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Nutritional and anti-nutritional analysis of wild edible plants in Hassan district of Karnataka, India

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The nutritional potential of twelve wild edible plants of Hassan district was botanically identified and analysed for their nutritional and antinutritional values. The present study showed that the crude protein varied from 0.26±0.05 g/100 g to 5.88±0.55 g/100 g for different plant species. Vitamin C was high and found to have a maximum content in fruits of *Gardenia latifolia* (71.2±1.7 mg/100 g), *Buchanania lanzan* (47.34±1.33 mg/100 g), and *Canthium parviflorum* (21.7±1.18 mg/100 g). In contrast, the tubers of *Aponogeton echinatus* has rich in carbohydrates (26.50±0.34 g/100 g). In the various wild edible plants, the energy content ranged from 83 to 158.3 kcal/100 g. Also, the minerals quantified in the fruit *Grewia tiliifolia* contained a fair amount of potassium (1179.6±8.35 mg/100 g) followed by calcium in *Canthium parviflorum* (356.2±3.75 mg/100 g), phosphorus in *Buchanania lanzan* (263.7±4.63 mg/100 g). We also examined at total phenolic contents, which ranged from 13.30.88 mg/100 g to 582.31.45 mg/100 g in fruits of *Grewia tiliifolia* and tubers of *Dioscorea pentaphylla*, as well as anti-nutritional factors like oxalate, which was present lowest in the fruit of *Buchanania lanzan* (7.8±0.72 mg/100 g). The findings show that the wild edible plants used were a good source of nutrients and could be used as a nutrition source.

Keywords: Anti-nutritional factor, Hassan district, Mineral contents, Proximate analysis, Wild edible plants.

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Introduction

Plants are the primary source of food and medicine and are very important for survival besides protecting the environment. From the nomadic time of humankind, the food needs were met directly from nature, mainly from forest resources. During the hunting and gathering period of evolution, man must have collected the edible plants' knowledge by observation, practices, and way of a preferred test. In most underdeveloped and developing countries, the food availability of high nutritional resources is deteriorating due to increasing population and fertile land[1]. These resulted in a high rate of food shortage and malnutrition. So the search for new sources of food and its nutritional content will be of value in the management of nutritional problems and shortage of food[2]. Food security is a severe threat in low-income families; people often under privileged of nutrient-rich foods and on the other hand by high levels of poverty, limited accessibility to diverse diets, and have to exclusively depend upon wild edible plants, minor food crops grown by local small and marginal farmers[2,3]. Most people living in rural and remote areas meet their nutritional requirements by regularly consuming wild, uncultivated plants and their parts such as leafy shoots, fruits, seeds, tubers, corms, roots, flowers, and tender stem[4]. They tend to supplement proteins, necessary minerals, micronutrients, and vitamins that improve dietary consistency[5] and provide rural and semi-urban households across cultures and continents with an accessible source of nutrition[6]. Consequently, there is no proper arbitration that seeks to encourage people to use traditionally known wild edible plants as sources of nutrients. Wild plants have been an object of numerous studies regarding the nutritional composition of wild edible plants in India[7-9]. Quite many commonly cultivated leafy vegetables, fruits, and tubers of nutritional values have been reported[10]. There is growing interest in evaluating the nutritional values of the various wild edible plants. However, many wild edible plants are commonly used by local people and whose nutritional values yet to be studied. As a region of a high level of

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biodiversity, the Western Ghats is currently at the risk of rapid loss of wealthy genetic resources[11]. The Western Ghats have a large number of wild relatives of cultivated crops and many less exploited crops known to local tribes. Many wild plants are thought to have edible values; however, they are not yet documented[12]. Many genetically diversified wild species in the tropical forests and nearby villages have yet to be explored, and the requisite steps need to be taken to conserve it[13]. Hassan district is the reservoir of nutritionally and therapeutically rich flora, shares a significant segment of the global hot spot in the Western Ghats of Karnataka. In this district, approximately 1,700 vascular plant species harbouring the richness of biological diversity account for 75% of the plant species of Karnataka and 10% of the plant species of India[14]. A wide variety of undomesticated flora integrated as a culture and tradition among the dwellers in the forest fringe region and the local inhabitants. Wild edible plants related to traditional knowledge are rapidly eroding, and traditional knowledge regarding wild edible plant research is still limited to specific cultures and region[15]. Still, many inexpensive wild edible plants are used by rural people, and their nutritional values are not yet been studied. The objective of the present study is to determine the nutritional value, minerals substance, and antinutritional content of 12 wild edible plant species, namely, *Aponogeton echinatus* (Keregedde), *Ceropegia tuberosa* (Guttalu), and *Dioscorea pentaphylla* (Kaadu gumbala) tubers; *Buchanania lanzan* (Murakal hannu), *Gardenia latifolia* (Aare bikkehannu), *Canthium parviflorum* (Karehannu), *Grewia tiliifolia* (Tadasalu hannu) and *Phoenix humilis* (Sanna echalu) fruits; *Cyanotis cristata* (Betta kannesoppu), *Hybanthus enneaspermus* (Hullekaramevu) and *Remusatia vivipara* (Marakesu) leaves; *Caralluma adscendens* (Manganakodu) tender stem, are most commonly and widely consumed in the rural people of Hassan district (Table 1 and Fig 1).

Table 1 — Description of the wild edible plants used in the present study

Botanical names/family names Accession No	Local name (Kannada)	Parts used	Seasons of availability	Preparation and consumption practices
Aponogeton echinatus Roxb. (Aponogetonaceae) RRCBI-8763	Keregedde	Tubers	March	Tubers are taken as in the boiled or roasted form.
Buchanania lanzan Spreng. (Anacardiaceae) RRCBI-16058	Murakal hannu	Fruits	Jan.-Mar.	Fruit eaten as raw.
Canthium parviflorum Lam. (Rubiaceae) RRCBI-13246	Karehannu	Fruits	June-Aug.	Fruit eaten as raw.
Caralluma adscendens (Roxb.) R. Br. (Asclepiadaceae) RRCBI-14414	Manganakodu	Tender stems	March-Aug.	The tender stems are used as a vegetable and also eaten as raw
Ceropegia tuberosa Roxb. (Asclepiadaceae) RRCBI-8623	Guttalu	Tubers	June-Oct.	Tubers are taken as in boiled or roasted form
Cyanotis cristata (L.) D. Don. (Commelinaceae) RRCBI-523	Betta kanne soppu	Leaves	July-Nov.	Leaves are chopped, boiled, and seasoned with chopped onion, garlic, and pieces of dry red chili and cook along with chopped beans and dal by adding a teaspoon of turmeric, boil
Dioscorea pentaphylla L. (Dioscoreaceae) RRCBI-15453	Kaadu gumbala	Tubers	July-Jan.	Tubers are sliced, boiled with tamarind, flirted out and cooked with onion
Gardenia latifolia Aiton (Rubiaceae) RRCBI-15978	Aare bikke hannu	Fruits	Jan.-Mar.	Fruit eaten as raw
Grewia tiliifolia Vahl. (Tiliaceae) RRCBI-14249	Tadasalu hannu	Fruits	Mar.-Aug.	Fruit eaten as raw
Hybanthus enneaspermus (L.) F.V. F. Muell. (Violaceae) RRCBI-15257	Hulle kara mevu	Leaves	July-Dec.	Leaves are ground and used in *dosa* preparation.
Phoenix humilis (L.) Cav. (Arecaceae) RRCBI-6872	Sanna echalu	Fruits	April-May	Fruit eaten as raw
Remusatia (Roxb.) Schot. (Araceae) RRCBI-6728	Marakesu	Leaves	January	Tender leaves are washed thoroughly; each leaf is rolled thin and tied to knots, chopped onions, black pepper, grated coconut, green chilies are blended to a thick paste and then ground paste, add a pinch of turmeric powder and salt it

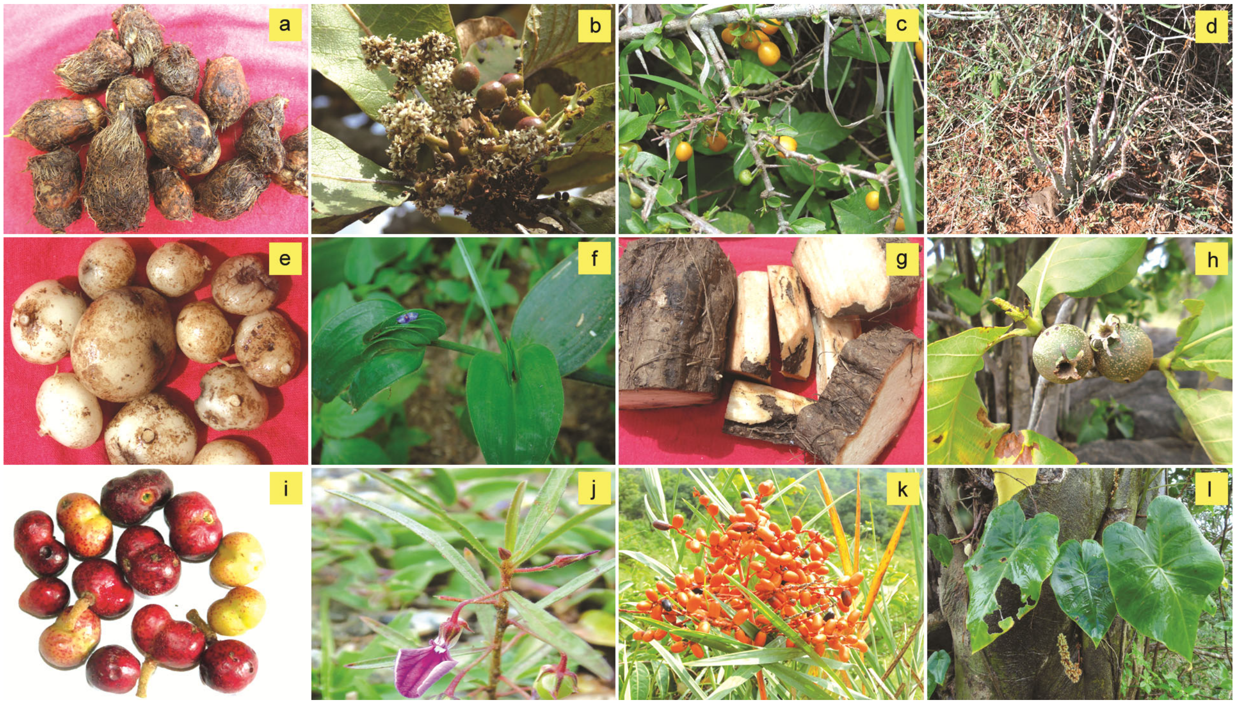

Fig. 1 — a) *Aponogeton echinatus*, b) *Buchanania lanzan*, c) *Canthium parviflorum*, d) *Caralluma adscendens*, e) *Ceropegia tuberosa*, f) *Cyanotis cristata*, g) *Dioscorea pentaphylla*, h) *Gardenia latifolia*, i) *Grewia tiliifolia*, j) *Hybanthus enneaspermus*, k) *Phoenix humilis*, and l) *Remusatia vivipara*.

Materials and Methods

Study area

Hassan district, Karnataka, begins at the base of the Western Ghats. It is located between $12^0 13^1$ and $13^0 33^1$ N and $75^0 33^1$ and $76^0 38^1$ E. The wide variation in climate and vegetation and can be divided into wet, the evergreen tropical rain forest in Malnad, and dry tropical scrub forests in Maidan areas constitute about 4.5 and 26%. Hassan district is noted for its rich diversity of plant species with a high rate of endemism in flowering plants. It has produced a large number of plants of enormous economic value.

Collection and identification

Surveys and collection of wild edible plants used by the local people of the Hassan district of Karnataka, India, have been carried out. The majority of this study's information was collected from the villagers and the tribal people using these wild edible plants as their regular food and livelihood. Botanical identification of the species was done with flora[14] and authentic herbarium specimens of RRCBI, Survey of Medicinal Plants Unit, CARI, Bengaluru. The most commonly and frequently consumed wild edible plant parts of 12 food plant species were subjected to nutritional analysis. Identified plants such as leaves of 3 species, tubers of 3 species, the fruits of 5 species, and tender stems of 1 species were selected for nutritional analysis in the present study (Table 1 & Fig. 1).

Preparation of plant materials

To analyse the nutritional values of plants mentioned in Table 1, healthy and infection-free samples such as tubers, fruits, leaves, and tender stems were collected. All the samples were washed meticulously to remove soil, and other extraneous substances then blotted dry. Later all the samples were cut into small pieces and shade dried. Dried samples were ground finely in a Wiley mill (Scientific Equipment Works, New Delhi) to 60-mesh size. Care was taken to clean the mesh thoroughly after powdering each sample to avoid mixing up of samples. To further use, powdered samples are stored in a screw cap bottle. However, vitamin C was analysed using fresh samples, ground with 6% meta-phosphoric acid, and stored in the freezer until analysis.

Proximate nutritional analysis

The moisture content, ash, crude fat, and crude fibre were determined by AOAC methods[16]. The moisture content was determined by sample material taken in a flat bottomed dish and kept overnight in a hot air oven at 100-110^0 C and weighed; the weight loss was regarded as a measure of moisture content. The ash content was determined by combusting the plant material in silica crucibles in a muffle furnace (High-Temperature Muffle Furnace-EMF-1H) at 620 °C for 3 hours. Crude protein was determined using routine Kjeldahl nitrogen assay (N x 6.25). The crude fibre was quantified by calculating weight loss on ignition of dried residue following the digestion of fat-free samples with sulfuric acid and sodium hydroxide solution. Carbohydrate (g/100 g) was estimated by using a different method by subtracting the per cent of protein, moisture, fat, and ash from 100. Vitamin C was determined by a reduction method using 2, 6-dichlorophenol indophenol dye, which turns blue in alkaline solution and red in acid solution and is reduced to a colourless by the addition of ascorbic acid[17]. Energy content was obtained by the summation of the multiplied mean value for protein, fat, and carbohydrate by their respective At water factor 4, 9, and 4. All results for proximate compositions were recorded as the basis of edible portion dry weight of the sample as g/100 g.

Estimation of minerals

The samples were digested in the muffle furnace, and ash was dissolved in a 10% nitric acid solution. The dissolved sample was transferred to a 250 mL volumetric flask, and the volume was made up with distilled water and then filtered. The filtrate was used for the further estimation of minerals. Sodium and potassium were estimated by using a flame photometer (Jenway-PFP-7 FPM). Phosphorus was estimated calorimetrically using potassium dihydrogen phosphate as the standard[17]. The samples were analysed for calcium, magnesium, copper, and iron using flame atomic absorption spectrophotometer[17] (Model No. AA-6400 F, Shimadzu Corporation, Japan). Each element's standard solution was prepared, and calibration curves were drawn for each element using AAS/FPM. All the results of mineral composition were recorded based on their edible portion of the sample as mg/100 g dry weight.

Analysis of total free phenolic contents and anti-nutritional compounds

Total phenolic contents were determined according to the Folin-Ciocalteu procedure as gallic acid equivalent (GAE) in mg/g dry weight of extract (DE). Tannin content was determined by modified vanillin-HCL method[18] using phloroglucinol as a standard at 500 nm. Total oxalate was analysed by extraction with hydrochloric acid and soluble oxalate with water, followed by precipitation with calcium oxalate from the deproteinized extract and subsequent titration with potassium permanganate[19].

Statistical analysis

All experiments were carried out in triplicates for each nutrient analysis and all the data were presented as mean±standard error (SE). One-way analysis of variance (ANOVA) followed by Tukey's post hoc test and Least Significant Difference (LSD) was used to identify significant differences (P <0.05) using Statistical Package for Social Sciences (SPSS) version 16.

Results and Discussion

Proximate nutritional analysis

The rural people of Hassan district are solely dependent on wild edible plants in their diet. The edible parts of the 12 food plants listed in Table 1 were subjected to nutritional analysis. Selected leaves, tubers, fruits, and tender stems, had reasonable nutritional value. Data on proximate composition of the wild edible fruits, tubers, leaves, and tender stem shown in Table 2. The moisture content in nourishment includes the measure of water present in the sustenance and decides the nourishment's genuine nature before utilization. The highest moisture content was found in the fruits of *Phoenix humilis* (79.66±1.85 g/100 g), a tender stem of *Caralluma adscendens* (79.66±0.88 g/100 g), and least in tubers of *Aponogeton echinatus* (66.3±0.52 g/100 g). In general, leafy vegetables were characterized with high water content; the maximum amount of moisture content in leaves was found in *Cyanotis cristata* (75.13±0.63 g/100 g) and least in *Remusatia vivipara* (70.56±0.86 g/100 g). The moisture content in food involves the amount of water present in the food and regulates the food's actual quality before consumption. Moisture content affects the physical, chemical features of food, which relates to the food storage's freshness and stability for an extended period of time[20]. The moisture content estimated in these wild edible plants was comparable to the moisture content reported to some regular fruits, leafy vegetables, and tubers such as mango (87%), spinach (90%), and potato (80%), cultivated in India[10]. The ash content of the wild edible plants was discovered most noteworthy (4.7±0.44 g/100 g) in the tender stem of *Caralluma adscendens,* followed by leaves of *Hybanthus enneaspermus* (3.86±0.20 g/100 g), fruits and tubers of other species contain less ash content. The absolute mineral substance in sustenance is

Table 2 — Proximate composition of selected wild edible plants studied (g/100 g)

Plant species/ parts used	Moisture	Ash	Crude protein (Nx6.25)	Crude fat	Crude fibre	Total carbohydrate *	Vitamin-C**(mg)	Energy content*** kcal
Aponogeton echinatus (Tubers)	66.3±0.52^{d}	2.5±0.15^{cd}	2.9±0.08^{bcde}	1.73±0.04^{de}	2.8±0.04^{c}	26.50±0.34^{a}	2.75±0.1^{e}	133.3±1.45
Buchanania lanzan (Fruits)	69.86±0.86^{cd}	1.9±0.05^{de}	5.9±0.55^{a}	9.0±0.08^{a}	1.0±0.05^{de}	13.3±0.98^{ef}	47.34±1.33^{b}	158.3±3.75
Canthium parviflorum (Fruits)	71.56±0.46^{bc}	0.46±0.02^{f}	0.93±0.2^{fg}	0.91±0.01^{f}	2.76±0.06^{c}	26.13±0.52^{ab}	21.7±1.18^{c}	116.6±2.0
Caralluma adscenden (Tender stems)	79.66±0.88^{a}	4.7±0.44^{a}	0.26±0.05^{g}	4.45±0.24^{c}	0.38±0.07^{e}	10.93±1.11^{f}	3.1±0.37^{e}	85±2.0
Ceropegia tuberosa (Tubers)	69±1.10cd^{cd}	3.06±0.17^{bc}	2.13±0.14^{cde}	1.03±0.03^{ef}	1.52±0.09^{d}	24.76±1.21^{abc}	6.38±0.12^{e}	117±4.93
Cyanoti scristata (Leaves)	75.13±0.63^{b}	1.10±0.11^{ef}	1.96±0.08^{def}	7.52±0.38^{b}	8.12±0.10^{b}	14.26±0.14^{ef}	21.79±1.64^{c}	132.6±4.0
Dioscorea pentaphylla (Tubers)	68.39±0.47^{cd}	2.55±0.17^{cd}	3.2±0.17^{bc}	1.92±0.01^{d}	2.7±0.07^{c}	23.96±0.44^{abc}	4.8±0.17^{e}	125.6±1.66
Gardenia latifolia (Fruits)	72.14±0.69^{bc}	1.09±0.1^{ef}	2.0±0.28^{def}	0.75±0.03^{f}	0.27±0.01^{e}	24±0.95^{abc}	71.2±1.7^{a}	111±2.30
Grewia tiliifolia (Fruits)	72.66±0.75^{bc}	2.03±0.14^{d}	3.13±0.3^{bcd}	0.81±0.02^{f}	2.57±0.13^{c}	21.35±0.8^{bcd}	15.6±0.69^{d}	105.3±3.48
Hybanthus enneaspermus (Leaves)	72.08±0.37^{bc}	3.86±0.20^{ab}	1.93±0.14^{ef}	1.64±0.03^{de}	10.53±0.4^{a}	20.5±0.35^{cd}	6.62±0.30^{e}	104.3±0.88
Phoenix humilis (Fruits)	79.66±1.85^{a}	0.37±0.01^{f}	1.89±0.05^{ef}	0.61±0.07^{f}	3.1±0.15^{c}	17.44±2de	7.57±0.28^{e}	83±7.0
Remusatia vivipara (Leaves)	70.56±0.86^{cd}	2.74±0.03^{cd}	3.83±0.23^{b}	1.09±0.07^{ef}	2.66±0.17^{c}	21.8±1.07^{abcd}	14.06 ±0.59^{d}	112.6±3.75

*Calculated by difference. ** Vitamin C based on 100 g fresh weight, all other parameters based on 100 g dry weight *** Calculated by using Atwater factors. Each value in the table was obtained by calculating the average of three experiments and data are presented as mean±SEM. Statistical analysis was carried out by Tukey's test at 95% confidence level and statistical significance were accepted at the P <0.05 level. The superscript letter a, b, c, d and e denotes the significant differences within the same parameters of the individual plant. SEM: Standard error of the mean.

referred to as ash content. The apparent amount was evaluated in different plant parts, demonstrating that the wild edible leaves, fruits, and tubers were wealthy in minerals and our eating routine can give many mineral components. Proteins are one of the most significant supplements required by the body and should be supplied in an adequate diet. Dietary proteins are required by the body for a variety of functions, including the best possible working of antibodies against infection, enzymes, and hormones, development, and body tissue repair[21]. The measure of unrefined protein substance was recognized most noteworthy in the fruit of *Buchanania lanzan* (5.88±0.55 g/100 g) and least in the tender stems of *Caralluma adscendens* (0.26±0.05 g/100 g). Different plant parts under scrutiny, viz., *Remusatia vivipara*, *Gardenia latifolia,* and *Dioscorea pentaphylla,* also contained an excellent protein measure 3.83±0.23, 3.13±0.3, and 3.2±0.17 g/100 g, respectively. These values were similar for protein content in cultivated leafy vegetables and tuber species of *Dioscorea*[10,22]. Fat is a vital part of routine eating, it provides simple unsaturated fats that the body cannot produce and should be obtained through nutrition. Linoleic acid and linolenic acid, essential for controlling aggravation, blood coagulation, and mental wellbeing, are the basic unsaturated fats. It also fills in as the ability portion for the extra calories of the body. Aside from these, fat in the eating regimen is significant for retaining fat-soluble nutrients such as Vitamin A and carotene in the body[21]. Fruits are essential components of a low-calorie diet due to their low-fat content. All wild edible fruits exhibit low crude fat levels, except *Buchanania lanzan* (9.0±0.84 g/100 g). The considerable measure of fat recognized in leaves of *Cyanotis cristata* (7.52±0.38 g/100 g) alongside a significant amount in different plant parts under scrutiny such as tubers of *Dioscorea pentaphylla* (1.92±0.01g/100 g) is found similar to the reports of *Dioscorea hispida* (1.9 g/100 g) and lower than tuber of *Dioscorea oppositifolia* (4.40g/100 g)[23].

Tubers are rich fibre springs with important health implications for preventing overweight, obstruction, diabetes, serum cholesterol, and heart disease, malignancies in the body and colon, and hypertension[24]. The World Health Organization (WHO) has proposed the admission of 22–23 kg of fibre per 1000 kcal of diet, which is vital for the processing and viable removal of squanders[22,25]. The wild edible plants' crude fibre substance was least in fruits of *Gardenia latifolia* (0.27±0.01 g/100 g) and maximum in leaves of *Hybanthus enneaspermus* (10.53±0.4 g/100 g), followed by *Cyanotis cristata* (8.12±0.10 g/100g). All wild edible plants studied have excellent crude fibre contents, which are comparable to and mostly higher than those of cabbage (3.76%), lettuce (1.79%), apple (2.54%), and carrot (4.18%)[10]. As a result, these wild edible plants could be used in the human eating routine to meet the WHO recommendation[25]. The most elevated carbohydrate measure was identified in the tubers of *Aponogeton echinatus* (26.48±0.36 g/100 g), while the most minimal was found in the tender stem of *Caralluma adscendes* (10.93±1.11g/100 g). Wild edible tubers such as *Ceropegia tuberosa* (24.76±1.21g/100 g) and *Dioscorea pentaphylla* (23.96±0.44 g/100 g) are good sources of carbohydrate. These results were aggregable with an earlier report of *Dioscorea pentaphylla*[22]. An excellent measure of carbohydrate was likewise present in other palatable plants and all around contrasted with cultivated eatable plants such as potato (14.89%), sweet potato (24.25%), tapioca (17.81%), and sapota (13.90%)[21]. Hence, these edible wild plants under investigation could be a decent source of carbohydrates for human use. Vitamin C is the most significant nutrient and it is excellent for its properties as a preventative agent for cancer, inorganic iron absorption, plasma cholesterol level reduction, immune system enhancement. Preventing scurvy and preserving solid skin, gums and veins are necessary, and the inadequacy of this nutrient causes illness, death, dry skin, and depression[9]. The outcome showed that vitamin C measurements (ascorbic acid) were evaluated in all plants under scrutiny ranged from 2.75±0.1 mg/100 g in tubers of *Aponogeton echinatus* to 71.2±1.7 mg/100 g in the fruit of *Gardenia latifolia.* In general, wild edible fruits are usually smaller than cultivated fruits, some are sour, and they are the source of vitamin C[26] Fruits are often recommended for their high vitamin C content and found maximum in the fruits of *Gardenia latifolia* followed by *Buchanania lanzan* (47.34±1.33 mg/100 g) and *Canthium parviflorum* (21.7±1.18 mg/100 g). The quantity of vitamin C relies on the stage of maturity, and the variable value may be based on the ripeness of the fruit[27]. In the present study, the energy content ranged from 83 to 158.3 kcal/100 g of dry sample. Similar energy content, which ranged between 80 to 148 kcal/100 g, was obtained in another study of wild edible plants of North East India[28]. The high calorific value is a clear indication that these wild plants can be used as foods in a diet. Therefore, the energy content agreement with the general observation that vegetables have low energy values[29]. The results of the investigation revealed that these plants had higher nutritional potential than common leafy vegetables and tubers such as cabbage (90 kcal/100 g), spinach (102 kcal/100 g), beetroot (149 kcal/100 g), and radish (134 kcal/100 g)[10].

Estimation of minerals

The data on the estimation of minerals in wild edible fruits, tubers, leaves, and tender stems are presented in Table 3. Minerals are essential for vital body functions such as acid-base and water balance. It is reported that the wild edible species are a good source of minerals for the local inhabitant in different parts of the world[30]. The location of growth or the year of harvest did not differ substantially. Minor

Table 3 — Mineral content of selected wild edible plants studied (mg/100 g)

Plant species/parts used	Sodium	Potassium	Calcium	Phosphorus	Magnesium	Iron	Magnesium	Copper
Aponogeton echinatus (Tubers)	44.1±0.94^{g}	939.33±4.09^{d}	267.66±4.9^{b}	70.45±1.23^{c}	123.3±1.2^{d}	28.93±0.6^{c}	123.3±1.2^{d}	1.3±0.02^{ef}
Buchanania lanzan (Fruits)	135.86±1.7^{c}	82.3±1.4^{i}	250.3±3.52^{b}	263.7±4.63^{a}	105±3.08^{e}	8.7±0.1^{e}	105±3.08^{e}	0.42±0.00^{g}
Canthium parviflorum (Fruits)	137.0±1.6^{c}	1034.3±7.7^{c}	356.2±3.75^{a}	12.14±0.68^{f}	126.2±1.17^{d}	16.6±0.19^{d}	126.2±1.17^{d}	7.13±0.08^{c}
Caralluma adscendens (Tender stems)	179.83±1.03^{b}	27.63±2.02^{j}	72.33±2.96^{fg}	37.55±0.99^{d}	203.0±4.58^{c}	52.1±0.26^{a}	203.0±4.58^{c}	8.66±0.04^{b}
Ceropegia tuberosa (Tubers)	30.84±0.6^{hi}	123.26±1.46^{h}	15.4±0.36^{h}	16.83± 0.5^{ef}	17.9±0.98^{i}	2.19±0.06^{g}	17.9±0.98^{i}	17.3±0.33^{a}
Cyanotis cristata (Leaves)	22.25±0.6^{i}	426.7±3.52^{e}	87.6±0.92^{f}	20.46±0.65^{ef}	70.51±0.9^{f}	8±0.08^{ef}	70.51±0.9^{f}	0.28±0.01^{g}
Dioscorea pentaphylla (Tubers)	93.1±1.72^{d}	1116.3±9.2^{b}	70.3±1.25^{fg}	87.55±2.53^{b}	321.3±5.81^{b}	1.16±0.01^{g}	321.3±5.81^{b}	6.13±0.09^{d}
Gardenia latifolia (Fruits)	34.44±1.54^{h}	221±2.08^{g}	58.1±1.27^{g}	14.36±0.43^{ef}	41.4±1.35^{g}	32.6±1.33^{b}	41.4±1.35^{g}	0.64±0.27^{fg}
Grewia tiliifolia (Fruits)	243.53±5^{a}	1179.6±8.35^{a}	116.7±3.38^{e}	23.3±1.88^{e}	350.7±4^{a}	32.8±0.67^{b}	350.7±4^{a}	1.87±0.03^{e}
Hybanthus enneaspermus (Leaves)	67.50±1.25^{e}	15.02±0.42^{j}	23.89±0.55^{h}	12.67±0.4^{f}	15.90±0.64^{i}	6.07±0.09^{f}	15.90±0.64^{i}	0.28±0.01^{g}
Phoenix humilis (Fruits)	7.57±0.28^{j}	430.7±12.9^{e}	163.7±10.5^{d}	38.9±0.64^{d}	27.0±1.73^{hi}	8.1±0.30^{ef}	27.0±1.73^{hi}	0.22±0.00^{g}
Remusatia vivipara (Leaves)	57.46±1.58^{f}	263.33±3.38^{f}	210.8±10.4^{c}	75.23±1.42^{c}	34.3±1.23^{gh}	15.27±2.5^{d}	34.3±1.23^{gh}	0.3±0.00^{g}

Each value in the table was obtained by calculating the average of three experiments and data are presented as mean±SEM. Statistical analysis was carried out by Tukey's test at 95% confidence level and statistical significance were accepted at the P <0.05 level. The superscript letter a, b, c, d and e denotes the significant differences within the same parameters of the individual plant. SEM: Standard error of the mean.

variations can be explained by the soil and the climate[30]. The most noteworthy measure of potassium (K) concentration was recognized in fruits of *Grewia tiliifolia* (1179 ±8.35 mg/100 g) followed by tubers of *Dioscorea pentaphylla* (1116.3±9.2 mg/100 g) and fruits of *Canthium parviflorum* (1034.3±7.7 mg/100 g). The leaves of *Hybanthus enneaspermus* contain the least amount (15.02±0.42 mg/100 g), which is higher than earlier report[31]. Sodium plays a significant role in the metabolite vehicle, and potassium is essential for its diuretic existence. There would be high sodium (Na) groupings available ranging from 7.57±0.28 mg/100 g in the fruit of *Phoenix humilis* to 179.83±1.03 mg/100 g in the tender stem of *Caralluma adscendens.* Calcium constitutes a large proportion of the bone, human blood, and extracellular fluid. It is particularly needed for heart muscles' normal functioning, blood coagulation, milk thickening, and cell permeability[32]. The grouping of calcium was most astounding in the fruits of *Canthium parviflorum* (356.2±3.75 mg/100 g) trailed by tubers of *Aponogeton echinatus* (267.66±4.9 mg/100 g) and the fruits of *Buchanania lanzan* (250.3±3.52 mg/100 g). Calcium levels in cultivated fruits and vegetables varied widely between 10 to 364 mg[21]. The data show that the wild edible plants used in this study are rich in calcium and could be a good source of calcium in our diet. A fair amount of phosphorous content was found in the fruit of *Buchanania lanzan* (263.7±4.63 mg/100 g), followed by leaves of *Remusatia vivipara* (75.23±1.42 mg/100 g). These values were similar to those reported for apricot (72.02±6.39 mg/100 g), dates (73.02±10.73 mg/100g), amaranthus(73.22±12.66 mg/100 g), and cauliflower leaves (62.82±2.98 mg/100gm)[10]. Magnesium (Mg) is particularly essential in the human body to maintain typical nerve and muscle work. The maximum magnesium content was found in the fruit of *Grewia tiliifolia* (350.7±4 mg/100 g) and tuber of *Dioscorea pentaphylla* (321.3±5.81 mg/100 g). Thus, the regular use of magnesium-rich plants regulate blood glucose levels and promotes a sound, unsusceptible system[9]. Iron is essential for haemoglobin formation in red blood cells that bind and transport oxygen in the body for immune function and nerve health and is also a cofactor in various reactions[33]. The routine use of iron-rich vegetables and fruits will prevent anaemia. The maximum amount of iron was available in the tender stem of *Caralluma adscendens* (52.1±0.2 mg/100 g) followed by the fruit of *Grewia tiliifolia* (32.8±0.67 mg/100 g), *Gardenia latifolia* (32.6±1.33 mg/100 g), and tuber of *Aponogeton echinatus* (28.93±0.6 mg/100 g), which are significantly higher than some cultivated fruits and tubers. The iron content of three green leaves, *Remusatia vivipara*, *Cyanotis cristata,* and *Hybanthus enneaspermus,* was found to be high 15.27±0.4, 8±0.08, and 6.07±0.09 mg/100 g, respectively. The iron content in the wild edible leaves was high and similar values (11.12 to 45.84 mg/100g) have been reported for some commonly and wildly consumed leafy vegetables[9]. However, to meet the recommended amount, 50-100 g (fresh weight) of iron-rich species will be needed. The consumption of iron-rich species should be a food of choice for local people suffering from iron deficiency anaemia. An adequate measure of copper was available in the tubers of *Ceropegia tuberosa* (17.3±0.33 mg/100 g) and *Dioscorea pentaphylla* (6.13±0.09 mg/100 g). Copper is a component of several enzymes and has also been recorded in various *Dioscorea* tubers species, with values as high as 9.4 mg/100 g (*Dioscorea bulbifera*) and 7.1 mg/100 g (*Dioscorea remotiflora*), respectively[34].

Total free phenolic contents and anti-nutritional compounds

Preliminary evaluation of total phenolic contents is expressed as mg gallic acid equivalent (GAE)/g dry extract, and antinutritional factors such as oxalate and tannins in raw tubers, leaves, fruits, and tender stems are presented in Table 4. The phenolic content of the tubers of *Dioscorea pentaphylla* (582.3±1.45 mg/g GAE) and *Ceropegia tuberosa* (347±2.6 mg/g GAE) was higher than that of other wild edibles plants studied. The total phenolic content in *Dioscorea pentaphylla* was higher than *Dioscoreahamiltonii* (158.2 mg/mL), which contributed to the significantly better antioxidant, anti-inflammatory, and immune regulation effects of *Dioscoreaoppositifolia* and *Dioscorea hamiltonii*[23]. Antioxidant molecules can neutralize the reactive free radicals and prevent chronic diseases, including diabetes, cancers, cardiovascular diseases, neurodegeneration, and inflammatory mediated diseases. Therefore a diet supplemented by different wild edible plants can supply different antioxidant molecules and then provide preventive measures. Thus, as a source of rich natural antioxidants, these wild edible plants should be brought to the general populations' attention as important health-promoting foods[35]. Anti-nutritional factors are the naturally occurring chemical compounds synthesized by normal metabolism, which reduces the nutrient utilization by the body[36].

Table 4 — Total free phenolic contents and anti-nutritional compounds in selected wild edible plants studied (mg/100 g)

Plant species/parts used	Total free phenolic contents (mg GAE/g)	Anti-nutritional compounds	
		Tannin	Oxalates
Aponogeton echinatus (Tubers)	253.5 ± 1.80^{c}	156.1 ± 1^{b}	145.5 ± 1.7^{c}
Buchanania lanzan (Fruits)	17.33 ± 1.45^{gh}	14 ± 1.15^{g}	7.8 ± 0.72^{i}
Canthium parviflorum (Fruits)	23 ± 1.15^{g}	13.6 ± 0.8^{gh}	21 ± 1.15^{h}
Caralluma adscendes (Tender stem)	135.6 ± 1.85^{d}	112 ± 1.4^{c}	125 ± 2^{d}
Ceropegia tuberosa (Tubers)	347 ± 2.64^{b}	116.3 ± 0.8^{c}	273.8 ± 0.92^{a}
Cyanotis cristata (Leaves)	79.33 ± 3.52^{e}	27.8 ± 1.3^{f}	97.3 ± 0.66^{f}
Dioscorea pentaphylla (Tubers)	582.3 ± 1.45^{a}	336 ± 2.1^{a}	244.3 ± 2.02^{b}
Gardenia latifolia (Fruits)	$25.6\pm.0.88^{g}$	9.6 ± 0.8^{gh}	13.56 ± 0.72^{i}
Grewiati liifolia (Fruits)	13.3 ± 0.88^{h}	7.3 ± 0.88^{h}	10.3 ± 0.88^{i}
Hybanthus enneaspermus (Leaves)	38 ± 1.15^{f}	94.5 ± 1.3^{d}	61.3 ± 1.45^{g}
Phoenix humilis (Fruits)	22.3 ± 1.2^{g}	14.3 ± 1.2^{g}	10.3 ± 0.8^{i}
Remusatia vivipara (Leaves)	73 ± 0.86^{e}	76 ± 1.4^{e}	116.6 ± 2^{e}

Each value in the table was obtained by calculating the average of three experiments and data are presented as mean±SEM. Statistical analysis were carried out by Tukey's test at 95% confidence level and statistical significance were accepted at the $P<0.05$ level. The superscript letter a, b, c, d and e denotes the significant differences within the same parameters of individual plant. SEM: Standard error of the mean

Anti-nutritional factors affect the bioavailability of dietary nutrients, particularly proteins, minerals, and vitamins, and reduce the nutritional value. The wild tubers are acridly containing various antinutritional factors associated with skin irritation and inflammation of the buccal cavity and throat after consumption. Oxalate, tannin is considered antinutritional factors in tubers, leaves, and fruits responsible for toxicity and bitterness[37]. The tubers of *Dioscorea pentaphylla*, *Ceropegia tuberosa, Aponogeton echinatus* and the young stem of *Caralluma adscendes*, are found to contain the highest quantity, the findings are consistent with previous research in tubers of *Dioscorea*[22]. Most of the wild tubers were boiled and consumed, prolonged boiling reduces the bitter taste concentration. The levels of oxalate varied greatly between species and ranged from 7.8 to 273 mg/100 g, the oxalate content was lower in fruits of *Buchanania lanzan* (7.8±0.72 mg/100 g) and highest in tubers of *Dioscorea pentaphylla* (244±2 mg/100 g) and *Ceropegia tuberosa* (273±0.9 mg/100 g) compared to earlier studies in the tubers of *Dioscorea bulbifera* (67 mg/100 g) and *Dioscorea deltoidea* (197 mg/100 g)[36]. In the form of calcium oxalate, oxalate is present and widely distributed in plants. Oxalic acid strongly binds to dietary minerals such as Ca, Mg, Na, and K, resulting in oxalate salts. In the kidney and urinary tract, insoluble calcium oxalate salts precipitate and form calcium oxalate crystals that trigger kidney stones. Nutritional deficiency and severe throat inflammation are caused by greater oxalate concentration in food. Owing to the presence of calcium oxalate crystals, the tubers' mucilage induces skin and mucous membrane irritation. A higher oxalate content causes skin irritation and the throat's inflammation has been reported in the *Dioscorea* species[36,37]. The tannin contents are found to be highest in tubers of *Dioscorea pentaphylla* (336±2.1 mg/100 g), higher to earlier reports in the tubers of *Dioscorea alata* (410 mg/100 g) and lowering to *Dioscorea oppositifolia* (240 mg/100 g)[34]. The higher tannin content influences the food's protein quality and interferes with the absorption of iron. The bitterness in them is due to the presence of tannins[37]. Compared with leaves and tubers, the analysed wild edible fruits such as *Buchanania lanzan*, *Canthium parviflorum*, *Gardenia latifolia, Grewia tiliifolia* and *Phoenix humilis* contained lower levels of analyzed antinutrients, so they are highly recommended for consumption.

Conclusion

The rural people have in-deep knowledge about the use of wild edible plants, but without any scientific context, they use them. From the present investigations, it can be concluded that these wild edible plants have significant nutritional value and antinutritional properties. The benefits of wild edible plant resources to rural people in the Hassan district cannot be ignored. Besides, studies are required to identify local preferences for edible plant species and promote their cultivation, popularization, and commercial use.

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Conflict of interest

The authors have no conflicts of interest to declare.

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