresh weight (FW) of edible portion (n=3)

Vegetable plant species	Moisture g/100 g	Ash mg/100 g	Energy kcal/100 g	Protein mg/100 g	Fibre mg/100 g	Total fat mg/100 g	Carbs mg/100 g
<i>Amaranthus caudatus</i>	84.50 ± 2.15 ^a	13.15 ± 2.80 ^{abc}	215.34 ± 35.20 ^a	6.15 ± 1.52 ^a	9.26 ± 2.30 ^a	1.73 ± 0.56 ^a	5.83 ± 1.50 ^{ad}
<i>Amaranthus cruentus</i>	81.15 ± 4.71 ^a	1.56 ± 0.85 ^{ab}	125.85 ± 21.45 ^b	5.72 ± 2.05 ^a	9.54 ± 2.51 ^a	0.75 ± 0.08 ^a	5.81 ± 2.05 ^{ad}
<i>Amaranthus hybridus</i>	84.2 ± 5.37 ^a	84.2 ± 5.37 ^a	315.25 ± 22.52 ^e	3.82 ± 0.53 ^a	21.15 ± 4.85 ^b	23.70 ± 4.25 ^b	38.2 ± 10.52 ^b
<i>Amaranthus spinosus</i>	83.10 ± 3.25 ^a	83.10 ± 3.25 ^a	189.52 ± 10.34 ^{ac}	5.20 ± 1.02 ^a	9.20 ± 2.34 ^a	0.85 ± 0.15 ^a	4.80 ± 1.08 ^{ad}
<i>Amaranthus thunbergii</i>	84.06 ± 5.60 ^a	2.80 ± 1.15 ^{ab}	156.53 ± 14.21 ^{abc}	5.52 ± 0.94 ^a	45.51 ± 8.36 ^c	2.34 ± 0.37 ^a	51.40 ± 12.53 ^b
<i>Chenopodium album</i>	84.06 ± 5.60 ^a	20.81 ± 5.61 ^{ac}	187.56 ± 15.25 ^{ac}	31.53 ± 8.65 ^b	8.90 ± 1.65 ^a	4.52 ± 0.25 ^a	68.25 ± 2.14 ^c
<i>Hypochoeris radicata</i>	89.80 ± 6.23 ^a	1.85 ± 0.24 ^{ab}	420.34 ± 35.20 [†]	4.08 ± 0.23 ^a	4.52 ± 1.83 ^a	0.95 ± 0.12 ^a	9.50 ± 1.50 ^{ad}
<i>Lactuca Serriola</i>	92.23 ± 8.25 ^a	2.01 ± 0.61 ^{ab}	45.85 ± 5.21 ^d	3.14 ± 0.31 ^a	10.09 ± 2.04 ^a	1.04 ± 0.35 ^a	13.52 ± 3.41 ^{ad}
<i>Rorippa nudiscula</i>	92.23 ± 8.25 ^a	14.85 ± 6.24 ^{ac}	53.16 ± 8.43 ^d	25.72 ± 3.15 ^b	12.13 ± 2.16 ^a	2.57 ± 0.55 ^a	3.58 ± 1.05 ^{ad}

Means with the same letter do not differ statistically at the significance level of $p < 0.05$ for each parameter

Table 3. Macromineral content of selected wild vegetables in mg/100 g fresh weight (FW) of edible portion (n=3)

Vegetable plant species	Ca mg/100 g	Mg mg/100 g	P mg/100 g	Na mg/100 g	K mg/100 g	Na-to-K ratio
<i>Amaranthus caudatus</i>	215.80 ± 45.21 ^{ab}	56.20 ± 15.20 ^{ae}	3.14 ± 0.85 ^a	43.36 ± 5.82 ^a	345.47 ± 45.16 ^{ab}	0.126 ^{bc}
<i>Amaranthus cruentus</i>	27.85 ± 2.30 ^{ab}	245.18 ± 32.25 ^b	85.50 ± 25.43 ^b	705.15 ± 62.21 ^a	465.48 ± 38.21 ^{abf}	1.515 ^d
<i>Amaranthus hybridus</i>	315.15 ± 65.10 ^{ab}	185.25 ± 10.05 ^c	65.5 ± 12.57 ^b	26.5 ± 0.83 ^a	765.41 ± 58.51 ^{cd}	0.034 ^{abc}
<i>Amaranthus spinosus</i>	462.75 ± 105.27 ^{bc}	258.6 ± 15.52 ^b	68.52 ± 8.25 ^b	14.25 ± 4.36 ^a	682.8 ± 45.24 ^{cdf}	0.021 ^{abc}
<i>Amaranthus thunbergii</i>	302.8 ± 71.52 ^{ac}	135.5 ± 12.18 ^c	58.61 ± 5.23 ^b	10.85 ± 2.15 ^a	352.5 ± 15.72 ^{ab}	0.031 ^{abc}
<i>Chenopodium album</i>	1598.2 ± 15.25 ^{bd}	505.14 ± 38.55 ^d	58.95 ± 3.56 ^b	23.50 ± 5.35 ^a	3415.8 ± 43.25 ^g	0.007 ^{abc}
<i>Hypochoeris radicata</i>	185.26 ± 35.67 ^{ab}	33.89 ± 4.52 ^{ae}	2.25 ± 0.76 ^a	75.20 ± 8.32 ^a	2585.25 ± 105.58 ^e	0.029 ^{abc}
<i>Lactuca serriola</i>	171.15 ± 10.26 ^{ab}	12.85 ± 5.74 ^{ae}	2.85 ± 1.05 ^a	54.23 ± 5.61 ^a	568.21 ± 85.21 ^{bdf}	0.095 ^{abc}
<i>Rorippa nudiscula</i>	1508.5 ± 25.40 ^{be}	525.18 ± 12.5 ^d	4.21 ± 1.62 ^a	45.7 ± 2.52 ^a	2520.8 ± 51.54 ^e	0.018 ^{abc}

Means with the same letter do not differ statistically at the same level of $p < 0.05$ for each parameter

Many enzymes and hormones contain P as a structural component. Intracellular P contributes to a number of processes associated with energy metabolism and is an active mineral in many biochemical processes in living cells. It acts as a buffer, neutralizing acids to maintain normal pH in the blood, it is a part of DNA and RNA molecules; the genetic code of every cell, which makes it essential for cellular growth and development. These vegetables may not be a good source of P because of the low content of this mineral, coupled with the fact that the bioavailability of organic P is low as it is usually in the form of phytates, which humans are unable to digest [52].

3.3 Micronutrients

Micronutrients, which include microminerals and vitamins are required in small amounts for growth, development, and maintenance of cellular processes in the body. Microminerals and vitamins constitute the two major classes of biologically critical micronutrients required for normal health and development of humans, so there is a clear correlation between deficiency of micronutrients in the body and the development of chronic metabolic disorders [53]. The main function of micronutrients is to enable the many biochemical reactions in the body to occur timely and efficiently. They are important components of hormones, enzymes and function as cofactors and activators of a variety of enzymes. According to the WHO, overall malnutrition is intricately intertwined with micronutrients status [54], hence the two have to be considered together to achieve adequate nutrition. Deficiency of micronutrients can be detrimental to health and is usually subtle because the symptoms of their deficiency develop slowly over time until permanent damage is done [53]. The mean values of the content of micronutrients of the vegetables are shown in Table 4. The ANOVA Tukey multiple comparisons analysis showed that the content of most of the micronutrients was statistically similar ($p < 0.05$) among the vegetables and within the species.

The content of iron (Fe) in the vegetables varied within a wide range from 3.25 ± 1.28 mg/100 g FW to 45.30 ± 1.65 mg/100 g FW. Three of the vegetables were very high in Fe *Rorripa nudiscula*, *Chenopodium album* and *Amaranthus spinosus*; with Fe content of 45.30 ± 1.65 mg/100 g FW (251.7% of RDA), 33.81 ± 5.78 mg/100 g FW (187.8% of RDA) and 12.56 ± 0.74 mg/100 g FW (69.8% of RDA) respectively [55]. These

three wild vegetables may be a good source of iron (non-haem Fe), but iron from plant sources has low bioavailability relative to Fe from animal sources (haem Fe) due to chelation with anti-nutrients like phytates and oxalates. These vegetables contained appreciable amounts of vitamin C, which enhances the absorption of Fe. Vitamin C combines with dietary non-haem Fe to form a chelate complex, a more soluble form of iron, which increases its absorption the small intestinal tract. Vitamin C, as an antioxidant, maintains the oxidation state of Fe as Fe(II), the form in which iron is used in the body [56].

Copper (Cu) is an essential trace element, which is found virtually in every cell of the body and together with Fe and Zn is vital for the well-being of humans. Cu plays a major role in the maintenance of nerve cells, immune system, absorption of Fe and the formation of red blood cells [57]. The staple diet in Lesotho is starch-based, which is usually low in Cu and other micronutrients, because most of the copper-rich foods, such as oysters, lobsters, nuts and seeds are too expensive for most rural consumers [58]. Therefore, the major source of Cu for this group of consumers is green vegetables. The wild vegetables in this study were very rich in Cu with contents ranging from 114.4% to 342.2% of the RDA. *Chenopodium album* had the highest content of 3.08 ± 0.12 mg/100 g FW or 342.2% of the RDA, followed by *Amaranthus cruentus* with content of 2.25 ± 0.06 mg/100 g FW or 250% of the RDA and *Amaranthus spinosus* with content of 2.06 ± 0.04 mg/100 g FW or 228.9% of the RDA [55]. These vegetables could be good and affordable source of dietary Cu.

Like all micronutrients, Mn is essential for the proper functioning of cells and the body as a whole. It is a component of many metalloenzymes, involved in the metabolism of carbohydrates, lipids and amino acids. It is required for proper immune function, regulation of blood sugar levels and cellular energy [59,60,61]. Four of the vegetables were found to be very rich in Mn: *Amaranthus cruentus* (12.93 ± 4.55 mg/100 g FW), *Chenopodium album* (5.65 ± 1.31 mg/100 g FW), *Rorripa nudiscula* (4.75 ± 0.16 mg/100 g FW), and *Amaranthus thunbergii* (3.01 ± 1.05 mg/100 g FW). The content of Mn in these four vegetables corresponds to 562.2%, 245.7%, 206.5% and 130.9% of the RDA respectively [55]. In terms of the RDA a moderate serving of 100 g these four green leafy vegetables would meet the daily requirement of Mn.

Table 4. Micromineral content of selected wild vegetables per 100 g fresh weight (FW) of edible portion (n=3)

Vegetable plant species	Cu mg/100 g	Fe mg/100 g	Mn mg/100 g	Se µg/100 g	Zn mg/100 g	Vitamin C mg/100 g
<i>Amaranthus caudatus</i>	1.13 ± 0.03 ^{acef}	3.58 ± 0.60 ^a	1.94 ± 0.36 ^{acef}	1.65 ± 0.12 ^a	1.75 ± 0.36 ^{ab}	118.27 ± 15.65 ^{abd}
<i>Amaranthus cruentus</i>	2.25 ± 0.06 ^{bd}	0.45 ± 0.15 ^a	12.93 ± 4.55 ^g	2.80 ± 0.25 ^a	1.05 ± 0.18 ^{ab}	145.20 ± 20.14 ^{ab}
<i>Amaranthus hybridus</i>	1.26 ± 0.08 ^{acf}	5.19 ± 0.48 ^a	0.96 ± 0.36 ^{abce}	5.90 ± 0.21 ^a	0.95 ± 0.15 ^{ab}	134.52 ± 18.25 ^{ab}
<i>Amaranthus spinosus</i>	2.06 ± 0.04 ^{bd}	12.56 ± 0.74 ^b	1.92 ± 0.52 ^{abcef}	18.70 ± 2.54 ^{bc}	2.15 ± 0.09 ^{abc}	115.08 ± 9.45 ^{abd}
<i>Amaranthus thunbergii</i>	1.28 ± 0.05 ^{acf}	3.89 ± 0.95 ^a	3.01 ± 1.05 ^{abcdef}	20.50 ± 5.20 ^c	1.32 ± 0.27 ^{abc}	45.64 ± 2.84 ^{ce}
<i>Chenopodium album</i>	3.08 ± 0.12 ^g	33.81 ± 5.78 ^c	5.65 ± 1.31 ^{cdt}	0.28 ± 0.12 ^a	12.9 ± 2.30 ^d	85.73 ± 9.45 ^{abde}
<i>Hypochoeris radicata</i>	1.03 ± 0.06 ^{aef}	0.76 ± 0.34 ^a	1.25 ± 0.25 ^{abce}	5.20 ± 0.23 ^a	0.72 ± 0.25 ^a	48.5 ± 7.26 ^{ce}
<i>Lactuca serriola</i>	1.68 ± 0.05 ^h	3.25 ± 1.28 ^a	1.08 ± 0.12 ^{abce}	11.4 ± 0.26 ^e	2.63 ± 0.72 ^{ac}	21.2 ± 5.25 ^{ce}
<i>Rorippa nudiscula</i>	1.19 ± 0.09 ^{acef}	45.30 ± 1.65 ^d	4.75 ± 0.16 ^{acdf}	21.08 ± 0.85 ^{bd}	3.91 ± 1.25 ^{ac}	52.4 ± 10.53 ^{ce}

Means with the same letter do not differ statistically at the same level of $p < 0.05$ for each parameter

The zinc (Zn) content of the wild vegetables in this study was low, except for *Chenopodium album*, which had a content of 12.9 ± 2.30 mg/100 g FW, which is 117.3% of the RDA [55]. Zinc as an essential micronutrient is involved in a multitude of fundamental biochemical functions in cells of the human body. It is a cofactor for many enzymes, influences normal growth, reproductive development and the immune system [62]. The biosynthesis, structural integrity and repair of nucleic acids require Zn. Consequently, Zn deficiency is expressed in retarded growth in almost all biological systems and impaired function of the immune system [63]. The results of this study showed that the Zn content of *Chenopodium album* meant it could be a good source of the micronutrient. *Rorripa nudiscula* and *Lactuta serriola* with Zn content of 35.6% and 23.9% of the RDA could be a good source to supplement the micronutrient in the diet.

Selenium (Se) is one of the biologically active micronutrients determined in the study. The Se content of the vegetables is shown in Table 3. The Se content was moderate in *Lactuta serriola*, *Amaranthus spinosus*, *Amaranthus thunbergii* and *Rorripa nudiscula* Se with values 11.4 ± 0.26 , 18.7 ± 2.54 , 20.50 ± 5.20 and $21.08 \pm 5.0.8$ mg/100 g FW respectively, which correspond to 20.75, 33.7%, 37.3% and 38.3% respectively of the RDA [64]. Se is reported to be involved in the regulation of a variety of cellular functions in the human body [65]. Some organic compounds of Se may act against toxicity of heavy metals and protect against cancers and viral infections and act as an antioxidant [66]. The deficiency of Se might make individuals liable to certain diseases due to a host of biochemical changes in cells of the body. These wild vegetables, *Lactuta serriola*, *Amaranthus thunbergii* and *Rorripa nudiscula* could be a readily available and cheap source of plant-based Se and other micronutrients for the rural communities, where animal-based sources of Se are usually unaffordable to the majority of households [58]. Moreover, the *Amaranthus* species are reported to show resistance to heat, drought, plant diseases and pests [67] and are adaptable to varying environmental conditions.

The vitamin C content of the vegetables varied within a wide range 19.2 ± 5.25 mg/100 g FW and 145.2 ± 20.142 mg/100 g FW. The *Amaranthus* species had the highest vitamin C content in the range 45.6 ± 2.84 mg/100 g FW and 145.2 ± 20.14 mg/100 g FW, which are comparable to values reported elsewhere [68]. The vitamin C content

of the *Amaranthus* species and *Chenopodium album* was higher than 100% of the RDA [64]. Vitamin C plays an important role in many cellular and physiological processes in the human body. Some of its functions include the maintenance of the immune system [69,70], synthesis of collagen [71], wound healing [72,73], repair and maintenance of cartilage, bones, and teeth, aids in the absorption of iron [74] and enhances its antioxidant activity thereby protecting from diseases such as scurvy, cancer, cardiovascular diseases, common cold, age-related muscular degeneration and cataracts [75]. The results show that the *Amaranthus* species and *Chenopodium album* could be good sources of vitamin C and daily consumption of a 100-grammes serving of these vegetables could satisfy the daily requirement of vitamin C.

4. CONCLUSION

The significant findings of this study were that the wild vegetables were rich in the essential macronutrients Ca, Mg, P, Na, and K and the micronutrients Cu, Fe, Mn, Se, Zn and vitamin C. The Na-to-K ratio of 0.018 to 0.126, suggests that these vegetables could be excellent alternative dietary source of balanced Na and K for hypertensive patients. The vegetables have a high nutritional potential and could contribute in a major way to balanced diets of rural households to alleviate the chronic micronutrient deficiencies among rural communities, and especially among children. The data cannot be generalized to a broader population of species, because collection of the vegetable samples was limited to a small area in the Roma Valley and the sample size was not large enough.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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