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Biochemical composition and antioxidant activity of three wild edible plants from Soro District of Hadiya Zone, Ethiopia

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ABSTRACT

In Ethiopia, wild edible plants (WEPs) are widely consumed. Despite the extensive usage of WEPs in Ethiopia, there have been few investigations on their nutritional composition.This study aimed to investigate the biochemical composition and antioxidants of the most commonly consumed three WEPs, *Amaranthus tortuosus, Landolphia buchananii*, and *Oncoba spinosa* in Soro District, Ethiopia. The proximate, mineral, vitamin C, and oxalate of them were determined using the method by AOAC. Anti-nutrients, total phenolic and flavonoids, and antioxidant capacity of the WEPs using standard spectroscopic methods. The highest crude protein content (38 g/ 100 g) was observed in *Amaranthus tortuosus*. Other nutrients on dry basis of crude fat, crude fiber, utilizable carbohydrate, gross energy, calcium, iron and zinc, vitamin C were resulted., including anti-nutrients of phytate, oxalate and tannin. *O. spinosa* has higher anti-nutrient content. The highest phenolic, flavonoid, and vitamin C in *L. buchananii* fruit. The *L. buchananii* extract had a comparable IC50 value with ascorbic acid in scavenging 2,2-diphenyl-1-picrylhydrazyl free radical. At 200 μg/ mL, the highest percentage of DPPH inhibition obtained for ascorbic acid. This study indicated, WEPs had more antioxidants than some common popular crops; it suggests that they can be incorporated to make more nutrient-dense and healthy-balanced diets.

1. Introduction

Food and nutrition insecurity is one of the biggest problems the world is experiencing. Globally, approximately two billion people are estimated to suffer from some micronutrient deficiencies (FAO, 2012). The issue of food insecurity is severe in sub-Saharan Africa (FAO, 2011). However, the continent has a highly biodiverse environment with valuable wild edible plants (WEPs), which are often neglected (Chennai Platform for Action, 2006). Wild edible plants are plants with edible parts that grow naturally on wild farmland, non-cultivated, or fallow-land (Duguma, 2020). Different WEPs have played an important function in different geographical regions of the world throughout human history (Duguma, 2020). Traditionally, WEPs have been used for medicinal purposes to treat various ailments (diarrhea, constipation, wounds, cancer, jaundice, heart disease, and diabetes) (Mir, 2014). Additionally, WEPs can be used as supplementary foods to combat malnutrition and provide for food security (Adamu et al., 2022b; Getachew et al., 2013; Lulekal et al., 2011). They have remarkable nutrient value providing a significant source of vitamins, fibers, minerals, and fatty acids (Datta et al., 2019; Getachew et al., 2013; Adedapo et al., 2011; Dansi et al., 2008). The nutritional values of WEPs are comparable to those of cultivated varieties of plant species (Ebert, 2014). Hence, they can support to achieve the zero hunger (SDG2) as well as good health and well-being (SDG3) objectives of sustainable development goals (SDGs) (Ishfaq et al., 2023).

Furthermore, WEPs are also potential sources of bioactive compounds, including phenolic and flavonoid compounds with high antioxidant capacity (Yu et al., 2021). These bioactive compounds can boost protection against various diseases including chronic diseases and cancer (Yu et al., 2021; Raghavendra et al., 2018). However, different parts of WEPs contain anti-nutrients such as phytate, oxalate, tannin, and cyanide (Toh et al., 2013), which their high amount can reduce the

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bioavailability of nutrients, protein digestion, and growth (Rout and Basak, 2015; Kumar et al., 2010). With their nutritional and bioactive compound composition, in recent years more ethnobotanical studies have been conducted to document local and indigenous knowledge as well as biochemical characterization of WEPs.

Thus, there is an increasing trend in the incorporation of WEPs into dishes in many developed countries (Geraci et al., 2018; Luczaj et al., 2012). WEPs have always been an essential and widespread food source for food-insecure families living in poverty in developing countries (Berihun & Molla, 2017; Yumkham et al., 2017; Mavengahama et al., 2013; Umaru et al., 2007). They are relevant to households in food security, nutritional and therapeutic values in some rural areas and rely on supplementing staple foods filling seasonal food shortages and serving as emergency food during famine. They are also vital for many communities in urban settings, including the poor and marginalized (Duguma, 2020). According to Lulekal et al. (2011) and Aberoumand (2009), approximately one billion people worldwide consume wild foods on a daily basis.

Ethiopia is known as a center of origin, biodiversity hotspot, and diversification for a significant number of food plants and their wild relatives (Edwards, 1991; cited in Lulekal et al., 2011). In fact, Ethiopia is the fifth largest country in tropical Africa in terms of the flora diversity (Kelbessa & Demissew, 2014). Lulekal et al. (2011) reported that 413 types of wild edible plants are consumed in Ethiopia. Despite these facts, studies on the biochemical composition of Ethiopian WEPs are limited (Lulekal et al., 2011). The biochemical composition and antioxidant activity of the wild edible plants in the study area have not yet been investigated until today. This current study attempts to fill the gap by documenting three nutritionally valuable wild edible plant species, which will contribute to the management plan for conservation and sustainable use of these plants in the area. Similarly, insufficient attention is given to research on the dietary values and anti-nutritional factors of WEPs in the Soro District, central Ethiopia. Therefore, this research aimed to evaluate the nutritional values, antioxidant activity and anti-nutritional factors of three most consumed wild edible plants (*Amaranthus dubius*/synonym of *Amaranthus dubius*), *Landolphia buchananii*, and *Oncoba spinosa*) in the Soro District, Ethiopia.

2. Methods and materials

2.1. Description of the study area

The study was conducted in Soro District, Hadiya Zone, Ethiopia (Fig. 1). The study area is one of the 15 Districts of the Hadiya Zone, including 33 kebeles (which are the smallest administrative units). Of the total 287, 589 population of 143, 835 were men and 143, 754 were women (SDFPEDO, 2020). With an average land tenure of 0.5–2.5 hectares per farmer household, mixed agriculture provides the primary means of subsistence for about 85% of the District's inhabitants. Civil servants make up 10% of the population, merchants make up 3%, and others make up 2%. The majority population (87.42%) lived in rural areas, and the remaining 12.58% lived in urban areas (SDFPEDO, 2020).

The District is located 264 km away from the capital city, Addis Ababa in the southwest direction and found between 37^0 20′ 0" to 37^0 47′ 23"E longitudes and 07^0 19′ 4" to 07^0 33′ 48" N latitudes with altitude ranges from 799 masl to 2934 masl adapted by (Hankiso et al., 2023), and the total land area of 36473.337 km^2. Highlands (39.4%), midlands (36.4%), and lowlands (24.2%) make up the majority of the district. The average lowest and maximum temperatures of the study area are 12 °C and 26 °C, respectively (SDFPEDO, 2020), and maximum annual rainfall ranges between 900 and 1500 mm. The variations in altitude and fluctuations in temperature, along with rainfall, support a diverse array of plant species, making this an ideal location for investigating wild edible plants.

The study area's vegetation is primarily characterized by the Afro-alpine belt (AA), dry evergreen Afro-Montane Forest, and grassland complex vegetable types (DAF), which are habitats of diverse plant compositions and diversity that include several nutritionally significant wild edible plant species, according to the current vegetation classification of Ethiopia (Friis et al., 2011). *Calpurnia aurea, Clausena anisata, Carissa spinarum, Clutia abyssinica, Euclea divinorum, Juniperus procera, Olea europaea* subsp. *cuspidata, Maesa lanceolata, Rhus natalensis*. In the

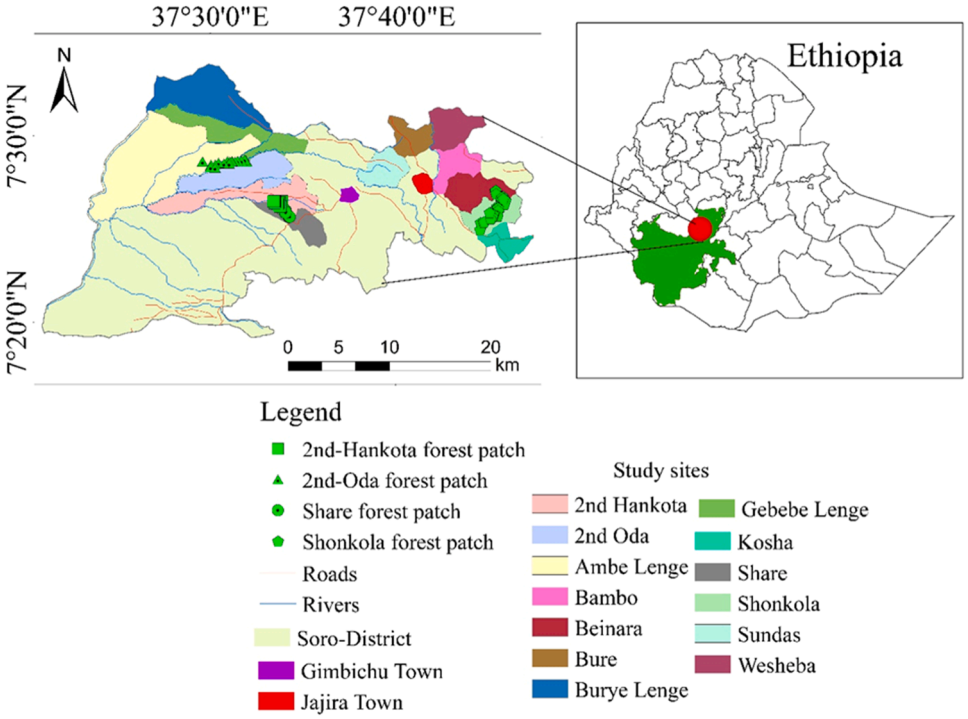

Fig. 1. Map of soro district in central Ethiopia (former in Southern Nations, nationalities, and peoples' region /SNNPR) (Hankiso et al., 2023).

District, forest patch of mountain Shonkola is characterized by the presence of *Lobelia giberroa* and *Erica arborea,* which represent the vegetation type of AA.

2.2. Plant sample selection

Three wild edible plants from Soro District, central Ethiopia, were selected from the survey among 64 WEPs based on the highest values of informant consensus, preference ranking, and fidelity level for their most preferred edible parts as well as species commonly consumed in Soro District (Hankiso et al., 2023). The edible parts of the plants are shown in Fig. 2 (A, B, and C). Matured leaves with shoots of *Amaranthus tortuosus* were collected from the community home garden (Fig. 2A). For *Landolphia buchananii*, riped fruits of various exocarp colors were collected from the agricultural land and riverine habitats (Fig. 2B). If the fruit was partially matured, it was allowed to ripen fully within 3-5 days. For *Oncoba spinosa*, ripened fruits with a light green color were collected and allowed for 4-6 days until fully ripened (*i.e.*, the color of the exocarp gradually changed to dark brown) (Fig. 2C).

All plant specimens were identified by the first author (Mulatu Hankiso). Also, all identifications were performed using the published volumes (volumes I–VIII) of the Flora of Ethiopia and Eritrea and comparing them with authentic specimens deposited in the National Herbarium of Ethiopia (ETH), Addis Ababa University. Also, they were checked at https://powo.science.kew.org/, and finally, taxonomic identification of voucher specimens was confirmed by a senior plant taxonomist (Ermias Lulekal and the National Herbarium Expert, AAU). The plant specimens with their labels were finally deposited at the National Herbarium (ETH) in Addis Ababa, Ethiopia.

2.3. Collection of selected plant samples

The triplicates of each edible parts of the selected WEPs were collected from three sites, fresh leaves with young shoots of *A. tortuosus,* fruit specimens of *L. buchananii* and *O. spinosa* were collected in (September) and (June and April), 2021 respectively, from different wild habitats in September, June, and April, 2021 respectively (Table 1). The composite samples of triplicates were pooled for each fruit edible plant species from different mother plants of the same species. Similarly a bunches of the triplicate leaves with shoots were used. The samples were collected at their optimal ripeness, free from disease, and handled with care to prevent degradation during transportation and storage. In addition, some partially ripened fruits were stored at room temperature until fully matured. Unpeeled fruit samples of *L. buchananii* and *O. spinosa* were washed in the field and laboratory to remove foreign matter and debris. The fruits were then peeled, and the edible parts were separated from the exocarp. Samples of peeled fruit and leaves were all promptly refrigerated at-20 °C for 48 h, followed by freeze-drying (MINI LYODEL, DIGITAL HI-PR-PIRANI GAUGE DHPG-222, HIND, HIVAC) for 72 h. The dried samples were ground to a sieve size of 0.5 mm using a high-speed sample miller (Xian Siway Scientific Instrument Co., Ltd, SIWAY), and stored in a plastic polyethylene bag in a deep freeze at -20 °C until analysis.

3. Methods

3.1. Total soluble solids (TSS)

The fruit juice's total soluble solids (TSS) were measured in triplicate using a digital refractometer optical prism (refractometer III, RFM-960, BS). The refractometer was auto-calibrated using 2-3 drops of distilled water. Five milliliters of the juice from *L. buchananii* and *O. spinosa* was well homogenized and three drops were added to the prism and closed, and the TSS was read directly according to Minuye (2021), and the results were recorded in ^{o}Brix.

3.2. pH

The ripened edible fresh fruits of *L. buchananii* and *O. spinosa* were peeled, and 5 g mesocarp of each fruit was crushed and homogenized with 100 mL deionized water to prepare the juice. The pH was determined directly with an auto-calibrated pH-meter (PHS-3DW, Campan HINOTEK China) with automatic temperature adjustment. Additionally, the pH of uncooked mature leaves of *A. tortuosus* was determined (Holcroft & Kader (1999). The results were recorded in triplicates.

3.3. Proximate composition

Moisture, crude protein, crude fat, crude fiber, and total ash contents were analyzed according to the methods of the Association of Official Analytical Chemists (AOAC) (AOAC, 2016). Oven drying was used to determine the moisture content (Genlab Thermal Engineers, Model: OV/125/SS/F/D/G/A, Serial No. 11B139, UK) according to protocol no. AOAC. 965.17 at 105°C to a constant weight. Based on the nitrogen content measurement (AOAC. 965:17), the protein content (N × 6.25) was calculated using the Kjeldahl (INOK1160 Automatic Kjeldahl Protein/Nitrogen Analyzer) technique. The content of the fat was determined using a fully automated Soxhlet system, Soxtec™ 800 (AOAC 965:17; Barnstead Electro-thermal, Staffordshire, UK). The content of crude fibre was determined according to AOAC (2016), while ash content was determined gravimetrically by heating the sample at 550°C for 4 hours in a muffle furnace until constant weight was achieved (Furnace type CSF 12/130; Aston, AOAC, 2010). Total carbohydrate content was calculated as follows (Eq. 1):

$$\text{Total carbohydrate content (\%)} = 100 - - (\text{Moisture} + \text{Total ash} + \text{Crude protein} + \text{Crude fat}), \quad (1)$$

Amount of gross energy was calculated from the protein, fat, and carbohydrate values (Eq. 2):

$$\text{Gross energy (kcal / 100 g)} = 4 \times \text{protein (\%)} + 4 \times \text{carbohydrate (\%)} + 9 \times \text{fat (\%)} \quad (2)$$

3.4. Minerals

The concentrations of calcium, iron, and zinc were determined using the official method of AOAC (2010).In summary, 2.5 g of the WEPs powder were ashed for 4 hours at 550°C in a muffle furnace. After the ash was dissolved in 5 mL of 10 M HCl, the solution was subsequently boiled. The digested sample was chilled or cooled, filtered, and adjusted to the required volume using demineralized water. The mineral concentrations were determined by dissolving the ashed sample in hydrochloric acid, followed by analysis using atomic absorption spectrophotometer (Perkin-Elmer AA 800, Perkin-Elmer Germany).

3.5. Vitamin C

The 2,6-dichloroindophenol titrimetric method (AOAC 967.21) was

Fig. 2. Samples of vegetable and fruits (leaf and young shoot of *Amaranthus tortuosus* (A), fruits (*Landolphia buchananii* (B), *Oncoba spinosa* (C)) from left to right, respectively) of three wild edible plants collected from Soro District, central Ethiopia.

used to quantify the amount of vitamin C present (Nielsen, 2017). A 10 g powder of the leaves of *A. tortuosus,* fruits of *L. buchananii,* and *O. spinosa* was dissolved in 100 mL of distilled water with 3% metaphosphoric acid in a 100 mL flask using an electric blender. The aliquot was then filtered using a cheese cloth. Subsequently, 5 mL of the filtrate was titrated against standard 2, 6-dichloroindophenol reagent. The initial blue color disappeared, which indicated the titration's end point. The concentration of vitamin C concentration was calculated using Eq. 3.

$$\text{Vitamin C}\left(\frac{\text{mg}}{100\text{ mL}}\right) = \frac{[V * C * M * v * 100]}{\text{Wt. of dry sample}} \quad (3)$$

where:

V	volume consumed (mL)
C	concentration of the titrant (0.005 M)
M	molecular weight of the titrant (g/ mol)
v	volume made up

3.6. Determination of anti-nutritional factors

3.6.1. Phytate content

Phytate content of WEPs was determined using the method described by Latta & Eskin (1980). In brief, 10 mL of 2.4% HCl was used to extract about 0.1 g of dried WEPs for 1 h at room temperature in a mechanical shaker. The extract was then centrifuged at 15 x g for 30 minutes.

The clear supernatant was aged to estimate the phytate content. To 3 mL of the sample solution, 1 mL Wade reagent (with 0.03% $FeCl_3{\cdot}6H_2O$ solution and 0.3% sulfosalicylic acid in water) was added and vortexed (VM-300P, 815424, Taiwan) for 5 s. A UV-Vis spectrophotometer (Perkin Elmer, Lambda 950 UV/Vis/NIR spectrophotometer, CFS288, UK) was used to measure the samples' absorbance at 500 nm. A series of standard solutions containing 5, 10, 15, and 20 μg/ mL of phytic acid (sodium phytate analytical grade) were prepared along with 2.4% HCl. In a 15 mL centrifuge tube containing 3 mL of water, a 3 mL standard was added as a blank. In each test tube, 1 mL of Wade reagent was added, and the solution was vortexed for 5 s. The mixture was centrifuged at 15 × g for 10 min, and the absorbance of the solution was measured by calibrating the spectrophotometer at 500 nm. Phytate content was determined using the Wade reagent, with results calculated from the calibration curve of sodium phytate (Eq. 4).

$$\text{Phytic acid}\left(\frac{\mu g}{100\text{ mg}}\right) = \frac{[(As - Ab) - [\text{Intercept}]] * 10}{\text{Slope} * W * 3} \quad (4)$$

where:

As	sample absorbance
Ab	blank absorbance
W	sample weight (g)
10	aliquot

3.6.2. Condensed tannin content

The condensed tannin content of the WEPs was determined according to the method described by Maxson & Rooney (1972). Briefly, 1 g of powdered was weighed using a screw-cap test. The sample solutions were extracted for 24 h at room temperature using 10 mL of 1% HCl in methanol with a mechanical shaker. The solution was centrifuged at 1 x g for 5 min, 1 mL supernatant was collected and 5 mL vanillin-HCl reagent was added. Weighing 40 mg of catechin, and 1% HCl was dissolved in 1000 mL of methanol stock solution. Test concentrations of 0.2, 0.4, 0.6, 0.8, and 1.0 mg/100 mL were used using 60 mg/100 mL catechin. The stock solution was added to the test tubes in increments of 0.12, 0.24, 0.36, 0.48, 0.60, and 1.00 mL. The volume of each test tube was adjusted to 1 mL with 1% HCl in methanol. Each test tube was supplemented with 5 mL of vanillin-HCl reagent. Then, the absorbance of the solution was measured at 500 nm using a UV-Vis spectrophotometer (Perkin Elmer, Lambda 950 UV/VIS/NIR spectrophotometer, at the model: Llantrisant, CF728YW, UK). The condensed tannin concentration was calculated using Eq. 5.

$$\text{Tannin}\left(\frac{\text{mg}}{100\text{ g}}\right) = \frac{[(As - Ab) - [\text{Intercept}]] * 10}{\text{Slope} * d * W} \quad (5)$$

where:

As	sample absorbance
Ab	blank absorbance
d	density of the solution (0.791 g/ mL)
W	sample weight (g)
10	aliquot

3.6.3.Oxalate. content determination

Using titration, the oxalate concentration of the WEPs was determined (AOAC, 2005; Ukpabi & Ejidoh, 1989). In a 250-mL conical flask, 1 g sample of freeze-dried and finely ground powder was digested using 75 mL of 3 M sulphuric acid (98%). Next, 10 mL of 6 M HCl was added, shaken, digested for 1 h at 90 °C, and cooled. Distilled water was added to the conical flask at a volume of 250 mL. The filtrate (25 mL) was poured into the flask followed by the addition of 4 drops of methyl red indicator solution, 1 mL of 6 M HCl, and a concentrated NH4OH solution, added drop by drop until the test sample solution was changed from pink to yellow. The solution was heated to 90 °C and cooled. The liquid extract was filtered and the precipitate containing ferrous ions was extracted. A 10 mL of 5% $CaCl_2$ was mixed with the filtrate and shaked.The solution was heated, and kept in refrigerator for a night at 5

Table 1
Ethnobotanical characterizations of three WEPs collected from Soro District, Ethiopia.

Local name	Scientific name	Family	Ripening/ available time	Parts used	Use	Code	Locality	Altitude (masl)
Gude'e	*Amaranthus tortuosus* Hornem.	Amaranthaceae	March to December	Leaves & young shoots	Food, as vegetable	MH-65 (A)	Weed of home garden and agricultural land	2065
Hoomba	*Landolphia buchananii* (Hall.f.) Stapf	Apocynaceae	September to June	Fruit, Mesocarp	Food, as fruit	MH-147 (B)	Agricultural land and riverine	2093
Itakkam kuukka	*Oncoba spinosa* Forssk.	Salicaceae	September to April	Fruit, Mesocarp	Food, as fruit	MH-351 (C)	Forest patch	1900

masl: mean above sea level; MH: Mulatu Hankiso

°C. After the solution was decanted and dissolved fully in 10 mL of 98% H2SO4, a total filtrate of 300 mL was titrated with a permanganate solution (0.1 M) until the colour persisted for 15 to 30 s. The volume consumed was recorded. The oxalate content was determined by the following relationship: 1 mL of 0.1 M $KMnO_4$ solution equals 0.006303 g of oxalate. Therefore, Eq. 6 was used to determine the percentage of oxalate content in 100 g of the poweder.

$$\text{Oxalate (g / 100 g)} = \text{titre} \times 100/\text{W} \quad (6)$$

where:

W	Weight of dry sample (g)
titre	volume of titrant ($KMnO_4$) consumed (mL)

3.7. Bioactive compounds determination

3.7.1. Sample extraction for bioactive compounds and antioxidant capacity determination

In brief, according to Addai et al. (2013), 5 g of powdered WEPs dissolved in 50 mL (99.8%, v/v) methanol in 100 mL conical flask and extracted for 24 h at 30 °C in a mechanical shaker at 150 rpm (Incubator shaker, Co., Ltd: ZHWY-103B, Shanghai, P.R. China). The Whatman No. 1 filter paper was used to filter the supernatant and transfer it into a 250-mL conical flask. The extraction was repeated by adding 50 mL methanol to the precipitates and placing them on a shaker for 2 h, followed by filtration. The filtrates were collected and stored in a freezer at 4 ◦C until bioactive compounds such as phenols and flavonoids and DPPH (2,2-diphenyl-1-picrylhydrazyl) antioxidant activity were determined.

3.7.2. Total phenolic content determination

Total phenolic extracts were determined using the Folin-Ciocalteu method (Musa et al., 2011; Singleton & Rossi, 1965). Crude extracts of 100 μL for the two fruits and 50 μL for the leaf and shoot edible parts were mixed with 0.9 mL of methanol and 1 mL of Folin-Ciocalteu's reagent. After 8 min, 1 mL of saturated sodium carbonate solution, (7.5 %, w/v in water) was dissolved to form a mixture, and the volume was made up to 10 mL using distilled water. In order to measure the absorbance at 765 nm using a UV-Vis spectrophotometer (Perkin Elmer, Lambda 950 UV/Vis spectrophotometer, model: Llantrisant, CF728YW, UK) against the reagent blank, the reaction mixture was vortexed and kept in the dark for 30 min at room temperature. In 1 mL of methanol 62.5 mg gallic acid was dissolved and a stock solution was prepared. In methanol various concentrations (0.02, 0.04, 0.06, 0.08, and 0.10 mg/mL) of gallic acid were prepared. All determinations were performed in triplicate. The TPC (total phenolic content) was expressed in GAE (gallic acid equivalents) per gram of dry weight of each extract (Eq. 7).

$$\text{TPC (mg GAE / g)} = \frac{\text{CxV}}{\text{m}} \quad (7)$$

where:

TPC	total phenolic content
GAE	gallic acid equivalent
C	gallic acid concentration obtained from standard curve (mg/ mL)
V	volume of extract solution (mL)
m	weight of the dry extract (g)

3.7.3. Total flavonoid content determination

The aluminum chloride colorimetric method was used to determine the total flavonoid content of the WEPs samples (Chandra et al., 2014; Pourmorad et al., 2006; Ribarova et al., 2005). Stock quercetin solution (mg/ mL) was prepared by dissolving 12.5 mg quercetin in 50 mL methanol. Standard solutions of quercetin were prepared by serial dilution in methanol (0.025, 0.050, 0.075, 0.100, and 0.125 mg/ mL). The sample extract was separately mixed with 1 mL of 2% alimunium chloride, and 0.03 mL of sample was mixed with 0.97 mL of methanol. After mixing the solution (1 mL) was incubated for 10 min at room temperature. The absorbance of the reaction mixtures was measured at 415 nm against a blank using a UV-Vis spectrophotometer. The amount of flavonoids in each mixture was calculated using the formula quercetin equivalent (QE)/g extract (Eq. 8).

$$\text{TFC (mg QE / g)} = \frac{\text{CxV}}{\text{m}} \quad (8)$$

where:

TFC	total flavonoid content
QE	quercetin equivalent
C	quercetin concentration from standard curve (mg/ mL)
V	volume of extract solution (mL)
m	weight of the dry extract (g)

3.7.4. Antioxidant capacity determination

3.7.4.1. DPPH. The assay of DPPH radical scavenging capacity of the WEP extract was determined according to the method described by Etim et al. (2015). Briefly, 50 mg/ mL crude extract of WEP samples was serially diluted in to the concentrations of 20, 40, 60, 80, and 100 μg/ mL with methanol. In each solution, 4 mL of 0.1 mM DPPH in methanol was added, and the solution was kept at room temperature in the dark for 30 min. Using 517 nm, the absorbance was measured at a UV-Vis spectrophotometer. As a blank solution, 1 mL of methanol and 3 mL of working DPPH solution were utilized. To determine, the results were compared to the same doses of standard ascorbic acid to calculate the percentage of DPPH inhibition (Eq. 9).

$$\text{DPPH(\% of inhibition)} = \frac{\text{A blank} - \text{A sample}}{\text{A blank}} * 100 \quad (9)$$

where:

A blank	absorbance of control
A sample	absorbance of sample

3.7.5. The statistical analysis

Results are expressed as mean ± standard deviation. Significant differences in mean values were determined at $p<0.05$, using one-way analysis of variance (ANOVA) and Duncan's multiple range test. Partly paired t-tests were used to compare the mean differences at $p<0.05$. All analyses were carried out in triplicate and analyzed using the SPSS software (version 22.0; SPSS Inc., Illinois, USA).

4. Results and discussion

4.1. Physico-chemical characteristics

The physico-chemical characteristics of *A. tortuosus, L. buchananii,* and *O. spinosa* collected from the Soro District, Ethiopia are reported in Table 2. The three WEPs were identified either in the field or at the National Herbarium ETH at Addis Ababa University. The edible parts of these plant species are shown in Fig. 2. The average total weight of *L. buchananii* and *O. spinosa* were 541 g and 1049 g, respectively ($p<0.05$). A highly significant difference was observed in the seed and mesocarp weights of the two fruits, which were (162 and 667) g and (84 and 450) g respectively ($p<0.05$). *O. spinosa* had the highest values of all physical parameters measured, including the weight of the exocarp ($p<0.05$) (Table 2). The fruit can resist decay by fungi and bacteria due to the hard, thick exocarp, thus assuming fit for rural areas with less or no facilities for fruit preservation technologies (Doyle, 2009). At the ripening stage, its fruit exocarp gradually changed from a slight green color to a dark-brown, and the color of the pulp also changed from a slight yellow to a dark-brown. At the ripening stage, the fruit and pulp

Table 2
Physico-chemical characteristics of *Landolphia buchananii* and *Oncoba spinosa* collected from Soro District, Ethiopia.

Wild edible plant	Total weight (g)	Exocarp weight (g)	Seed weight (g)	Mesocarp weight (g)	TSS (^{o}Brix)	Fresh fruit pH
Landolphia buchananii	541.0 ± 54.0	331.7 ± 56.6	161.9 ± 80.9	83.7 ± 36.8	2.4 ± 0.2	4.5 ± 0.1
Oncoba spinosa	1049.4 ± 237.3*	399.8 ± 1.6*	667.4 ± 56.0*	449.6 ± 332.4*	8.4 ± 0.4*	5.5 ± 0.2*

Data were expressed as the mean ± standard deviation (*n=3* independent composite samples). *Mean values within a column are significantly different using paired t-test at $p<0.05$.

color of *L. buchananii* changed from white latex to slightly white, whereas the latex disappeared gradually. The fruit contains bean-sized seeds. The *Amaranthus tortuosus* is a WEP with a dark-green color, relatively broad leaves, and young shoots, which is commonly used as a vegetable by the local community.

The TSS and pH of the fresh juice from *L. buchananii* and *O. spinosa* were (2.36 ^{o}Brix, 4.53) and (8.37 ^{o}Brix, 5.53), respectively ($p<0.05$). The TSS of *O. spinosa* fruit juice (8.37 ^{0}Brix) is comparable to that of certain cultivated fruit juices, such as papaya (*Carica papaya*) (10.3 ^{0}Brix) (Minuye, 2021), and some wild edible fruits of *Hippophae salicifolia* (10.80 ^{o}Brix) and *Berberis aristata* (10.96 ^{o}Brix) (Singh et al., 2023). Some wild edible fruits had higher TSS than this value; for instance, *Malus baccata, Pyrus pashia, Ramaria botrytis*, and *Prunus cornuta* had a respective TSS content of 23.77, 21.80, 20.06, and 18.53 ^{o}Brix in the northwest Himalaya, India (Singh et al., 2023). In a similar study, a lower TSS (6.13 ^{o}Brix) was reported than that in the current study of *O. spinosa.*

4.2. Proximate composition

The proximate compositions of the three WEPs, leaves and shoots of *A. tortuosus*, fruits of *L. buchananii,* and *O. spinosa* are presented in Table 3. The fresh and raw leaves and shoots of *A. tortuosus* and fruits of *L. buchananii* and *O. spinosa* had moisture contents of 85, 79, and 59 g/100 g, respectively ($p<0.05$). The total ash content of the two fruit samples (*O. spinosa* and *L. buchananii*, respectively) was 6.6 and 3.0 g/100 g ($p<0.05$); in contrast, the leaf sample had a significantly higher amount of 20.60 g/100 g compared to the fruits ($p<0.05$). Adamu et al. (2022b) reported a high amount of ash (15 g/100 g) in *A. hybridus* leaf. Similarly, the content of crude protein in *A. tortuosus* was significantly higher than that of fruit samples (33.77 g/100 g) ($p< 0.05$). The protein content in *Amaranthus tortuosus* was significantly higher than that of common legumes, which typically contain 20-25 g/100g. A lower crude protein content of 17.63 g/100 g in the leaf of *A. hybridus* was reported by Adamu et al. (2022b). Relatively higher crude protein content in the leaves of Ethiopian WEPs of *Erucastrum abyssinicum, Erucastrum arabicum, Urtica simensis* (33.63, 30.15, 30.55 g/100 g) respectively was reported by Adamu et al. (2022b). Apparently, the groups of plants might contribute to protein intake in areas with the lowest intake. In fact, these WEPs in this study offer relatively higher protein contents than cultivated vegetable crops such as *Brassica oleracea* (1.1-2.7 g/100 g), *Brassica carinata* (2.5-2.8 g/100 g), and *Allium sativum* (1.0-4.5 g/100 g) (Getachew et al., 2013).

The crude fiber content in WEPs ranged from 6.05-8.03 g/100 g ($p<0.05$) (Table 3). This range is lower for plant-based foods. Similarly, Adamu et al. (2022b) reported 6.21 g/100 g crude fiber content in the leaves of *A. hybridus*. In the present study, the crude fat content of the WEPs ranged from 3.0-5.5 g/100 g ($p< 0.05$). Total carbohydrate content was 72.14, 74.02, and 33.67 g/100 g in the *O. spinosa, L. buchnanii* (fruits), and *A. tortuosus* (leaves and shoots) respectively ($p<0.05$). The carbohydrate content of the two fruit samples was comparable with the content in WEPs like *Pachycymbium laticoronum* (60.5 g/100 g), harvested from Southern Ethiopia (Uyoh et al., 2013). According to Blessing et al. (2011) and Afolayan & Mbaebie (2010), the total carbohydrate content in the WEPs of this study is higher than the values in cultivated fruits like papaya (9.81 g/100 g), pineapple (11.82 g/100 g), guava (14.3 g/100 g), mango (17.00 g/100 g), and banana (22.84 g/100 g).

The caloric values in the leaves and shoots of *A. tortuosus*, fruit of *L. buchananii,* and *O. spinosa* were 284, 330, and 313 kcal/100 g respectively. Diets with energy densities greater than 1 kcal/g or even 2 kcal/g may help children who are experiencing hardship consume an appropriate amount of energy and avoid waste during food insecurity (Mahapatra et al., 2012). Thus, the WEPs in this study will significantly contribute in mitigating such forms of malnutrition, particularly during the lean season.

Table 3
Proximate composition of *Amaranthus tortuosus* leaves and shoots, *Landolphia buchananii, Oncoba spinosa* fruits collected from Soro District, Ethiopia.

Proximate composition	*Amaranthus tortuosus* (leaf and shoot)	*Landolphia buchananii* (fruit)	*Oncoba spinosa* (fruit)
Moisture (fresh sample) (g/100 g)	84.80 ± 0.56^{a}	79.07 ± 2.15^{b}	59.53 ± 1.82^{c}
Moisture (g/100 g)	5.80 ± 0.38^{c}	11.33 ± 0.58^{b}	12.75 ± 0.25^{a}
Total ash (g/100 g)	20.60 ± 0.28^{a}	3.00 ± 0.28^{c}	6.60 ± 0.28^{b}
Crude protein (g/100 g)	33.77 ± 0.00^{a}	8.31 ± 0.12^{b}	5.51± 0.37^{c}
Crude fat (g/100 g)	5.50 ± 0.29^{a}	3.67 ± 0.76^{b}	3.00 ± 0.50^{c}
Crude fiber (g/100 g)	9.60 ± 1.6^{a}	8.03 ± 0.40^{b}	6.05 ± 0.02^{c}
Total carbohydrate (g/100 g)	33.67 ± 1.02^{c}	74.02 ± 1.60^{a}	72.14 ± 1.16^{b}
Utilizable carbohydrate (g/100 g)	24.07 ± 1.03^{b}	65.99 ± 1.56^{a}	66.09 ± 1.17^{a}
Energy (kcal/100 g)	283.70 ± 1.57^{c}	330.23 ± 2.44^{a}	313.40 ± 2.04^{b}

Data were expressed as the mean ± standard deviation (*n=3* independent composite samples) on a dry basis (except for fresh sample moisture determination). Mean values within a row with different superscripts indicate significant differences at $p<0.05$, using one-way analysis of variance (ANOVA), in mean comparisons using Duncan's multiple range test.

4.3. Mineral composition

The contents of the macro-mineral (calcium) and microminerals (iron and zinc) in the three WEPs from Soro District, Ethiopia are reported in Table 4. The calcium content in the fruits of *L. buchananii* and *O. spinosa* was 86.83 mg/100 g and 88.02 mg/100 g, respectively,

Table 4
Mineral contents of *Amaranthus tortuosus* leaf and shoot, *Landolphia buchananii,* and *Oncoba spinosa* fruits collected from Soro District, Ethiopia.

Minerals	*Amaranthus tortuosus* (leaf and shoot)	*Landolphia buchananii* (fruit)	*Oncoba spinosa* (fruit)
Calcium (mg/100 g)	1059.50 ± 2.20^{a}	86.83 ± 0.33^{b}	88.02 ± 0.33^{b}
Iron (mg/100 g)	34.22 ± 0.07^{a}	3.10 ± 0.03^{b}	2.10 ± 0.01^{c}
Zinc (mg/100 g)	5.01 ± 0.02^{a}	2.90 ± 0.03^{b}	1.26 ± 0.01^{c}

Data were expressed as the mean ± standard deviation (*n=3* independent composite samples) on dry basis. The mean values within a row with different superscripts indicate significant difference at $p<0.05$, using one-way-analysis of variance (ANOVA), in mean comparisons using Duncan's multiple range test.

whereas the leaves and shoots that were edible had the highest content in *A. tortuosus* (1059.50 mg/100 g) at $p<0.05$. The calcium content of *L. buchananii* (86.83 mg/100 g) is closely comparable with the content in the WEP *Crocus sativus*, 86.25 mg/100 g in Morocco (Ibourki et al., 2022), and lower than the content in *Ziziphus spina-christi* collected from Ethiopia (339.5 mg/100 g) (Duguma, 2020). Adamu et al. (2022b) reported lower calcium content than in the present study (59.94 mg/100 g) in the dried leaves of *Amaranthus hybridus*. But (Duguma, 2020) reported a higher calcium content of 3029 mg/100 g in *Amaranthus graecizans* collected from Ethiopia. In other leafy WEPs, including the wild edible plant species *Erucastrum abyssinicum, Erucastrum arabicum, Haplocarpha rueppelii, Haplocarpha schimperi*, and *Urtica simensis,* macronutrient content (calcium) was reported between the range of 44-60 mg/100 g (Adamu et al., 2022b). In this current investigation, calcium content in the leaves and shoots of *A. tortuosus* was much higher than that reported previously but much less than that of *Amaranthus graecizans*. This may be because of various environmental and genetic factors.

The iron concentration in the three WEPs was 34.22, 3.10, and 2.10 mg/100 g respectively in *A. tortuosus, L. buchananii,* and *O. spinosa* (Table 4) ($p<0.05$). The iron content of *A. tortuosus* leaf and shoot was significantly higher. The dried edible leaf of *Amaranthus hybridus* had 19.3 mg/100 g of iron (Adamu et al., 2022b) and from the other *Amaranthus* species *A. graecizans* was 18.81 mg/100 g Duguma (2020). The iron content of the WEPs in this study is comparable with the content in other WEPs investigated from Southern Ethiopia (*i.e.*, 1.9 mg/100 g in *Ximenia caffra*, 22.0 mg/100 g in *Launaea intybacea*) (Uyoh et al., 2013). Thus, with this study, one can assume that the WEPs could be a suitable dietary source of iron, providing 0.11–1.90 times the adult recommended daily allowance (RDA) of 18 mg/day; nevertheless, further evaluation of their bioavailability may need to be necessary (Azene & Molla, 2017; Khan et al., 2011). The zinc content in *A. tortuosus, L. buchananii,* and *O. spinosa* was 1.26, 2.90, and 5.01 mg/100 g ($p<0.05$) (Table 4). Adamu et al. (2022b) reported a zinc concentration of 8.35 mg /100 g in dried leaves of *Amaranthus hybridus*. But a lower iron content in *Amaranthus graecizans* leaves (2.3 g /100 g) was reported by Duguma (2020). Overall, the leaves and shoots of *A. tortuosus* had the highest concentrations of calcium, iron, and zinc among the three WEPs (Table 4).

4.4. Determination of anti-nutritional factors

The phytate, oxalate, and tannin contents of the three WEPs from Soro district are reported in Table 5. The oxalate concentrations in the two fruit samples were 0.40 and 8.66 mg/100 g respectively for *L. buchananii* and *O. spinosa* ($p<0.05$). Oxalate content in the leaves of *A. tortuosus* was 1.43 mg/100g. The oxalate content in the leaves of WEPs collected in Lasta district, Ethiopia were *Amaranthus hybridus* (5.13), *Erucastrum abyssinicum* (11.73), *Erucastrum arabicum* (5.13), *Haplocarpha rueppelii* (9.09), *Haplocarpha schimperi* (5.57), *Urtica simensis* (5.13) mg/100 g (Adamu et al., 2022a). The oxalate content in the leaf of *A. tortuosus* was lower than these values. Accordingly, it was the highest in licorice root (*Glycyrrhiza glabra*; 3569.3 mg/100 g), blue fenugreek (*Trigonella coerulea*; 1245.9 mg/100 g) and white beans (*Phaseolus vulgaris* L.; 547.9 mg/10 g), in sweet potatoes (*Ipomoea batatas*, 495.6 mg/100 g), cocoa powder (*Theobroma cacao*, 619.3 mg/100 g), in okra (*Abdelmoschus esculentus*, 317.2 mg/100 g). The oxalate content of the WEPs in this study was much lower than these values. Oxalate-containing foods enhance the formation of kidney stones, cause irritation of the tongue, and decrease calcium absorption (Fekadu et al., 2013).

The phytate content in *O. spinosa, L. buchananii*, and *A. dubius* was 0.89, 0.74, and 0.47 mg/100 g, respectively ($p<0.05$). The phytate content in the leaves of WEPs collected in Lasta district, Ethiopia, was *Amaranthus hybridus* (0.08), *Erucastrum abyssinicum* (0.03), *Erucastrum arabicum* (0.17), *Haplocarpha rueppelii* (0.17), *Haplocarpha schimperi* (0.17), *Urtica simensis* (0.08) mg/100g (Adamu et al., 2022a). The phytate content in the three WEPs in this study was higher than these values. Phytic acid interferes with daily functions of the human body, including digestion and protein breakdown (Schjønning et al., 2004). Nutritional problems such as osteomalacia and rickets are associated with over consumption of meals with high phytate-rich diets. However, this anti-nutrient can be rapidly gotten rid of by soaking, boiling, and cooking (Ekop and Eddy, 2005). The tannin contents in *A. tortuosus, L. buchananii*, and *O. spinosa* was 29.11, 46.71, and 35.63 mg/100 g, respectively ($p<0.05$). While the anti-nutrient content in these plants is within safe levels for consumption, and increases bioavailability of minerals like calcium absorption and also important to against human health problems (Fekadu et al., 2013), further research is needed to assess its bioavailability and potential impact on nutrient absorption.

4.5. Bioactive compounds

4.5.1. Determination of total phenolics and flavonoids

The leaves and shoots of *A. tortuosus*, fruits of *L. buchananii,* and *O. spinosa* had total phenolic content of 114.45, 171.39, and 115.45 mg GAE/100g, respectively (Table 6). The total phenolic content in the leaves of six WEPs collected from northeastern Ethiopia was within the range of 0.79 (*Urtica simensis*) to 17.02 mg GAE/100g (*Haplocarpha rueppelii*) (Adamu et al., 2022a). In the same report, *Amaranthus hybridus* leaves had a total phenolic content of 13.13 mg GAE/100 g. This is a much lower value than that obtained in the current study within the same genus. It has been demonstrated that the high phenolic content of WEPs is beneficial in the prevention of a number of chronic diseases (Asami et al., 2003).

The leaf and shoot of *A. tortuosus*, fruits of *L. buchananii,* and *O. spinosa* had total flavonoid content of 81.70, 132.43, 74.17 mg QE/100 g (Table 6), respectively. The total flavonoid content in the leaf and young shoot of six WEPs collected from northeastern Ethiopia was

Table 5
Anti-nutritional factors of *Amaranthus tortuosus* leaf and shoot, *Landolphia buchananii,* and *Oncoba spinosa* fruits from Soro District, Ethiopia.

Anti-nutritional factors	*Amaranthus tortuosus* (Leaf and shoot)	*Landolphia buchananii* (Fruit)	*Oncoba spinosa* (Fruit)
Phytate (mg/100 g)	0.47 ± 0.00^{c}	0.74 ± 0.34^{b}	0.89 ± 0.02^{a}
Oxalate (mg/100 g)	1.43 ± 0.16^{b}	0.40 ± 0.04^{c}	8.66 ± 0.16^{a}
Tannin (mg/100 g)	29.11 ± 0.19^{c}	46.71 ± 0.15^{a}	35.63 ± 0.26^{b}

Data were expressed as the mean ± standard deviation ($n=3$ independent composite samples) on a dry basis. The mean values within a row with different superscripts indicate significant differences at $p<0.05$, using one-way analysis of variance (ANOVA), in mean comparisons using Duncan's multiple range test.

Table 6
Total phenolic and flavonoid contents of *Amaranthus tortuosus* leaf with shoot, *Landolphia buchananii,* and *Oncoba spinosa* fruits were collected from Soro District, Ethiopia.

Bioactive compounds	*Amaranthus tortuosus* (leaf and shoot)	*Landolphia buchananii* (fruit)	*Oncoba spinosa* (fruit)
TPC (mg GAE/100 g)	114.45 ± 4.29^{b}	171.39 ± 11.25^{a}	115.45 ± 0.10^{b}
TFC (mg QE/100 g)	81.70 ± 2.16^{b}	132.43 ± 19.61^{a}	74.17 ± 6.84^{c}

Data were expressed as the mean ± standard deviation ($n=3$ independent composite samples) on a dry basis.The mean values within a row with different superscripts indicate significant differences at $p<0.05$, using one-way-analysis of variance (ANOVA), in mean comparisons using Duncan's multiple range test. TPC: total phenolic content; TFC: total flavonoids content; GAE: gallic acid equivalent; QE: Quercetin Equivalent

within the range of 2.27 (*Rumex nervosus*, young shoots) to 7.12 mg QE/ 100g (*Amaranthus hybridus*) (Adamu et al., 2022a). These values are significantly lower than those reported in the present study. This diversity makes WEPs a potential candidate for the research of antioxidants (Kwinana-Mandindi, 2015). Flavonoids may prevent membrane lipids from oxidizing because of their antioxidant and free radical scavenging properties (Williams et al., 2004).

4.5.2. Antioxidant activity

4.5.2.1. DPPH assay of radical scavenging activity. The DPPH free radical scavenging activity of the WEPs was estimated by comparison with a conventional ascorbic acid standard. Apparently, with all the extracts as concentration increased the DPPH scavenging capacity also increased (Table 7). At 200 μg/ mL concentration, the highest percentage of inhibition was observed for ascorbic acid (96.42%), followed by *L. buchananii* (94.63%), *O. spinosa* (77.37%), and *A. tortuosus* (66.85%). Methanolic extract of *L. buchananii* fruit showed the highest inhibition percentage, which was comparable to that of ascorbic acid. In one of the WEPs in northeastern Ethiopia, *Rumex nervosus* young shoots, Adamu et al. (2022a) reported a 97.30% inhibition of DPPH at 200 μg/mL. At the same concentration, *Amaranthus hybridus* seeds showed the lowest percent of inhibition recorded (52.31%). Similarly, in the present study, the lowest inhibition was observed with the extract of leaves and shoots of *A. tortuosus*. The extracts of IC50 values from *A. tortuosus, L. buchananii*, and *O. spinosa* were 124 μg/mL, 84 μg/mL, and 125 μg/ mL, respectively (Table 7). The *L. buchananii* extract had an IC50 value (84 μg/ mL) comparable to that of an ascorbic acid (82 μg/ mL). The comparable IC50 values suggest that *L. buchananii* may be a potent source of antioxidants, similar to ascorbic acid, which is a well-known antioxidant.

4.5.3. Vitamin C

Among the WEPs under investigation, there was a significant variation in vitamin C content (p 0.05), as shown in Table 8. The results indicated that the fruit of *L. buchananii* had the highest vitamin C content of 43.15 mg/100 g ($p<0.05$) followed by *A. tortuosus* and *O. spinosa* 26 mg/100 g at $p>0.05$. Adamu et al. (2022b) reported vitamin C content of 70.42 mg/100 g in leaves of the WEP *Erucastrum abyssinicum* collected from North Eastern Ethiopia. According to the same report, the leaves of *Amaranthus hybridus* had 33.09 mg/100 g vitamin C, while *Rumex nervosus* leaves showed the lowest vitamin C content of 2.16 mg/100 g. The highest vitamin C content (44.4 mg/100 g) of *L. buchananii* plant species was comparable to that in cultivated fruits such as papaya (*Carica papaya* L.) (44.61 mg/100 g) (Minuye, 2021). Thus, one can assume that the WEPs under investigation are potential sources of vitamin C in Soro District to play a role in prevent of vitamin C deficiency-related diseases (Santos et al., 2016).

Table 7
DPPH free radical scavenging activities of *Landolphia buchananii, Oncoba spinosa* fruits and *Amaranthus tortuosus* leaf and shoot collected from Sor District, Ethiopia.

Concentration (μg/ mL)	Ascorbic acid Inhibition %	*A. tortuosus* (leaf and shoot)	*L.buchananii* (fruit)	*O. spinosa* (fruit)
20	17.41 + 0.03^{a}	14.49 + 0.01^{b}	13.49 + 0.03^{c}	9.96 +0.02^{d}
40	28.09 + 0.09^{b}	21.70 + 0.02^{c}	46.33 + 0.03^{a}	16.89 +0.03^{d}
80	48.46 + 0.06^{b}	39.35 + 0.05^{c}	53.42 + 0.02^{a}	34.78 + 0.04^{d}
120	74.77 +0.10^{a}	51.66 + 0.20^{c}	63.75 + 0.05^{b}	50.18 + 0.10^{d}
160	96.18 + 0.10^{a}	66.63 + 0.03^{c}	82.10 + 0.10^{b}	62.41 + 0.40^{d}
200	96.42 + 1.00^{c}	66.85 + 0.05^{b}	94.63 + 2.00^{c}	77.37 +1.00^{a}
IC_{50} (μg/ mL)	82	124	84	125

Data were expressed as the mean ± standard deviation (*n=3* independent composite samples) on a dry basis. The mean values within a row with different superscripts indicate significant differences at $p<0.05$, using one-way analysis of variance (ANOVA), in mean comparisons using Duncan's multiple range test.

Table 8
Vitamin C content of *Landolphia buchananii, Oncoba spinosa* fruits and *Amaranthus tortuosus* leaf and shoot collected from Soro District, Ethiopia.

Wild edible plants	Edible part	Vitamin C content (mg/100 g)
Amaranthus tortuosus	Leaf and shoot	26.42 ± 0.00^{b}
Landolphia buchananii	Fruit	43.15 ±1.25^{a}
Oncoba spinosa	Fruit	26.75 ± 0.01^{b}

Data were expressed as the mean ± standard deviation (*n=3* independent composite samples) on a dry basis. The mean values within a column with different superscripts indicate significant differences at $p<0.05$, using one-way analysis of variance (ANOVA) in mean comparisons using Duncan's multiple range test.

5. Conclusions

The WEPs (leaf and shoot of *A. tortuosus*, fruit of *L. buchananii,* and *O. spinosa*) in this study had relatively higher protein and total carbohydrate contents than cultivated vegetable crops. Additionally, the WEPs had high energy density (calorific value) that can contribute to adequate energy intake. Specifically, the leaf/shoot of *A. tortuosus* had the highest ash and protein contents among the WEPs investigated. As a result, the highest iron and calcium contents were in the leaf/shoot of *A. tortuosus*. The amount of iron in the leafy WEP can contribute significantly to the adult recommended daily allowance. The oxalate content in the WEPs was lower than in previous reports. In contrast, the total phenolic and flavnoid contents of the WEPs were higher than in previous reports. Thus, the extracts of the WEPs had increased free radical inhibition with increased concentration. Specially, the *L. buchananii* extract had comparable IC50 value with ascorbic acid in scavenging DPPH free radical. Additionally, the fruit of *L. buchananii* had the highest vitamin C content among the WEPs, which was comparable with the content in cultivated fruits. Therefore, these WEPs are very important in contributing to energy and nutrient intake for the people in Soro District, Ethiopia.These WEPs complement deficiencies associated with the consumption of monotonous cereal grains of the study area, and beyond. Thus, the WEPs can be targeted for further study and new food product development. Furthermore, the more promising WEPs can also be considered candidates for cultivation geared to dietary food source diversification, which support nutrition-sensitive agriculture and conservation priority underutilized plant crops.

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Data availability

The data used to support this study are available within the paper. Additionally, the raw data are also available upon request to the corresponding author.

CRediT authorship contribution statement

Mulatu Hankiso: Writing – original draft, Software, Methodology, Investigation, Formal analysis, Conceptualization. **Ermias Lulekal:** Writing – review & editing, Validation, Supervision, Methodology,

Formal analysis, Conceptualization. **Zemede Asfaw:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Bikila Warkineh:** Writing – review & editing, Validation, Methodology, Conceptualization. **Paulos Getachew:** Writing – review & editing, Visualization, Validation, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interests.

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Supplementary materials

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References

Aberoumand, A. (2009). Nutritional evaluation of edible *Portulaca oleracia* as plant food. *Food Analytical Methods, 2*(3), 204–207.

Adamu, E., Asfaw, Z., Demissew, S., & Baye, K. (2022a). Antioxidant activity and anti-nutritional factors of selected wild edible plants collected from Northeastern Ethiopia. *Foods, 11*(15), 2291.

Adamu, E., Asfaw, Z., Demissew, S., & Baye, K. (2022b). Proximate, minerals, and vitamin C contents of selected wild edible plants in Lasta District, Northeastern Ethiopia. *International Journal of Plant Biology, 13*(4), 613–624.

Addai, Z., Abdullah, A., Sahilah, A. M., & Dauqan, E. (2013). Antioxidant activity and physicochemical properties changes of papaya (*Carica papaya* L. cv. Hongkong) during different ripening stage. *International Food Research Journal, 20*, 1653–1659.

Adedapo, A., Jimoh, F., & Afolayan, A. (2011). Comparison of the nutritive value and biological activities of the acetone, methanol and water extracts of the leaves of *Bidens pilosa* and *Chenopodium album*. *Acta Poloniae Pharmaceutica, 68*(1), 83–92.

Afolayan, A. J., & Mbaebie, B. O. (2010). Ethnobotanical study of medicinal plants used as anti-obesity remedies in Nkonkobe municipality of South Africa. *Pharmacognosy Journal, 2*(11), 368–373.

AOAC. (2005). *Official methods of analysis of association of official analytical chemists International* (8th edition).

AOAC. (2010). In W. Horwitz, & G. W. Latimer (Eds.), *Official methods of analysis of AOAC International, Revision 3*. Gaithersburg, Maryland: AOAC International. AOAC Intl.2010.

AOAC. (2016). In G. W. Latimer (Ed.), *AOAC official method 965.17. Phosphorus in animal feed and pet food* (20th ed.). Gaithersburg, MD: AOAC, International. editorOfficial methods of analysis of AOAC International.

Asami, D. K., Hong, Y.-J., Barrett, D. M., & Mitchell, A. E. (2003). Comparison of the total phenolic and ascorbic acid content of freeze-dried and air-dried marionberry, strawberry, and corn grown using conventional, organic, and sustainable agricultural practices. *Journal of Agricultural and Food Chemistry, 51*(5), 1237–1241.

Azene, H., & Molla, T. (2017). Nutritional composition and effects of cultural processing on anti-nutritional factors and mineral bioavailability of *Colocasia esculenta* (Godere) grown in Wolaita Zone, Ethiopia. *Journal of Food and Nutrition Sciences, 5*(4), 147–154.

Berihun, T., & Molla, E. (2017). Study on the diversity and use of wild edible plants in Bullen district Northwest Ethiopia. *Journal of Botany, 2017*.

Blessing, A. C., Ifeanyi, U. M., & Chijioke, O. B. (2011). Nutritional evaluation of some Nigerian pumpkins (*Cucurbita* spp.). *Fruit, Vegetable and Cereal Science and Biotechnology, 5*(2), 64–71.

Chandra, S., Khan, S., Avula, B., Lata, H., Yang, M. H., ElSohly, M. A., & Khan, I. A. (2014). Assessment of total phenolic and flavonoid content, antioxidant properties, and yield of aeroponically and conventionally grown leafy vegetables and fruit crops: A comparative study. *Evidence-Based Complementary and Alternative Medicine, 2014*.

Chennai Platform for Action. (2006). Chennai Platform for Action. (2006). Agricultural biodiversity and elimination of hunger and poverty: UN Millennium Development Goals. http://cgiar.org/Events/IFAD-NUS/PDF/Agreement5.

Dansi, A., Adjatin, A., Adoukonou-Sagbadja, H., Faladé, V., Yedomonhan, H., Odou, D., & Dossou, B. (2008). Traditional leafy vegetables and their use in the Benin Republic. *Genetic Resources and Crop Evolution, 55*, 1239–1256.

Datta, S., Sinha, B. K., Bhattacharjee, S., & Seal, T. (2019). Nutritional composition, mineral content, antioxidant activity and quantitative estimation of water-soluble vitamins and phenolics by RP-HPLC in some lesser used wild edible plants. *Heliyon, 5*(3), Article e01431.

Doyle, M. P. (2009). *Compendium of the microbiological spoilage of foods and beverages*. Springer.

Duguma, H. T. (2020). Wild edible plant nutritional contribution and consumer perception in Ethiopia. *International Journal of Food Science, 2020*.

Ebert, A. W. (2014). Potential of underutilized traditional vegetables and legume crops to contribute to food and nutritional security, income and more sustainable production systems. *Sustainability, 6*(1), 319–335.

Edwards, S. B. (1991). Crops with wild relatives found in Ethiopia. *Plant Genetic Resources of Ethiopia*, 42–74.

Ekop, A. S., & Eddy, N. O. (2005). Comparative studies of the level of toxicant in the seeds of *Terminalia catappa* (india almond) and *Coula edulis* (African walnut). *Chem Class Journal, 2*, 74–76.

Etim, E., Udobre, A., Udoh, A., & Eduoku, E. (2015). Evaluation of the antioxidant property of *Vernonia cinerea* (L.) Less. (Asteraceae) using 2.2-diphenyl-1-picrylhydrazine (DPPH) assay method. *The Pharma Innovation, 4*(6, Part A), 10.

FAO. (2011). *The state of food insecurity in the world: How does international price volatility affect domestic economies and food security?* Rome, Italy: FAO. http://www.fao.org/docrep/014/i2330e/i2330e00.htm.

FAO. (2012). *The state of food insecurity in the world: Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition*. Rome, Italy: FAO. http://www.fao.org/publications/Sofi/2012/en/.

Fekadu, H., Beyene, F., & Desse, G. (2013). Effect of traditional processing methods on nutritional composition and anti-nutritional factors of anchote (*Coccinia abyssinica* (lam.) Cogn) tubers grown in Western Ethiopia. *Journal of Food Processing and Technology, 4*(07).

Friis, I., Demissew, S., & van Breugel, P. (2011). *Atlas of the potential vegetation of Ethiopia. Addis Ababa, Ethiopia*. Addis Ababa University Press, Shama Books [Google Scholar].

Geraci, A., Amato, F., Di Noto, G., Bazan, G., & Schicchi, R. (2018). The wild taxa utilized as vegetables in Sicily (Italy): A traditional component of the Mediterranean diet. *Journal of Ethnobiology and Ethnomedicine, 14*(1), 1–27.

Getachew, G. A., Asfaw, Z., Singh, V., Woldu, Z., Baidu-Forson, J. J., & Bhattacharya, S. (2013). Dietary values of wild and semi-wild edible plants in Southern Ethiopia. *African Journal of Food, Agriculture, Nutrition and Development, 13*(2).

Hankiso, M., Warkineh, B., Asfaw, Z., & Debella, A. (2023). Ethnobotany of wild edible plants in Soro District of Hadiya Zone, southern Ethiopia. *Journal of Ethnobiology and Ethnomedicine, 19*(1), 21.

Holcroft, D. M., & Kader, A. A. (1999). Controlled atmosphere-induced changes in pH and organic acid metabolism may affect color of stored strawberry fruit. *Postharvest Biology and Technology, 17*(1), 19–32.

Ibourki, M., Ait Bouzid, H., Bijla, L., Sakar, E. H., Asdadi, A., Laknifli, A., El Hammadi, A., & Gharby, S. (2022). Mineral profiling of twenty wild and cultivated aromatic and medicinal plants growing in Morocco. *Biological Trace Element Research, 200*(11), 4880–4889.

Ishfaq, M., Wang, Y., Xu, J., Hassan, M. U., Yuan, H., Liu, L., He, B., Ejaz, I., White, P. J., & Cakmak, I. (2023). Improvement of nutritional quality of food crops with fertilizer: A global meta-analysis. *Agronomy for Sustainable Development, 43*(6), 74.

Kelbessa, E., & Demissew, S. (2014). Diversity of vascular plant taxa of the flora of Ethiopia and Eritrea. *Ethiopian Journal of Biological Sciences, 13*(Supp), 37–45.

Khan, K. Y., Khan, M. A., Niamat, R., Munir, M., Fazal, H., Mazari, P., Seema, N., Bashir, T., Kanwal, A., & Ahmed, S. N. (2011). Element content analysis of plants of genus Ficus using atomic absorption spectrometer. *African Journal of Pharmacy and Pharmacology, 5*(3), 317–321.

Kumar, V., Sinha, A. K., Makkar, H. P., & Becker, K. (2010). Dietary roles of phytate and phytase in human nutrition: A review. *Food Chemistry, 120*(4), 945–959.

Kwinana-Mandindi, T. (2015). Phytochemical and antioxidant composition of selected local wild plants in south africa: Consideration of alternative nutrients for health promotion. *5th Intern Conference on Biomed Eng Tech, 81*(17), 96–102.

Latta, M., & Eskin, M. (1980). A simple and rapid colorimetric method for phytate determination. *Journal of Agricultural and Food Chemistry, 28*(6), 1313–1315.

Luczaj, L., Pieroni, A., Tardío, J., Pardo-de-Santayana, M., Sõukand, R., Svanberg, I., & Kalle, R. (2012). Wild food plant use in 21 st century Europe, the disapperance of old traditions and the search for new ciusines involving wild edibles. *Acta Societatis Botanicorum Poloniae, 81*(4).

Lulekal, E., Asfaw, Z., Kelbessa, E., & Van Damme, P. (2011). Wild edible plants in Ethiopia: A review on their potential to combat food insecurity. *Afrika Focus, 24*(2), 71–122.

Mahapatra, A. K., Mishra, S., Basak, U. C., & Panda, P. C. (2012). Nutrient analysis of some selected wild edible fruits of deciduous forests of India: An explorative study towards non conventional bio-nutrition. *Advance Journal of Food Science and Technology, 4*(1), 15–21.

Mavengahama, S., McLachlan, M., & De Clercq, W. (2013). The role of wild vegetable species in household food security in maize based subsistence cropping systems. *Food Security, 5*, 227–233.

Maxson, E. D., & Rooney, L. W. (1972). Evaluation of methods for tannin analysis in sorghum grain. *Cereal Chemistry, 49*(6), 719–728.

Minuye, M. (2021). *Dried papaya processing; effect of drying methods and treatments of papaya on the nutrient retentions, sensorial quality, and shelf-life stability*.

Mir, M. Y. (2014). Documentation and ethnobotanical survey of wild edible plants used by the tribals of Kupwara, J & K, India. *International Journal of Herbal Medicine, 2*(4), 11–18.

Musa, K. H., Abdullah, A., Jusoh, K., & Subramaniam, V. (2011). Antioxidant activity of pink-flesh guava (*Psidium guajava* L.): Effect of extraction techniques and solvents. *Food Analytical Methods, 4*(1), 100–107.

Nielsen, S. S. (2017). Vitamin C determination by indophenol method. *Food analysis laboratory manual* (pp. 143–146). Springer.
Pourmorad, F., Hosseinimehr, S. J., & Shahabimajd, N. (2006). Antioxidant activity, phenol and flavonoid contents of some selected Iranian medicinal plants. *African Journal of Biotechnology, 5*(11).
Raghavendra, H. L., Prashithkekuda, T. R., & Chetan, D. M. (2018). Phytochemical analysis and in vitro antioxidant activity of *Rubus apetalus* Poir. (Rosaceae). *Pharmacology OnLine, 1*, 187–195.
Ribarova, F., Atanassova, M., Marinova, D., Ribarova, F., & Atanassova, M. (2005). Total phenolics and flavonoids in Bulgarian fruits and vegetables. *Journal of the University of Chemical Technology and Metallurgy, 40*, 255–260.
Rout, P., & Basak, U. C. (2015). Screening of antinutritional factors of nine underutilized wild edible fruits of Odisha. *Annals of Biological Sciences, 3*(4), 21–27.
Santos, C. A., Fonseca, J., Carolino, E., & Guerreiro, A. S. (2016). Serum trace elements in dysphagic gastrostomy candidates before endoscopic gastrostomy for long term enteral feeding. *Clinical Nutrition, 35*(3), 718–723.
Schjønning, P., Elmholt, S., & Christensen, B. T. (2004). *Managing soil quality: Challenges in modern agriculture*. CABI.
SDFPEDO. (2020). *Soro District Finance, Planning and Economic Development Office Annual summary of work report*. Soro, Haddiya zone: SNNPR. Unpublished.
Singh, J., Rajasekaran, A., Negi, A. K., Pala, N. A., Panwar, V. P., Bussmann, R. W., & Malik, Z. A. (2023). Potential of wild edible fruits for nutrition in indigenous communities of Northwest Himalaya, India. *Ethnobotany Research and Applications, 25*, 1–15.
Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture, 16*(3), 144–158.
Toh, J. J., Khoo, H. E., & Azrina, A. (2013). Comparison of antioxidant properties of pomelo [*Citrus grandis* (L) Osbeck] varieties. *International Food Research Journal, 20*(4).
Ukpabi, U., & Ejidoh, J. (1989). *Effect of Deep Oil Frying on Oxalates Contents and Degree of Itching of Cocoyam* (pp. 84–88). London: Computer Edge Publishers.
Umaru, H. A., Adamu, R., Dahiru, D., & Nadro, M. S. (2007). Levels of antinutritional factors in some wild edible fruits of Northern Nigeria. *African Journal of Biotechnology, 6*(16).
Uyoh, E. A., Ita, E. E., & Nwofia, G. E. (2013). Evaluation of the chemical composition of tetrapleura tetraptera (schum and thonn.) taub. Accessions from cross river state, Nigeria. *International Journal of Medicinal and Aromatic Plants, 3*(3), 386–394.
Williams, R. J., Spencer, J. P., & Rice-Evans, C. (2004). Flavonoids: Antioxidants or signalling molecules? *Free Radical Biology and Medicine, 36*(7), 838–849.
Yu, M., Gouvinhas, I., Rocha, J., & Barros, A. I. (2021). Phytochemical and antioxidant analysis of medicinal and food plants towards bioactive food and pharmaceutical resources. *Scientific Reports, 11*(1), 1–14.
Yumkham, S. D., Chakpram, L., Salam, S., Bhattacharya, M. K., & Singh, P. K. (2017). Edible ferns and fern–allies of North East India: A study on potential wild vegetables. *Genetic Resources and Crop Evolution, 64*, 467–477.