Heliyon 9 (2023) e16541

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Nutritional composition of some wild edible plants consumed in Southwest Ethiopia

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ARTICLE INFO

Keywords:
Anti-nutritional content
Mineral analysis
Nutrient composition
Wild edible plants

ABSTRACT

Wild Edible Plants (WEPs), namely Chaw (*Solanum nigrum* L.), Shutamodoroy (*Vigna membranacea* A. Rich), Entut (*Dioscorea praehensilis* Benth.), Gagut (*Trilepisium madagascariense* D.C.), and Tikawoch (*Cleome gynandra* L.), are naturally grown WEPs and are consumed by the Meinit cultural community in the Bench Maji zone of southwest Ethiopia. However, their nutritional and anti-nutritional compositions of these WEPs have not been documented. In this regard, the proximate, mineral and anti-nutrient contents of the edible portions of these WEPs were analyzed using standard food analysis methods. The nutritional analysis revealed that the WEPs contain valuable nutrients in the following ranges: protein (4.0–21.7%), fat (0.7–6.1%), fiber (8.9–22.3%), carbohydrates (38.1–83%) and energy (275–371.1 kcal/100 g). These WEPs were also rich in macro and micro minerals such as calcium (3.7–594.8 mg/100 g), potassium (440.6–1487.8 mg/100 g), sodium (174.9–277.4 mg/100 g), magnesium (68.2–588.1 mg/100 g), iron (0.8–38.5 mg/100 g), zinc (2.4–5.9 mg/100 g) and copper (0.1–0.5 mg/100 g). The phytate, condensed tannin, and oxalate content of WEPs varied from 8.6 to 307.3 mg/100 g, 5.8–329.0 mg/100 g, and 43.7–443.9 mg/100 g, respectively. The result indicated that these WEPs are rich sources of nutrients that could help combat nutrient deficiencies, particularly in rural communities. The results of this study can be used as baseline information for the nutraceuticals industry and community-based nutrition practitioners.

1. Introduction

Food and nutrition insecurity has been a major challenge in sub-Saharan Africa due to climate extremes, economic downturns, conflict and multiple causes [1]. In addition, few crops are considered dietary habits; as a result, protein, vitamin A and micronutrient deficiencies are widespread in the region [2–6].

Diet diversification and the search for alternative food sources have been recommended to combat food insecurity and malnutrition. Recently, the nutrient content of wild edible plants (WEPs) has been intensively studied to ensure food security and dietary diversity because they are readily available, cheap, grow without agricultural inputs such as fertilizer, are drought tolerant and pest resistant [4,7]. WFPs have the potential, through diversification, to make global food production more sustainable and resilient [8]. WEPs supplement the staple diet, which is high in fiber, carbohydrates, iron, zinc, calcium, potassium, and vitamins C and A [9,10].

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https://doi.org/10.1016/j.heliyon.2023.e16541
Received 6 September 2022; Received in revised form 30 April 2023; Accepted 19 May 2023
Available online 23 May 2023

Some WEPs are also a good source of fat and protein and have appealing dietary and medicinal potential for adulthood illness and other conditions [9,11,12].

Although WEPs are rich in many macro- and micronutrients, comparable to or greater than cultivated crops [13], their nutritional and anti-nutritional compositions of these foods are overlooked by researchers. Few studies have been conducted on analyzes of nutritional and anti-nutritional factors of semi-wild or WEPs grown in Ethiopia [14–17]. Therefore, more effort is needed to study the nutritional, anti-nutritional, and other compositions of these lesser-known WEPs. Therefore, this study aimed to assess the diet quality of some WEPs, namely *Solanum nigrum* L., *Vigna membranacea* A. Rich., *Dioscorea praehensilis* Benth., *Trilepisium madagascariense* D.C., and *Cleome gynandra* L. grown and consumed in Bench Maji zone, southwest Ethiopia.

2. Materials and methods

2.1. Study site and plant specimen collection

A total of sixty-six edible wild plants have been documented and mainly these WEPs have been used for food and medicine by the Meinit society in the Bench Maji zone, southwest Ethiopia. The plant species were identified and authenticated by Mr. Melaku Wendafrash from the Department of Botany, Addis Ababa University, Ethiopia. Specimens were prepared and deposited in the National Herbarium of Addis Ababa University, Ethiopia. From the documented WEPs, five commonly used WEPs were selected for further food quality analysis. *Solanum nigrum* L., *Vigna membranacea* A. Rich., *Dioscorea praehensilis* Benth., *Trilepisium madagascariense* D.C. and *Cleome gynandra* L. were collected from Guraferda, Meinit Goldiye and Meinit Shasha districts in the Bench-Maji zone of southwest Ethiopia. Images of these five WEPs are shown in Fig. 1.

2.2. Plant sample collection and preparation

The selection and collection of edible plant samples for chemical analysis was performed as suggested by Ref. [18]. Edible parts, e.g., *S. nigrum* (leaves), *V. membranacea* (leaves), *D. praehensilis* (tubers), *T. madagascariense* (fruits), and *C. gynandra* (leaves) were collected from the wild for proximate, mineral, and anti-nutritional analyses. At least 2 kg of each sample was collected from more than ten randomly selected plants that reached the optimal stage of maturity. Samples were collected from each plant species to prepare a pooled sample for individual plant.

The plant samples were packed in an ice box with a sample in a plastic bag and immediately transported to the Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) Post-harvest Laboratory. In addition, the seed samples of *C. gynandra* were brought from Guraferda District and grown at the JUCAVM Horticultural Farm. After four weeks of planting, the mature edible fresh leaves of *C. gynandra* were harvested before flowering was set.

Each plant sample was trimmed, cleaned and washed with distilled water to remove foreign matter. Then samples were blotted dry to remove excess surface moisture. Then, *D. praehensilis* tuber samples were cut into small pieces and the outer skin of *T. madagascariense* fruits was removed manually. The prepared samples were dried using drying ovens (DHG-9203 A, Shanghai, China) maintained at 45 °C for 18 h [18]. The dried samples were pulverized with a laboratory grinder (RRH-200, Zhejiang, China) and sieved with a sieve size of 0.5 mm. Finally, the powdered samples were packed in a zip-lock plastic bag and stored at −18 °C until needed for chemical analysis. All experiments were performed in triplicate.

2.3. Proximate analysis

2.3.1. Moisture content determination

Moisture content was determined by the oven drying method as described by Ref. [19] method 925.10. An empty drying box was oven dried at 105 °C for 1 h, cooled in a desiccator and weighed (W_1). Briefly, a 1 g sample of flour was weighed and placed in a pre-cleaned and weighed drying box (W_2). Then the drying box with the sample was placed in an oven dryer (DHG-9203 A, Shanghai, China) and allowed to dry at 105 °C until a constant weight was reached, cooled in a desiccator and finally weighed (W_3). The weight

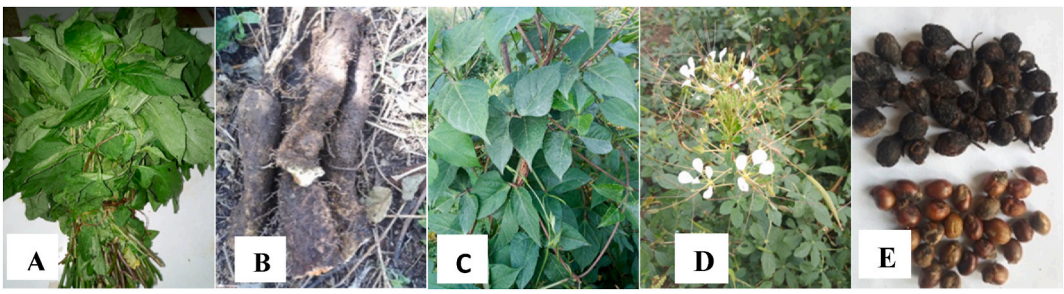

Fig. 1. Wild edible plant species used for the present investigation: (**A**) *Solanum nigrum*, (**B**) *Dioscorea praehensilis*, (**C**) *Vigna membranacea*, (**D**) *Cleome gynandra*, and (**E**) *Trilepisium madagascariense*.

loss after drying was determined as a percentage of the moisture content using in Equation (1).

$$\text{Moisture content}(\%) = \left(\frac{W_2 - W_3}{W_2 - W_1}\right) \times 100 \quad (1)$$

Where: W_1 = weight of empty drying box, W_2 = weight of sample and drying box, W_3 = weight of sample with contents after drying.

2.3.2. Ash determination

Ash was determined by igniting the samples in a muffle furnace according to Ref. [19] method 923.03. Washed and dried crucibles were weighed correctly (W_1). Briefly, 2 g of the sample was weighed and placed on each crucible (W_3). The samples were burned and ignited in a muffle furnace (Nabertherm, D-6072 Dreieich, Germany) at 550 °C for 4 h until the grey-white color of the sample developed. Then the sample was cooled in a desiccator for about 1 h and immediately weighed (W_2). Ash was then determined using in Equation (2).

$$\text{Ash}(\%) = \left(\frac{W_2 - W_1}{W_3}\right) x100 \quad (2)$$

Where: W_1 is the weight of the crucible, W_2 is the weight of the sample and crucible after drying, and W_3 is the weight of the sample in dry weight basis (db).

2.3.3. Crude fat determination

The crude fat was determined using Soxhlet extraction (SZC-D Manual Fat Soxhlet Fat Analyzer, Zhejiang, China) by gravimetric method [19] method 920.85. Briefly, a 1 g sample was weighed (Ws) and placed in a previously cleaned and weighed aluminum beaker. Petroleum ether was added as a solvent in a 1:10 ratio (sample to solvent) into the aluminum cup through the condenser and the sample was degreased at 120 °C for 8 h. Degreased samples were dried in an oven at 92 °C for 30 min to remove petroleum ether residues and the samples were cooled in a desiccator and then weighed (Wf). The crude fat content was determined using in Equation (3).

$$\text{Crude fat}(\%) = \left(\frac{Wf}{Ws}\right) x100 \quad (3)$$

Where: weight of fat, Wf = weight of aluminum cup after extraction - weight of aluminum cup before extraction, Ws = weight of samples (db).

2.3.4. Crude protein determination

The protein content was determined according to Ref. [19] method 920.87 with an automated Kjeldahl device (UDK 159, VELP Scientifica, Nemko, USA, Italy). Briefly, 1 g of the sample was carefully measured with a digital scale and placed in a digestion tube. Five grams of K_2SO_4 and 2 g of $CuSO_4$ catalysts were carefully weighed using an electronic balance and added to each digestion tube containing the sample. Accordingly, 25 mL of H_2SO_4 was poured into each digester tube containing the sample and catalyst solution. The sample solution was digested at 420 °C for 2 h, cooled to ambient temperature in the digester and formed an ammonium sulfate solution. After the sample had cooled, the digestion tube was inserted into the distillation and titration unit. The sample solution was treated with NaOH and boiled to convert NH_4 to NH_3. Then, ammonia in the sample was trapped in a 4% boric acid solution containing 7 mL of methyl red and 10 mL of bromocresol green, and the instrument was automatically titrated with 0.2 N HCl. After the distillation and titration process, the instrument displayed the total amount of nitrogen and a conversion factor of 6.25 was used.

2.3.5. Crude fiber determination

The crude fiber was analyzed gravimetrically using the modified Weende [19] method 985.29 with a fiber analyzer (SLQ-6A, Shanghai, China). Briefly, a 0.5 g sample was weighed with an analytical balance (W_3). The sample was boiled in 1.25% H_2SO_4 in a beaker for 30 min and then hydrolyzed for another 30 min with 1.25% NaOH. The sample was rinsed with hot water and acetone and dried at105 °C for 1 h until a constant weight was obtained, which was later cooled in a desiccator and weighed (W_1). The sample residue was re-ignited in a muffle furnace kept at 55 °C for 3 h and then cooled in a desiccator and weighed again (W_2). The crude fiber content was determined using in Equation (4).

$$\text{Crude fiber}(\%) = \left(\frac{W_1 - W_2}{W_3}\right) \times 100 \quad (4)$$

Where: W_1 = crucible weight before drying, W_2 = crucible weight after drying, W_3 = sample weight (db).

2.3.6. Carbohydrate determination

The carbohydrate (%) was determined by subtracting the sum of ash, crude fat, crude fiber and crude protein values from 100.

2.3.7. Energy content calculation

The calorific value (kcal/100 g sample) was calculated using the Atwater factors of 9*x* for crude fat and 4*x* for crude protein and

total carbohydrate.

2.4. Mineral analysis

A dry ashing method was used for mineral analysis. Briefly, 3 g of the WEPs flour was weighed and dried in an oven at 105 °C overnight and cooled to room temperature in a desiccator. The dried sample was burned in a muffle furnace (Nabertherm, D-6072 Dreieich, Germany) at 450 °C for 4 h. The sample was allowed to cool in the closed oven. The ashed sample was transferred to a 200 mL flask with 20 mL of 20% HNO_3, heated to near boiling on a hot plate for 30 min while stirring intermittently with a glass rod, and allowed to cool. The sample was filtered using Whatman number 42 filter paper and made up to a volume of 100 mL with distilled water. A series of standard solutions containing all elements of interest were prepared. Blank samples for mineral analysis were prepared from distilled water mixed with the reagents under the same conditions as the treated samples. The sample aliquot of minerals was determined by microwave induced plasma atomic emission spectrometry (MP-AES) using plasma nitrogen (N_2) gas. Each mineral element of the sample was measured at the required emission wavelength for calcium (393.366 nm), potassium (766.491 nm), sodium (588.995 nm), magnesium (285.213 nm), iron (371.993 nm), zinc (213.857 nm) and copper (324.754 nm) [20] method 985.35. The respective minerals were then determined using in Equation (5).

$$\text{Mineral concentration}\left(\frac{\text{mg}}{100\text{g}}\right) = \frac{(a-b)\text{xVxD}}{10\text{xW}_s} \tag{5}$$

Where: a = concentration in ppm (mg/L) of sample, b = concentration in ppm of blank solution, V = volume in ml of extract, D = dilution factor (50 mL for Na, K, Ca & Mg), Ws = sample weight in g and 10 = conversion factor.

2.5. Determination of ant-nutritional factors

2.5.1. Phytate determination

The phytate content was determined as described by Ref. [21]. Briefly, 0.1 g of the sample was extracted with 10 mL of 2.4% HCl using a mechanical shaker (Hy-2(C), Shanghai, China) for 1 h at room temperature. The extract was centrifuged at 3000 rpm for 30 min (Sigma 2-16 KC, U.K.). The clear supernatant was used for phytate determination. 1 mL of Wade's reagent (containing 0.03% solution of $FeCl_3$ $6H_2O$ and 0.3% sulfosalicylic acid in water) was added to 3 mL of the sample solution (supernatant) and the mixture was vortexed for 5 s mixed. The absorbance of the sample solutions was measured at 500 nm using a UV-VIS spectrophotometer (721 Visible Spectrophotometer, Shanghai, China).

A series of phytic acid sodium salt standard solutions were prepared containing 0.0, 4.5, 9.0, 18.0, 27.0 and 36.0 g/mL phytic acid (analytical grade sodium phytate) contained in 0.2 N HCl. 1 mL of Wade's reagent was added to each tube and the solution was vortexed for 5 s. The mixtures were centrifuged for 10 min and the absorbance of the standard solutions was measured at 500 nm. Deionized water was used as a blank for the standard solutions and the samples. The phytate content was determined from a standard curve of the sodium salt of phytic acid and the result reported in mg/100 g.

2.5.2. Condensed tannins determination

Condensed tannin content was quantified based on the method described by Ref. [22]. A powdered 1 g sample was measured and mixed with 10 mL of a 1% HCl solution in methanol in a 50 mL falcon tube. The falcon tube containing the sample solution was shaken on a mechanical shaker (Hy-2(C), Shanghai, China) at room temperature for 24 h. The solution was later centrifuged at 1000 rpm for 5 min by a centrifuge machine (Sigma Laborzentrifugen, 2-16 KC, Germany). Then 1.00 mL of the supernatant was transferred to a test tube and diluted with 5 mL of vanillin HCl reagent prepared by mixing an equal volume of 8% concentrated HCl in methanol and 4% vanillin in methanol).

The standard stock solution was prepared from D (+)-catechin by taking 40 mg of D (+)-catechin and mixing it with 100 mL of 1% HCl solution in methanol. A series of standard solutions (0, 12, 24, 36, 48 and 60 g/mL) were prepared using 1% HCl in methanol. After 20 min incubation, the absorbance of the samples and the standard solutions was quantified at 500 nm using a UV-VIS spectrophotometer (721 Visible Spectrophotometer, Shanghai, China). The concentration of the condensed tannin content was determined from a standard curve of catechin and the result was expressed as mg/100 g.

2.5.3. Oxalate determination

Oxalate levels were determined according to Ref. [20] method 974.24. Briefly, 2 g of each sample was mixed with a solution containing 190 mL distilled water and 10 mL 6 M HCl and digested at 100 °C for 1 h. The digested sample was cooled, made up to 250 mL and filtered. About 125 mL of the filtrate was transferred to a beaker and four drops of methyl red indicator were added and mixed. The solution was titrated with concentrated NH_4OH until the test solution changed from salmon pink to a faint yellow color (pH 4 to 4.5). Each portion, containing 125 mL of solution, was then heated to 90 °C, cooled and filtered to remove ferrous ion precipitate.

The filtrate was again heated to 90 °C., and 10 mL of 5% $CaCl_2$ solution were added with constant stirring. After heating and cooling, the filtrate was left standing in a refrigerator (5 °C) overnight. The solution was centrifuged (Sigma laboratory centrifuges, 2-16 KC, Germany) at 2500 rpm for 5 min. The supernatant was decanted and the precipitate was completely dissolved in 10 mL of 20% (v/v) H_2SO_4 solution. The total filtrate resulting from the digestion of 2 g of the sample was made up to 300 mL 125 mL aliquots of the filtrate were heated to near boiling and then titrated with 0.05 M $KMnO_4$ standard solution to a faint pink color which persisted for 30

s. The calcium oxalate content was expressed as calcium oxalate equivalent and calculated using in Equation (6).

$$\text{Oxalate}(\text{mg}/100\text{g}) = \frac{\text{TxV}_{\text{me}}\text{xDFx}10^5}{\text{ME xMF}} \quad (6)$$

Where: T is the $KMnO_4$ titre (ml), Vme is the volume mass equivalent (i.e.1 cm^3 of a 0.05 M $KMnO_4$ solution corresponds to 0.00225 g of anhydrous oxalic acid), DF is the dilution factor (2.4):it is the total volume of the filtrate (300 mL) divided by the aliquot used for the titration (125 mL), ME is the molar equivalent of $KMnO_4$ in oxalate ($KMnO_4$ redox reaction) and MF is the mass of flour used.

2.6. Statistical analysis

Data were analyzed using SAS software (version 9.3 USA). One-way analysis of variance (ANOVA) was used at $p < 0.05$ significant level. Tukey's HSD test was used for mean separation. Mean and standard deviation were used to report the results.

3. Results and discussions

3.1. Limitations of the study

Although this WEPs study was provide nutritional information for consumers, it has some study limitation. The study was conducted in remote area of Bench Maji zone of southwest Ethiopia. It was challenging to cover every spots of study area due to limitation of resource, time, distance and facilities. Collecting samples from these distance areas may affect the final results.

Additionally sample collected from *T. madagascariense* fruit was very difficult to harvest due to *T. madagascariense* fruit is too long to reach the canopy. Thus, fruit samples were collected from the ground similar to the local community mode of collection. This could slightly impact on nutritional composition of the fruit. Moreover, comparison of results within or between the WEPs was challenging due to limited previous studies on nutritional composition of WEPs in the same families, discrepancy in soil, stage of maturity and growing environment.

3.2. Proximate composition of wild edible plants

3.2.1. Moisture content

The moisture content of the WEPs ranged from 77.6 to 95.6% fresh weight and results are presented in Table 1. The lowest fresh moisture content was found in *D. praehensilis* tubers while the highest was in *C. gynandra* leaves. The present result is consistent with previous study results [15,23] which reported that the moisture content of fresh wild vegetables and roots and tubers is between 85 and 95 g/100 g. From a nutritional point of view, a higher moisture content of the fresh WEPs could be essential for the body's physiological functions since 20% of the water source comes from the diet [24,25]. However, the higher moisture content of fresh WEP is favorable for microbial growth and enzymatic activities, which can lead to spoilage of the vegetables [15]. Therefore, it should be dried to increase durability and reduce bulkiness during transportation.

Accordingly, the powder moisture content of WEPs was determined on a dry weight basis and found to range from 5.2 to 7.9% in *D. praehensilis* tuber and *T. madagascariense* fruits, respectively. The results were comparable to the results of [26] in wild *Rumex crispus* leaf (7.57%) and root (7.59%). In contrast, the present study results were lower than the moisture levels of *Eruca sativa* leaves (5.9 g/100 g) and *Raphanus sativus* roots (12.9 g/100 g) [15]. Slightly higher results have also been reported; a moisture content of 8.33% in leaves of *C. conglomeratus* and 12.90% in leaves of *C. capitatus* [27]. The lower moisture content of WEPs might be desirable for powder product shelf stability as it affects microbial growth and enzymatic activity.

3.2.2. Ash content

The highest ash content was observed in leaves of *C. gynandra* (16.4%), while the lowest ash content was recorded in tubers of *D. praehensilis* (3.5%), as presents in Table 1. Comparable results were reported by Ref. [23] who found that the ash content ranged from 8.68 in *Nymphaea stellata* stem to 13.26 g/100 g in *Dryopteris filix-ma* leaves in Bangladesh. The ash content recorded in the

Table 1
Proximate composition (% on a dry basis) of five selected WEPs (mean ± SD).

Edible plant	MC(wb)	MC(db)	Ash	Fat	Protein	Fiber	Carbohydrate	Energy
S. nigrum	88.2 ± 0.5^{b}	6.0 ± 0.6^{b}	14.0 ± 0.4^{b}	4.0 ± 0.6^{b}	21.7 ± 0.9^{a}	22.3 ± 0.4^{a}	38.1 ± 1.2^{e}	275.0 ± 5.9^{c}
V. membranacea	94.3 ± 1.5^{ab}	5.9 ± 0.5^{b}	12.6 ± 0.8^{b}	4.3 ± 0.1^{b}	11.8 ± 1.1^{b}	21.1 ± 0.4^{a}	50.3 ± 1.9^{c}	286.6 ± 5.0^{c}
D.praehensilis	77.6 ± 5.8^{c}	5.2 ± 0.4^{b}	3.5 ± 0.1^{c}	0.7 ± 0.1^{c}	4.0 ± 0.5^{d}	8.9 ± 1.3^{c}	83.0 ± 0.8^{a}	354.1 ± 5.4^{b}
T.madagascariense	93.3 ± 1.8^{ab}	7.9 ± 0.1^{a}	4.9 ± 0.3^{c}	6.1 ± 0.1^{a}	6.3 ± 0.6^{c}	10.1 ± 0.6^{c}	72.6 ± 0.8^{b}	371.1 ± 1.6^{a}
C. gynandra	95.6 ± 0.0^{a}	7.1 ± 0.7^{a}	16.4 ± 0.7^{a}	3.3 ± 0.6^{b}	20.1 ± 0.6^{a}	18.8 ± 0.8^{b}	41.4 ± 0.5^{d}	276.0 ± 4.5^{c}
CV(%)	3.1	7.9	6.8	10.7	6.0	4.6	2.0	1.5
LSD ($p < 0.05$)	5.1	5.1	0.1	0.2	0.6	0.1	3.2	12.7

Values are the mean of three independent measurements; Values within a column followed by different superscripts are significantly different at $p < 0.05$ level; MC stands for moisture content, wb for wet weight basis, and db for dry weight basis.

present study was higher than the finding of [2] who reported from 3% in *D. mespiliformis* fruit to 6.37% in *S. birrea* fruit in Ghana. The total ash content indicates the mineral content of the plant. With this in mind, it could be concluded that the leaf of *C. gynandra* contained a high ash content and this plant could contribute as an excellent dietary mineral source among the plant species studied.

3.2.3. Crude fat content

The crude fat composition of WEPs ranged from 0.7 to 6.1% and results are shown in Table 1. The lowest value was observed in *D. praehensilis* tuber and the highest in *T. madagascariense* fruits. These results are consistent with the content report found at a range of 1.45% in wild *Nymphaea stellata* and 4.76% in *Corchorus capsularis* [23]. In contrast, the crude fat content of WEPs ranges from 4.25% in *C. album* to 8.5% in *S. nigrum* [28], slightly higher than in the present study.

These differences could mainly depend on the type of plant organ used, the stage of maturity and the growth environment. Fat provides the energy content of food and fat contribute to the body's physiological processes such as digestion, absorption and transport of fat-soluble vitamins. Among the plants studied, the fruit of *T. madagascariense* had the richest fat content that could be used as an ingredient in the preparation of high-energy food products. In contrast, the low fat content observed in the *D. praehensilis* tuber implied that the tuber might help reduce cardiovascular disease and obesity.

3.2.4. Crude fiber content

The mean result of the crude fiber content of WEP was between 8.9 and 22.3%. *D. praehensilis* tubers had the lowest value while *S. nigrum* leaves had the highest value, values are shown in Table 1. Similar results were obtained by Ref. [28] who reported 11.08% in leaves of *U. urens* to 18.08% in *S. nigrum* leaf in South Africa. Comparable results were also reported by Ref. [23] who found between 9.26% and 17.70%, lowest in *Ipomoea aquatica* leaf and highest in *Dryopteris filix-mas* leaf, respectively, in the fiber value of WEPs.

In contrast to the present study [29], that the fiber content ranges from 0.9% in *P. oleracea* to 7.8% in *C. juncea* in north-eastern Portugal. Crude fiber indicates the content of indigestible carbohydrates and lignin in plant tissue. These results imply that the WEPs studied represent a slightly higher source of dietary fiber content. These high-fiber could have health benefits such as the reduction of constipation, obesity and colon cancer.

3.2.5. Crude protein content

The obtained crude protein content of WEPs ranges from 4 to 21.7% as shown in Table 1. Among the WEPs, the highest total protein was obtained in *S. nigrum* leaves, while the lowest protein was observed in *D. praehensilis* tuber. The protein content of these WEPs was consistent with a previous study by Ref. [30] who reported a protein content of 17.1–20.1 g/100 g in *Rumex vesicarius* leaves. Another study by Ref. [10] also reported 7.03% in the root of *Achyranthes aspera* and 21.56% in the leaves of *Eclipta alba*. The protein content present was lower than reported by Ref. [31], 17.18% for *Amaranthus thunbergii* to 24.4% for *Rumex patientia*, and [14] also reported a range from 5.8% for *Gombozianus* to 36.3% for *C. grandis*.

These discrepancies in protein value are due to differences in plant species, climate and soil type, analytical methods and plant parts used. Plant foods contain incomplete protein. Surprisingly, the collected wild vegetables were usually consumed by blending cooked legumes or other locally available vegetables, in which this dietary habit may improve protein quality. Among WEPs, *S. nigrum* leaves contained high levels of crude protein, followed by *V. membranacea* leaves, and these two wilds green plants may contribute to combat protein deficiency diseases in rural communities.

3.2.6. Carbohydrate and energy value

The useable carbohydrate content of WEPs varied from 38.1% in *S. nigrum* leaves to 83.0% in *D. praehensilis* tuber in Table 1. The highest carbohydrate value was obtained in *D. praehensilis* tuber, followed by *T. madagascariense* fruit. These significant variations between the plants studied could result from different compositions in crude fat, crude fiber and other similar compositions. Comparable results were recorded by Ref. [16], who found that carbohydrate content of WEPs falls between 30.7 g/100 g in *Celosia argentea* and 60.5 g/100 g in *Pachycymbium laticoronum* in northeastern Ethiopia. These results also comparable to the report by Ref. [10], the carbohydrate content obtained ranged from 36.21 in *Eclipta alba* leaves to 65.54 g/100 g in *Vitex negundo* tuber.

The mean gross energy value of the present study was recorded ranging from 275.0 in *S. nigrum* leaves to 371.1 kcal/100 g in

Table 2
Mineral composition of wild edible plant in mg/100 g (dry weight basis).

Wild edible plant	Macro-minerals				Micro-minerals		
	Sodium	Potassium	Calcium	Magnesium	Iron	Zinc	Copper
S. nigrum	272.1 ± 0.6^{a}	1429.9 ± 14.9^{a}	241.1 ± 4.0^{c}	207.3 ± 2.6^{d}	26.9 ± 13.1^{ba}	3.7 ± 0.0^{d}	0.38 ± 0.0^{ba}
V. membranace	174.9 ± 51.5^{b}	802.4 ± 83.0^{c}	322.8 ± 13.6^{b}	324.9 ± 12.9^{c}	38.5 ± 0.2^{a}	3.9 ± 0.0^{c}	0.5 ± 0.3^{a}
D.praehensilis	207.6 ± 2.9^{b}	440.6 ± 13.9^{d}	3.7 ± 0.6^{e}	68.2 ± 5.1^{e}	3.4 ± 0.1^{c}	5.9 ± 0.0^{a}	0.1 ± 0.0^{b}
T. madagascariense	221.0 ± 11.7^{ba}	1185.8 ± 1.4^{b}	57.4 ± 2.3^{d}	374.7 ± 7.8^{b}	0.8 ± 0.0^{c}	2.4 ± 0.1^{e}	0.1 ± 0.0^{b}
C. gynandra	277.4 ± 2.8^{a}	1487.8 ± 123.0^{a}	594.8 ± 32.9^{a}	588.1 ± 12.5^{a}	21.7 ± 2.0^{b}	5.5 ± 0.04^{b}	0.1 ± 0.0^{b}
CV(%)	10.3	6.3	6.6	2.9	32.4	0.9	58.6
LSD ($p < 0.05$)	63.7	180.0	43.1	24.6	15.9	0.1	0.3

Values are the mean of three independent measurements S.D.; Values within a column followed by different superscripts differ significantly at a $p < 0.05$ level.

T. madagascariense fruit (Table 1). Similar work was also done by Ref. [15] found in the energy content of WEPs between 237 in leaves of *Raphanus sativus* and 376 kcal/100 g in seeds of *Hibiscus sabdariffa*. However, the current study results were lower than the results of [32], which reported energy content in the range of 364–427.23 kcal/100 g and higher than the report of [33] who found between 256.14 and 302.39 kcal/100 g energy content of the WEPs.

In general, a relatively high amount of energy observed in the five WEPs studied implies a good source of food composition. In this sense, the studied WEPs could contribute to combating protein-energy malnutrition in rural communities and elsewhere among users of these WEPs.

3.3. Mineral composition of wild edible plant

The mineral analysis of calcium, potassium, sodium, magnesium, iron, zinc and copper of five wild edible plants is presented in Table 2. Analysis of variance revealed a significant difference ($p < 0.05$) between five WEPs in all mineral analyses.

3.3.1. Calcium (Ca)

The mean calcium content ranged from 3.7 to 594.8 mg/100 g, with the lowest value observed in the *D. praehensilis* tuber and the highest in the leaves of *C. gynandra* in Table 2. These values were consistent with the results of [34] reported in *Solanum retroflexum* Dun (199 mg/100 g) and *Amaranthus cruentus* (443 mg/100 g). In contrast, the present result was much lower than the report by Ref. [28] in the leaves of *Chenopodium album* (2172 mg/100 g) and *Urtica urens* (12,262 mg/100 g). These fluctuations in the calcium content could be attributed to different soil types, plant species and the stage of maturity of the plants. Calcium contributes to bone health, osteoporosis, and muscle and tooth strength [35].

3.3.2. Potassium (K)

The highest mean potassium value was found in *C. gynandra* leaves, 1487.8 mg/100 g, followed by *S. nigrum* leaves, 1429.9 mg/100 g, while the lowest value was recorded in the tuber of *D. praehensilis* tuber, 440.6 mg/100 g, as shown in Table 2. These values were comparable to those reported by Ref. [36] who found that 1280 mg/100 g of potassium content in leaves of *Astraeus hygrometricus*.

The potassium level reported in this study was consistent with that reported by Ref. [13] in *Malva Neglecta* leaves of 1415.7 mg/100 g and 440.07 mg/100 g in *Ceropegia hirsute* tuber [37]. However, this study result was lower than *Rumex vesicarius* leaves (2950 mg/100 g in db) reported by Ref. [30]. Although many studies report the associated risk of stroke when the Na/K ratio is more significant than one, the result obtained for potassium was higher than that for sodium.

This result confirmed that the consumption of these WEPs is in the safe range ($Na/K < 1$), with negligible risk of adult diseases such as stroke and blood pressure [38]. Increased dietary potassium intake lowers blood pressure, while reduced potassium intake increases blood pressure in animals and humans.

3.3.3. Sodium (Na)

The highest sodium content of WEPs was found in *C. gynandra* leaves (277.4 mg/100 g), while the lowest was found in *V. membranacea* leaves (174.9 mg/100 g) in Table 2. The results were consistent with the study by Ref. [29] who reported 244 mg/100 g in the young stem of *Apium nodiflorum* with leaves and 125 mg/100 g in the leaf of *Sonchus oleraceus*. However, the mean of *C. gynandra* (277.42 mg/100 g) was significantly lower than in *Rumex vesicarius* leaf (1010 mg/100 g) reported by Ref. [30], while the value of this study was higher than in *Raphanus sativus* (67.5 mg/100 g) reported by Ref. [15] was reported.

Sodium is important for regulating blood pressure and fluid balance in the body. Consuming high levels of Na above the tolerable upper intake (2300 mg/day) may be associated with hypertension. The recommended daily allowance (RDA) for sodium is 1000–2300 mg/day [39] and the WEPs studied were below the recommended values. The WEPs studied may not cause hypertension because they contain negligible levels of sodium compared to the RDA.

3.3.4. Magnesium (Mg)

The magnesium content of the analyzed WEPs ranged from 68.2 mg/100 g in *D. praehensilis* tubers to 588.1 mg/100 g in *C. gynandra* leaves in Table 2. Study results were consistent with those reported for 57.38 mg/100 g in *Enhydra fluctuans* and 315.21 mg/100 g in *Corchoruscapsularis* leaves [23]. Similarly, magnesium levels in *C. gynandra* were comparable to previous reports by Ref. [28] who reported that magnesium levels in *S. nigrum* leaves were 667 mg/100 g. However, our results were higher than those reported for *Solanum retroflexum* (92 mg/100 g) and *C. gynandra* (76 mg/100 g) [34]. Magnesium is required for heart and nerve function, most energy metabolism reactions, and protein synthesis [40]. The RDA value of Mg from nine to fifty years is 240–420 mg/day [39]. For example, the *C. gynandra* leaf contains a slightly higher amount of magnesium compared to the RDA value. In addition, *V. membranacea* leaves and *T. madagascariense* fruits in one serving meet RDA-Mg requirements.

3.3.5. Iron (Fe)

The iron value varied greatly between the five WEPs examined in Table 2. The leaves of *V. membranacea* contained the highest iron content (38.5 mg/100 g), while the fruits of *T. madagascariense* had the lowest (0.8 mg/100 g). This highest Fe value was consistent with those of [30] who reported 36.2 mg/100 g in the *Rumex vesicarius* leaf and comparably favorable values from 3.59 in the *Nymphaea stellata* leaf to 73.54 in the *Corchorus capsularis* leaf [23].

Iron is a vital nutrient for hemoglobin formation, proper central nervous system function, and fat, protein, and carbohydrate metabolism. Anemia is linked to iron deficiency, which is a critical health problem worldwide. According to Ref. [39], the RDA of iron

for adult males (8 mg), adult females (18 mg), pregnant (27 mg), and lactating females (9 mg), respectively, are required in daily meals. As a result, *V. membranacea* leaves appeared to be a rich source of iron and met the RDA for all groups.

3.3.6. Zinc (Zn)

Zinc levels were relatively high in *D. praehensilis* tubers (5.9 mg/100 g) and *C. gynandra* leaves (5.5 mg/100 g), while the lowest Zn levels were in *T. madagascariense* fruits (2.4 mg/100 g) was found in Table 2. Zn levels were consistent with [28], from 4.2 mg/100 g in *Solanum nigrum* to 5.5 mg/100 g in *Urtica urens*. In our study, zinc levels were higher than in the previous studies by Ref. [41] who reported 0.26 mg/100 g in *Amaranthus dubius* to 0.80 mg/100 g in *Lomariopsis guineensis*.

Zinc plays an important role in proper growth and mental function, boosting the immune system, sexual development and normal heart health. The RDA value of Zn is 11 mg for an adult male, 8 mg for an adult female, 11 mg for pregnant females and 12 mg/day for lactating females [39]. Two servings of *D. praehensilis* tuber diet can meet the RDA requirement for Zn for a healthy individual. Therefore, increasing the frequency of administration of these WEPs from two to three per day can prevent Zn deficiency.

3.3.7. Copper (Cu)

Our result for Cu ranged from 0.1 mg/100 g in *T. madagascariense* fruits to 0.5 mg/100 g in *V. membranacea* leaves as results are shown in Table 2. The Cu content in this study was similar to that reported by Ref. [23] with 0.61 mg/100 g in *Ipomoea aquatica* and 0.15 mg/100 g in *Corchorus capsularis*, but lower than *Amaranthus viridus* (300 mg/100 g) in South Waziristan Agency of Pakistan and *Chenopodium murale* (21mg/100 g) from the northwestern region of Pakistan [4]. Copper is a critical enzyme cofactor in the electron transport chain and hemoglobin formation [42]. The RDA value of Cu is 0.9 mg for adult males and females [39]. The Cu level in this study was slightly lower compared to the RDA values for pregnant (1 mg/day) and lactating women (1.3 mg/day). Thus, two servings of dietary nutrition of *V. membranacea* can meet the adult RDA of Cu.

3.4. Anti-nutritional factors of wild edible plants

3.4.1. Phytate

In this study, the mean phytate content varied from 8.6 in *D. praehensilis* tubers to 307.3 mg/100 g in *C. gynandra* leaves, as reported in Table 3. These results were lower than the results of [43] who reported phytate levels of 520–3290 mg/100 g in pumpkin leaves and *Amaranthus flavus* leaves, respectively. However, our result was higher than the phytate content from 17.25 in *V. unguiculata* to 86.45 in mg/100 g in *H. sabdariffa* [44].

Phytic acid (negatively charged structure) and its associated salts such as magnesium, potassium and calcium salts are collectively referred to as phytate and are stored primarily as phosphorus in mature seeds, vegetables, fruits, starchy roots and tubers [45]. The phytate compound inhibits polyvalent metal ions (positively charged metals) such as iron, zinc, magnesium, potassium, copper and calcium, reducing their bioavailability [44–46].

Relatively lower phytate levels were found at 8.60 mg/100 g in the *D. praehensilis* tuber and 65 mg/100 g in the *T. madagascariense* fruit, suggesting that these WEPs may exhibit less inhibitory effect to mineral bioavailability. Interestingly, all WEPs studied that are consumed in boiled and fried form can decrease the anti-nutritional effects.

3.4.2. Condensed tannin

This study found the highest condensed tannin in leaves of *C. gynandra* (329.0 mg/100 g), while the lowest was found in *D. praehensilis* tuber (5.8 mg/100 g), as shown in Table 3. This variation could be related to genetic variability, phonological period and environmental factors. These results were higher than previously reported values of 30–70 mg/100 g for various wild yams (*Dioscorea* spp.) reported by Ref. [47] and significantly lower than the values of 413 in *Panicum turgidum* to 2610 mg/100 g in aerial parts of *Cyperus conglomeratus* reported by Ref. [27]. Furthermore [48], said that condensed tannin in date fruit varieties ranges from 82.81 to 525.06 mg/100 g. The results were compared to the reported value, which ranges from 13 to 346.3 mg/100 g in brown-red calyces of *Hibiscus sabdariffa* [15].

Tannins are secondary metabolites from plant bark, fruits, roots and leaves [49]. These condensed tannin molecules chelate metals such as Fe and Zn, reducing the bioavailability of these micronutrients. It also inhibits the activity of digestive enzymes and can precipitate proteins [50]. Although the results of this study showed high levels of condensed tannin, these WEPs were consumed

Table 3
The phytate, condensed tannin, and total oxalate contents of wild edible plants in mg/100 g.

Wild edible plant	Phytate	Condensed Tannin	Total oxalate
S. nigrum	233.3 ± 83.7^{a}	260.8 ± 0.6^{b}	443.9 ± 10.9^{a}
V. membranacea	175.6 ± 32.9^{b}	142.7 ± 1.3^{c}	307.3 ± 70.9^{b}
D. praehensilis	8.6 ± 0.9^{d}	5.8 ± 0.6^{e}	64.6 ± 37.6^{d}
T. madagascariense	65.5 ± 10.5^{c}	28.9 ± 0.1^{d}	43.7 ± 0.7^{d}
C. gynandra	307.3 ± 70.9^{a}	329.0 ± 2.6^{a}	205.0 ± 11.1^{c}
CV (%)	32.5	0.5	17.1
LSD ($p < 0.05$)	93.5	2.1	66.5

Values are the mean of three independent measurements S.D.; Values within a column followed by different superscripts differ significantly at a $p < 0.05$ level.

exclusively in boiled or fried form, which may reduce the anti-nutritional effects of tannin.

3.4.3. Total oxalate

The total oxalate content of WEPs varied from 43.7 in *T. madagascariense* fruits to 443.9 mg/100 g in *S. nigrum* leaves. Oxalate levels obtained in the present study were lower than in cultivated vegetables, ranging from 189.12 mg in *Lactuca sativa* lettuce to 630.4 mg/100 g in *Abelmoschus esculentus* okra [51]. However, it was slightly higher than that reported by Ref. [52] reported total oxalates from 14.34 in *Berberis lycium* to 362.66 mg/100 g in *Nasturtium officinale*. The value of the present study was comparable to the report by Ref. [53] for total oxalate 161.28 mg/100 g in *Goldbachia laevigata* to 200.08 mg/100 g) in *Melilotus officinalis*, and 46 in *Gleichenia linearis* to 356 mg/100 g in *Bauhinia purpurea* [54].

A salt formed from oxalic acid is known as an oxalate; soluble salts are absorbed by the body and form strong chelates with dietary calcium, inhibiting its absorption; at higher doses consumed, it causes calcium deficiency diseases such as osteomalacia, rickets and kidney stones [55]. The values obtained in the present study were lower than the lethal dose of 450 mg/100 g oxalate [38]. Thus, the study results are a safe zone for consumption, and traditional cooking methods of these edible plants could also reduce the effects of oxalic acid.

4. Conclusions and recommendations

This work shows that the studied WEPs can make a significant contribution to a dietary nutrient for subsistence farmers in the rural community. Among them, the leaves of *V. membranacea*, the tuber of *D. praehensilis* and the fruits of *T. madagascariense* were rich sources of energy. *Cleome gynandra* leaves contain the highest mineral composition compared to the other WEPs, while *D. praehensilis* tuber contains the lowest anti-nutritional factors. In addition, *T. madagascariense* fruits, *V. membranacea* leaves and *D. praehensilis* tubers are observed to have good fat, iron and zinc contents, respectively. As a result, they could serve as a good and inexpensive source of diet diversification and help combat micronutrient deficiencies in rural communities.

In addition, the *S. nigrum* leaf sample contains a significant nutritional composition, particularly protein, dietary fiber, calcium, iron and zinc. Therefore, *S. nigrum* leaves could be a candidate as a green vegetable to support food and nutrition security in southwest Ethiopia or elsewhere. Sustainable conservation practices and production of these studied WEPs is recommended. Future experiment should focus on anti-bacterial and anticancer effects of these plants.

Author contribution statement

Abebe Yimer Tadesse: Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Sirawdink Fikreyesus Forsido, Getachew Addis: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Abebe Ayelign: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data will be made available on request.

Ethical approval

This study does not involve any human or animal testing.

Declaration of competing interest

The authors declare that they have no conflict of interest.

Acknowledgments

The authors thank Jimma University, College of Agriculture and Veterinary Medicine (JUCAVM) for financial support. Likewise, the authors acknowledge the Ethiopian Food and Drug Administration for allowing us to use the laboratory facilities.

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