Antioxidant and nutritional potential of some underutilized leafy vegetables consumed by tribals of Jharkhand, India

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In the present study, 20 species of local underutilized leafy vegetables commonly consumed by tribals of Jharkhand, India have been identified through market survey of seven districts of the state. Among the leafy vegetables sold in fresh form, *Amaranthus gangeticus* was found highest in quantity followed by *Amaranthus viridis*, *Ipomoea aquatica, Chenopodium album* and *Basella alba*. Amongst those sold in dried form, *Cassia tora* was found highest in quantity followed by *Vangueria spinosa* and *Ipomoea batatas*. The leafy vegetables were found to be rich in antioxidant activity, vitamin C and various minerals.

Keywords: Antioxidants, leafy vegetables, nutritional potential, underutilized.

THE state of Jharkhand is rich with respect to the diversity of underutilized green leafy vegetables that are commonly consumed by the natives. These vegetables are nutritionally rich and adapted to low-input agriculture. A sizable proportion of these underutilized leafy vegetables is not cultivated and is collected from the wild. The term 'underutilized' is commonly applied to refer to species whose potential has not been fully realized. The underutilized plant species are traditionally used for their food, fibre, fodder, oil or medicinal properties. They have local or regional importance, but generally lack national recognition and appreciation. However, these species have under-exploited potential to ensure food security, nutrition, health, income generation and environmental services[1]. Jharkhand is the leader in the production of vegetables, as the agro-climatic conditions of the state are suitable for the cultivation of almost all types of vegetables. A wide range of underutilized leafy vegetables also constitute an integral part of the diet of tribal people, as they can consume these plants in their immediate surroundings without any investment. These underutilized leafy vegetables most often come from short-lived herbaceous plants, whereas leaves or flowers of some woody plants are also eaten by local people. During rainy and summer season, rural people collect various species of edible weeds from their agricultural and non-agricultural fields as well as from forestlands to supplement their staple food. These species consumed by tribal people in the form of leafy vegetables vary from locality to locality and season to season depending on the availability of resources. These leafy vegetables are cooked as 'saag', eaten raw or dried, and stored for use round the year. The diversity of leafy vegetable species offers a variety in family diet and contributes to household food and nutritional security as well as increase in dietary diversity. Further, it provides rural households with supplemental income opportunities through sale in the markets. However, sometimes consumption of these underutilized vegetables is not socially acceptable by the urban community because they are considered to be food for the poor and hence inadequate importance is given to them in cropping pattern, production and consumption.

Many varieties of these underutilized leafy vegetables, both cultivated and wild varieties, are sold in these local markets in both fresh and dried form. Fresh leaves, tender shoots or flowers of these vegetables are cooked as vegetables with or without spices. During peak season, a large quantity of these leafy vegetables is harvested and dried by the local people. The method of household drying involves collection or harvesting of the leafy vegetables from agricultural fields, household surroundings or forests followed by washing and sorting to remove dirt and other unwanted particles. Leaves are then spread on a clean cloth in the sun for drying. Complete drying usually takes 2–5 days depending upon the weather and type of leafy vegetable. The dried leaves are then either simply pulverized with hands or ground in a pestle and mortar followed by sieving to produce a fine powder. These powdered, dried leaves are generally prepared in the form of soup with cooked rice water to be consumed during the lean period, when the supply of other vegetables is limited and prices are high.

The local leafy vegetables are among the most nutritious as they are rich sources of minerals such as calcium, magnesium, iron and potassium as well as a good source of vitamins. They are also high in fibre, extremely low in fat and carbohydrates, and also provide a fair source of proteins. Thus, these leafy vegetables play a significant

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role in reducing micronutrient deficiency and provide food security to the tribal population of rural Jharkhand; however, no systematic information is available regarding the nutritional composition of these lesser-known leafy vegetables. Apart from being a rich source of micronutrients and vitamins, the leafy vegetables are also a good source of antioxidants. They contain a number of phytochemicals which help protect the cells from oxidative damage induced by free radicals and thereby help reduce the oxidative stress[2] and play a role in health management, especially lowering the risk of chronic human ailments such as cancer, cardiovascular disease and other age-related disorders[3].

Earlier studies have analysed the essential micronutrients content in leafy vegetables and also in few wild species of plant in India[4]. Researchers have also enumerated the traditional uses of these leafy vegetables along with their nutritional properties[5–7]. Information on the antioxidant activity of some leafy vegetables is also available[8–12]. However, no study has been conducted to estimate the antioxidant activity of underutilized leafy vegetables in Jharkhand, where they constitute a major part of the daily diet of the tribals. Further, only scattered information is available on the traditionally used local leafy vegetables in Jharkhand and their nutritional properties. Keeping these facts in view, we have surveyed selected districts of Jharkhand to assess the availability and extent of consumption of these lesser known leafy vegetables among the tribal people. Besides, biochemical analysis of these underutilized leafy vegetables, including antioxidant potential and nutritive value has been done to establish their nutritional and therapeutic authenticity.

Materials and methods

Study area

The present study was conducted during 2014–15, in seven districts of Jharkhand – Ranchi, Khunti, Gumla, Lohardaga, West Singhbhum, Ramgarh and Hazaribagh. The area extends between 22°27′23–23°16′31N lat., 85°23′50–85°47′5E long. and was selected due to the higher proportion of tribals inhabiting the region. A total of 20 markets, covering 306 vendors, including both primary and secondary vendors were surveyed for identifying potential underutilized leafy vegetables of the state. The markets were surveyed during different seasons as the availability and the type of leafy vegetables vary widely with season.

Methodology

The main aim of the survey was to identify and collect information regarding the availability and consumption of underutilized leafy vegetables by the tribals and local people of Jharkhand. Plants were identified with their botanical names based on local names and after considering the literature on the flora of Jharkhand and Bihar[13–15]. Markets of tribal villages called 'haat bazar' were surveyed. A preliminary survey was conducted to identify the important underutilized leafy vegetables sold in the markets and to collect information regarding their season of availability and annual consumption. For this, a year-round continuous survey of randomly selected market places of all the districts was made to identify the potential underutilized leafy vegetables of Jharkhand. The primary and secondary vendors available in each market place explored were interviewed through pre-designed questionnaires to understand the annual rate of consumption of these vegetables. Information on their habit, habitat, parts used, their availability in the markets, the quantity sold in the market and period of their availability was collected from all the market places. On the basis of the information and primary data recorded, annual consumption of these underutilized leafy vegetables in the markets (tonnes/year) was estimated using the following formula

Annual consumption (tonnes/year)

= Daily consumption per market (kg/day)

× found in markets (numbers)

× availability in markets (days/year)

Sample preparation for biochemical analysis

Samples of 20 potential species of these underutilized leafy vegetables were also collected from the markets and subjected to biochemical analysis. Five samples of each underutilized leafy vegetable were collected from different markets and pooled for analysis. Antioxidant activity and nutritive properties, including moisture, vitamin C (ascorbic acid), total carotenoids and minerals content (marcominerals, viz. calcium, phosphorus, magnesium, potassium, sodium and sulphur and microminerals, viz. iron, zinc, copper and manganese) of these vegetables were analysed. All the biochemical analyses were carried out in three replications using fresh leaf samples, irrespective of whether they were sold in fresh or dried form in the markets. Analysis of antioxidant activity, vitamin C, total carotenoids and moisture content was performed on fresh samples for all the leafy vegetables. For minerals estimation, samples of fresh leafy vegetables were washed initially using tap-water followed by dilute hydrochloric acid (0.05 N) and finally with double-distilled water. The samples were then dried in an air oven at a temperature of 65° ± 5°C till the weight remained constant for three consecutive days. The dried samples were then ground and passed through a 80-mesh sieve (180 μm) to be used for analysis of minerals.

Antioxidant activity

Antioxidant activity of the leaf samples was determined using two assays, viz. 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging activity and ferric reducing antioxidant potential (FRAP). Both assays are highly reproducible, accurate, simple and can be rapidly performed[16,17].

Extraction: Sample extraction for both DPPH and FRAP assays was carried out using 80% methanol. One gram of fresh leaf sample was homogenized with 20 ml of methanol (80%) in a pestle and mortar, and centrifuged at 4000 rpm. Supernatant was collected to be used for measuring the antioxidant activity. The pellet was again homogenized with 10 ml of methanol (80%). This extraction was repeated 2–3 times and the supernatants were pooled making up the volume to 50 ml.

DPPH free radical scavenging activity assay: Antioxidant activity of fresh leafy vegetable samples was measured by DPPH radical scavenging ability[18]. The assay is based on the reduction of DPPH radicals in methanol by antioxidants, which cause a reduction of absorbance at 517 nm. The decrease in absorbance with sample addition was used for calculation of antioxidant activity.

FRAP assay: This is based on the reduction of colourless ferric complex (Fe^{3+} tripyridyltriazine) to blue-coloured ferrous complex (Fe^{2+} tripyridyltriazine) by the action of electron-donating antioxidants at low pH (ref. 19). Antioxidant activity was calculated by measuring the change in absorbance at 593 nm. A standard curve using different concentrations of ascorbic acid (20–100 µg/ml) was also developed and results were expressed as mg ascorbic acid equivalent antioxidant capacity (AEAC)/100 g for both the assays.

Ascorbic acid (vitamin C)

Ascorbic acid was determined from fresh samples by volumetric method using 2,6-dichlorophenol-indophenol dye, which turns pink in acid solution[20].

Extraction: Ascorbic acid was extracted by macerating 2 g of sample with 3% metaphosphoric acid in a pestle and mortar. The extract was filtered through Whatman No. 1 filter paper and volume was made up to 25 ml with 3% metaphosphoric acid.

Estimation: A suitable aliquot from the extract was titrated against 2,6-dichlorophenolindophenol-dye till the light pink colour appeared. Results were expressed in mg of ascorbic acid per 100 g of fresh weight.

Total carotenoids

Total carotenoids content was measured from the fresh leaf samples. Accurately weighed 500 mg of fresh leaf sample was homogenized with 500 ml of absolute ethanol followed by filteration. Absorbance of the diluted filtrate was then measured at 470, 649 and 665 nm wavelength. The total carotenoids content was then calculated on fresh weight (FW) basis[21].

Moisture content

Moisture content of all the leafy vegetables was determined using the standard method of the Association of Official Analytical Chemists[20].

Minerals

One gram of oven-dried sample was digested with diacid mixture ($HNO_3 : HClO_4 : 9 : 4$). After digestion and extraction of samples, total P was determined with the vanodomolybdophosphoric acid yellow-colour method[22], total S was determined by turbidimetric method[23], and total K and Na were determined using the flame photometric method[22]. Water-soluble Ca and Mg were determined by the versanate method[23]. Water-soluble Fe, Mn, Cu and Zn were measured with an atomic absorption spectrophotometer (Analyst 100, Perkin Elmer, Norwalk, CT, USA).

Statistical analysis

Standard deviation was calculated for all the biochemical parameters. The data obtained on minerals content were also subjected to statistical analysis of variance (ANOVA) using completely randomized design.

Results and discussion

In the present study, 20 species of local underutilized leafy vegetables consumed by tribals of Jharkhand were identified through market surveys. These vegetables were sold in two forms in the village markets, viz. fresh and dried. Most of them were available during monsoon season, when they were collected and sold in fresh form in the local markets, while the surplus was dried and powdered at home and sold throughout the year in dried form, especially during the lean season, i.e. in winter. Some of these underutilized leafy vegetables are cultivated and others grow wild either in agricultural fields, wasteland or forest area. These underutilized leafy vegetables can be obtained from different plant types: herbs, shrubs, trees or creepers. The parts most commonly consumed are leaves, but tender shoots, buds, flowers, flower

Table 1. Availability/consumption of underutilized leafy vegetables (fresh) in the markets surveyed

Scientific name	Local name	Cultivated/ non-cultivated	Habit	Parts consumed	Found in markets (number)	Consumption per market (kg/day)	Availability in markets (days/year)	Total consumption (tonnes/year)
Amaranthus gangeticus L.	Lal Gandhari	C	H	Leaf, tender shoot	9	107 ± 20.41	306 ± 15.28	294.68
Amaranthus viridis L.	Hara Gandhari	C	H	Leaf, tender shoot	8	60 ± 11.45	306 ± 15.16	146.88
Ipomoea aquatica L.	Kalmi	C	C	Leaf, tender shoot	12	24.7 ± 5.23	365	108.19
Chenopodium album L.	Bathua	NC	H	leaf	5	73.8 ± 15.81	122 ± 10.56	45.02
Basella alba L.	Poi	C	C	Leaf, tender shoot	8	16.7 ± 3.66	240 ± 11.85	32.06
Centella asiatica (L.) Urban	Beng	NC	C	leaf, shoot	8	4.6 ± 1.34	350 ± 17.32	12.88
Hygrophylla spinosa T. Anders	Muchari	NC	H	leaf, shoot	6	3.1 ± 1.17	351.6 ± 18.93	6.53
Bauhinia variegata L.	Koinaar	NC	T	Flower bud, leaf	7	13.4 ± 2.62	61 ± 8.93	5.72
Moringa oleifera Lam.	Munga	C	T	Flowers, leaf	4	11.3 ± 3.06	92 ± 10.59	4.16
Crotolaria juncea L.	Sanai	C	H	Flowers	5	17.6 ± 5.29	31 ± 5.71	2.73
Morsilea minuta L.	Sunsunia	NC	H	Leaf	4	2.3 ± 1.02	122 ± 16.10	1.12
Ficus geniculata Kurz	Phutkal	NC	T	Leaf bud	3	8.3 ± 2.90	30.5 ± 6.62	0.76
Indigofera pulchella Roxb.	Girhul	NC	S	Flower	1	5.0 ± 1.15	30.9 ± 7.37	0.15

C, Cultivated; NC, Non-cultivated; H, Herb; S, Shrub; T, Tree and C, Creeper.

Table 2. Availability/consumption of underutilized leafy vegetables (dried) in the markets surveyed

Scientific name	Local name	Cultivated/ non-cultivated	Habit	Parts consumed	Found in markets (number)	Consumption per market (kg/day)	Availability in markets (days/year)	Total consumption (tonnes/year)
Cassia tora L.	Chakor	NC	H	Leaf	9	9.4 ± 2.55	365	30.88
Vangueria spinosa (Roxb. ex Link) Roxb.	Katai/Sarla	NC	S	Leaf	7	5.14 ± 2.70	365	13.13
Ipomoea batatas (L.) Lam.	Kanda	C	H	Leaf, shoot	8	4.2 ± 2.34	365	12.26
Antidesma diandrum (Roxb.) B. Heyne *ex* Roth	Mattha	NC	S	Leaf	4	3.8 ± 1.85	365	5.55
Ficus geniculata Kurz	Phutkal	NC	T	Leaf	4	1.6 ± 0.68	365	2.34

Figure 1. Major underutilized leafy vegetables sold in fresh form in the tribal markets of Jharkhand, India. ***a***, *Amaranthus gangeticus* L.; ***b***, *Amaranthus viridis* L.; ***c***, *Ipomoea aquatica* L.; ***d***, *Chenopodium album* L.; ***e***, *Hygrophylla spinosa* T. Anders; ***f***, *Basella alba* L.; ***g***, *Marsilea minuta* L.; ***h***, *Ficus geniculata* Kurz; ***i***, *Bauhinia variegate* L. (leaves); ***j***, *Bauhinia variegate* L. (flower buds); ***k***, *Crotolaria juncea* L.; ***l***, *Indigofera pulchella* Roxb.

buds are also eaten. Table 1 provides information on local name, mode of cultivation, habit, parts consumed, availability and consumption of the underutilized leafy vegetables sold in fresh form in the markets. Based on availability and consumption in the market, *Amaranthus gangeticus* L. was found highest in quantity in the markets followed by *Amaranthus viridis* L., *Ipomoea aquatica* L., *Chenopodium album* L., *Basella alba* L., *Centella asiatica* (L.) Urban, *Hygrophylla spinosa* T. Anders, *Bauhinia variegata* L. etc. (Figure 1). Besides these, few other local leafy vegetables are not sold in the market but rural people collect them from their surroundings and consume them on a daily basis; for example, *Oxalis corniculata* L., *Amaranthus spinosus* L. and *Polygonum plebeium*. Table 2 provides information regarding the local name, mode of cultivation, habit, parts consumed, availability and

Figure 2. Major underutilized leafy vegetables sold in the dried form in the tribal markets of Jharkhand. ***a***, *Cassia tora* L.; ***b***, *Antidesma diandrum* (Roxb.) B. Heyne *ex* Roth; ***c***, *Ipomoea batata* (L.) Lam; ***d***, *Ficus geniculata* Kurz; ***e***, *Vangueria spinosa* (Roxb. ex Link) Roxb.

consumption of underutilized leafy vegetables sold in dried form. Based on availability and consumption in the market, *Cassia tora* L. was found highest in quantity followed by *Vangueria spinosa* (Roxb. *ex* Link) Roxb., *Ipomoea batatas* (L.) Lam., *Antidesma diandrum* (Roxb.) B. Heyne *ex* Roth and *Ficus geniculata* Kurz (Figure 2).

Antioxidant activity

Figure 3 shows the antioxidant activity (mg AEAC/100 g) of 20 underutilized leafy vegetables analysed by DPPH and FRAP assays.

DPPH free radical scavenging activity

Figure 3 reveals that among the leafy vegetables studied, *C. tora* showed the highest DPPH free radical scavenging activity (2159.8 ± 142.5 mg AEAC/100 g) followed by *A. spinosus*, *H. spinosa*, *Moringa oleifera* (leaves) and *Ficus geniculata* (2137.1 ± 140.1, 1979.9 ± 130.7, 1782.5 ± 68.34 and 1570.1 ± 52.93 mg AEAC/100 g FW respectively).

FRAP assay

FRAP value for *H. spinosa* (5200 ± 163.9 mg AEAC/100 g) was recorded to be the highest followed by *Indigofera pulchella*, *Moringa oleifera* (leaves), *Chenopodium album* L. and *Ficus geniculata* (4708.3 ± 68.2, 4570 ± 152, 4500 ± 163.3 and 4100 ± 94.6 mg AEAC/100 g respectively) among all the leafy vegetables analysed (Figure 3). The differences in the antioxidant activity by different assays may be due to various kinds of antioxidants present in the samples, which react differently with the radicals used[24].

Leafy vegetable species like *H. spinosa*, *M. oleifera* (leaves) and *F. geniculata* showed high antioxidant activity for both DPPH and FRAP assays, thus proving to be potent antioxidants. The high antioxidant activity of these wild leafy vegetables may be responsible for their wide use in the diet of the tribals[25], probably because of their consequential health benefits and ethno-medicinal values. The leaves of *H. spinosa* have been reported to be useful in the treatment of abdominal disorders, urinary disorders, inflammation, eye diseases, pain, ascites and anaemia[26]. *M. oleifera* leaves are used in the treatment of scurvy, hypertension and catarrhal infection[7], and young leaves of *F. geniculata* help prevent colic and dysentery[5].

Ascorbic acid (vitamin C)

Figure 4 shows the ascorbic acid content of 20 potential underutilized leafy vegetables of Jharkhand. It varied from 2.41 ± 0.5 mg/100 g FW in *A. viridis* to 156.92 ± 4.37 mg/100 g FW in leaves of *M. oleifera*. In similar studies, vitamin C content of 34 leafy vegetables cultivated in India and 38 tropical leafy vegetables have been reported to be in the range 11.91 ± 3.07–133 ± 16.3 mg/100 g and 10.19–211.20 mg/100 g respectively[27,28]. Moreover, *Marsilea minuta*, *B. alba* and *B. variegata* also showed higher ascorbic acid content (56.25 ± 1.3, 41.04 ± 1.2 and 26.75 ± 1.2 mg/100 g FW respectively) compared to other leafy vegetables analysed.

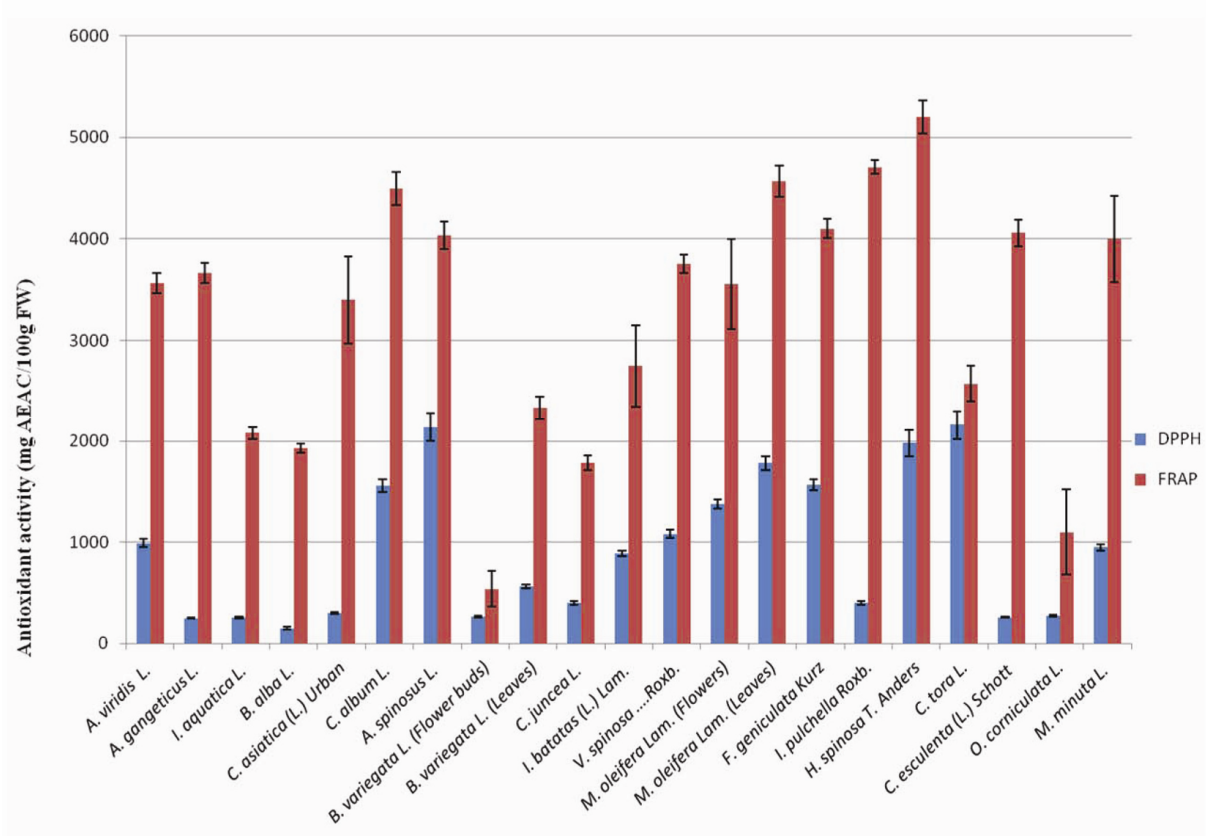

Figure 3. Antioxidant activity of potential underutilized leafy vegetables of Jharkhand.

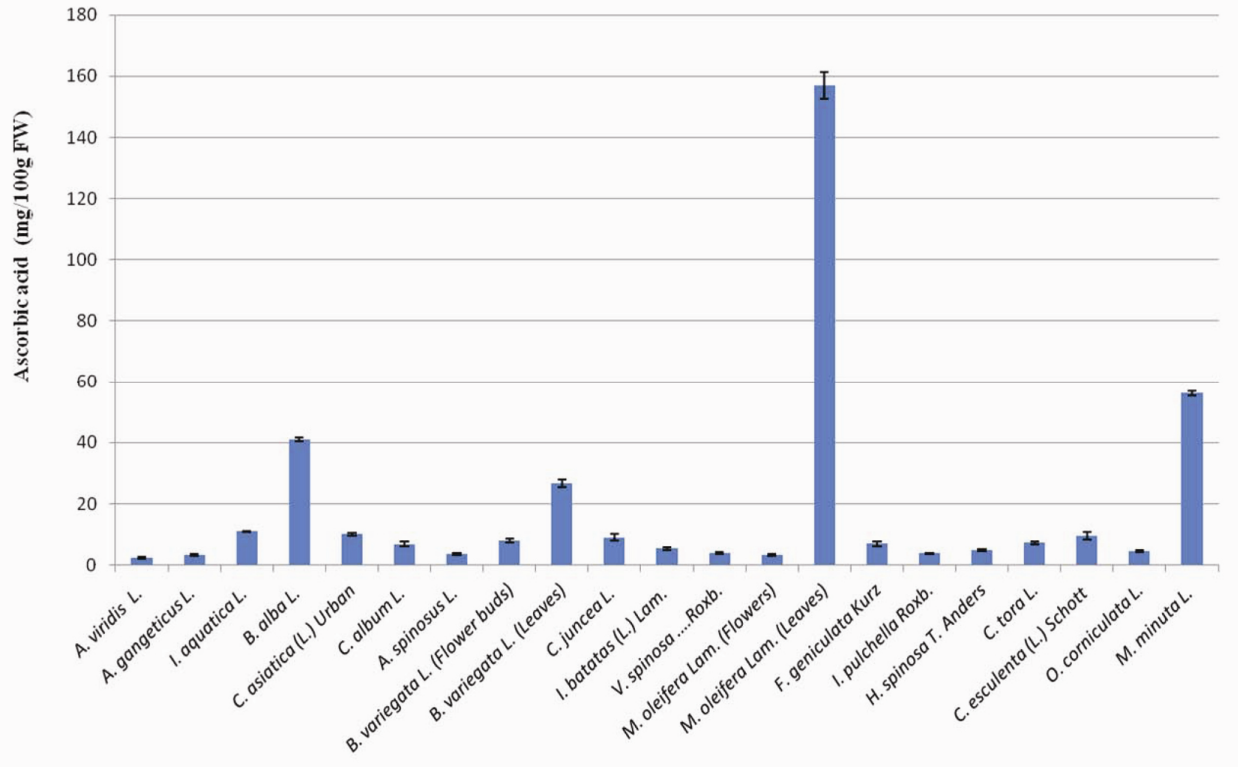

Figure 4. Ascorbic acid (vitamin C) content of potential underutilized leafy vegetables of Jharkhand.

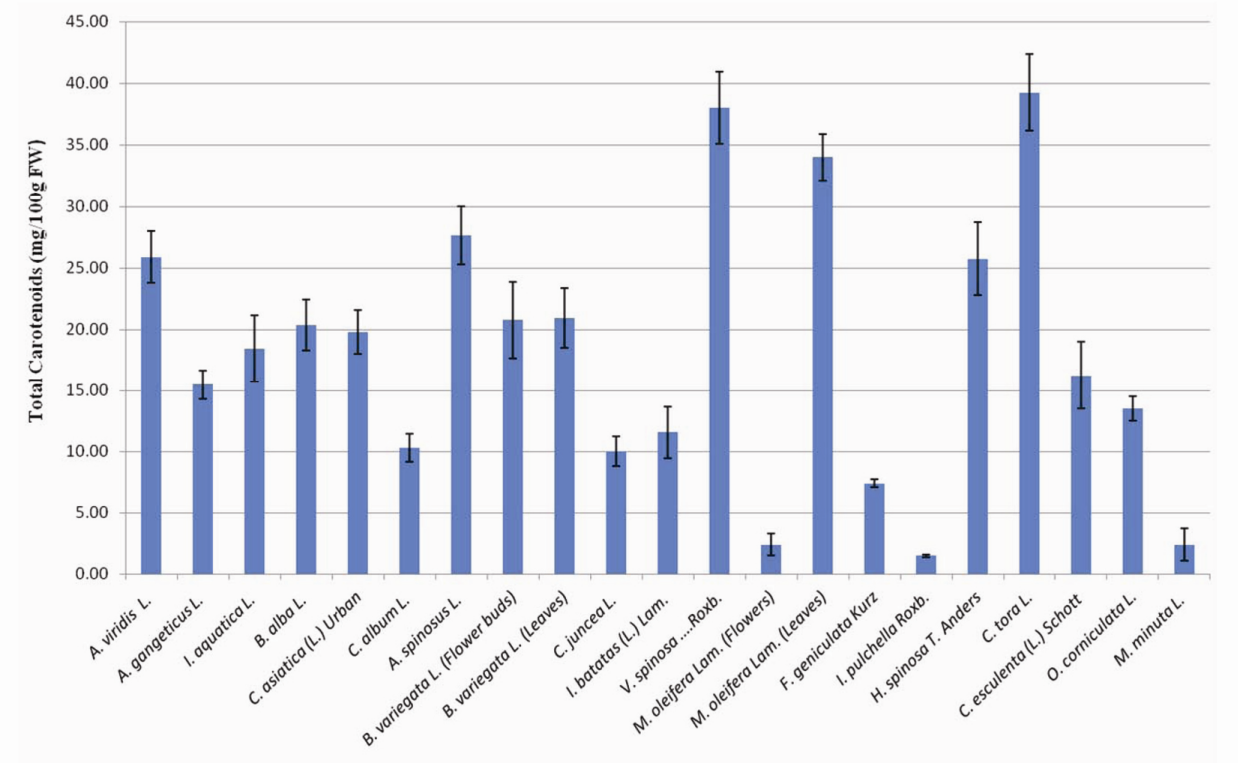

Figure 5. Total carotenoids content of potential underutilized leafy vegetables of Jharkhand.

Total carotenoids

Carotenoids, besides their well-known provitamin A activity[29], also function as antioxidants and enhancers of the immune response, and as such are associated with lowered risk of developing degenerative diseases[30,31]. In the present study total carotenoids content of 20 underutilized leafy vegetables varied from 1.48 ± 0.12 mg/100 g FW in *Indigofera pulchella* to 39.25 ± 3.13 mg/100 g FW in *C. tora*. Moreover, *V. spinosa*, *M. oleifera* (leaves) and *A. spinosus* also showed higher amount of total carotenoids (38.02 ± 2.91, 33.98 ± 1.90 and 27.68 ± 2.36 mg/100 g FW respectively) (Figure 5). Similarly, total carotenoids content of 70 edible wild forest green leafy vegetables collected and consumed by tribals of Andhra Pradesh has been reported to vary from 5.12 to 36.13 mg/100 g (ref. 32).

Moisture content

The moisture content of 20 underutilized leafy vegetables varied from 55.52 ± 0.22 g/100 g FW in flowers of *I. pulchella* to 94.15 ± 0.33 g/100 g FW in *B. alba* leaves. Moisture content of some species whose edible parts are flowers, viz. *I. pulchella* (55.52 ± 0.22 g/100 g FW), *Crotolaria juncea* (66.11 ± 0.07 g/100 g FW) and *B. variegata* (71.96 ± 0.35 g/100 g FW) was observed to be lower compared to other species (Figure 6). In another study, moisture content of 34 Indian leafy vegetables has been reported to be in the range 71.69 ± 0.06–93.56 g/100 g (ref. 27).

Minerals

Table 3 shows the minerals content (mg/100 g) of potential underutilized leafy vegetables of Jharkhand, including both marcominerals, viz. calcium, phosphorus, magnesium, potassium, sodium and sulphur and microminerals, viz. iron, zinc, copper and manganese. Calcium and phosphorus are important for growth and healthy maintenance of bones, teeth, muscle and blood[33]. Calcium content in all the leafy vegetables analysed ranged from 125.8 ± 3.1 mg/100 g FW in *M. oleifera* flowers to 1737.8 ± 9.2 mg/100 g FW in *A. spinosus*. Besides these, *C. tora*, *I. batatas*, *C. asiatica* and *M. oleifera* leaves also contained high amounts of calcium (1454.6 ± 13.1, 1329.6 ± 7.2, 1189.1 ± 9.3 and 1114.2 ± 9.1 mg/100 g FW respectively). Similar results have been reported in 34 green leafy vegetables of India, where although the values were lower (48.00–901 mg/100 g), *A. spinosus*, *A. gangeticus* and *M. oleifera* also showed comparatively higher amounts of Ca (372, 330 ± 74.2 and 314 ± 71.0 mg/100 g respectively) compared to other leafy vegetables[27]. Phosphorus content in the samples varied from 26.7 ± 1.6 mg/100 g FW in *I. pulchella* to 525.3 ± 5.2 mg/100 g FW in *A. gangeticus*. Moreover, *A. viridis*,

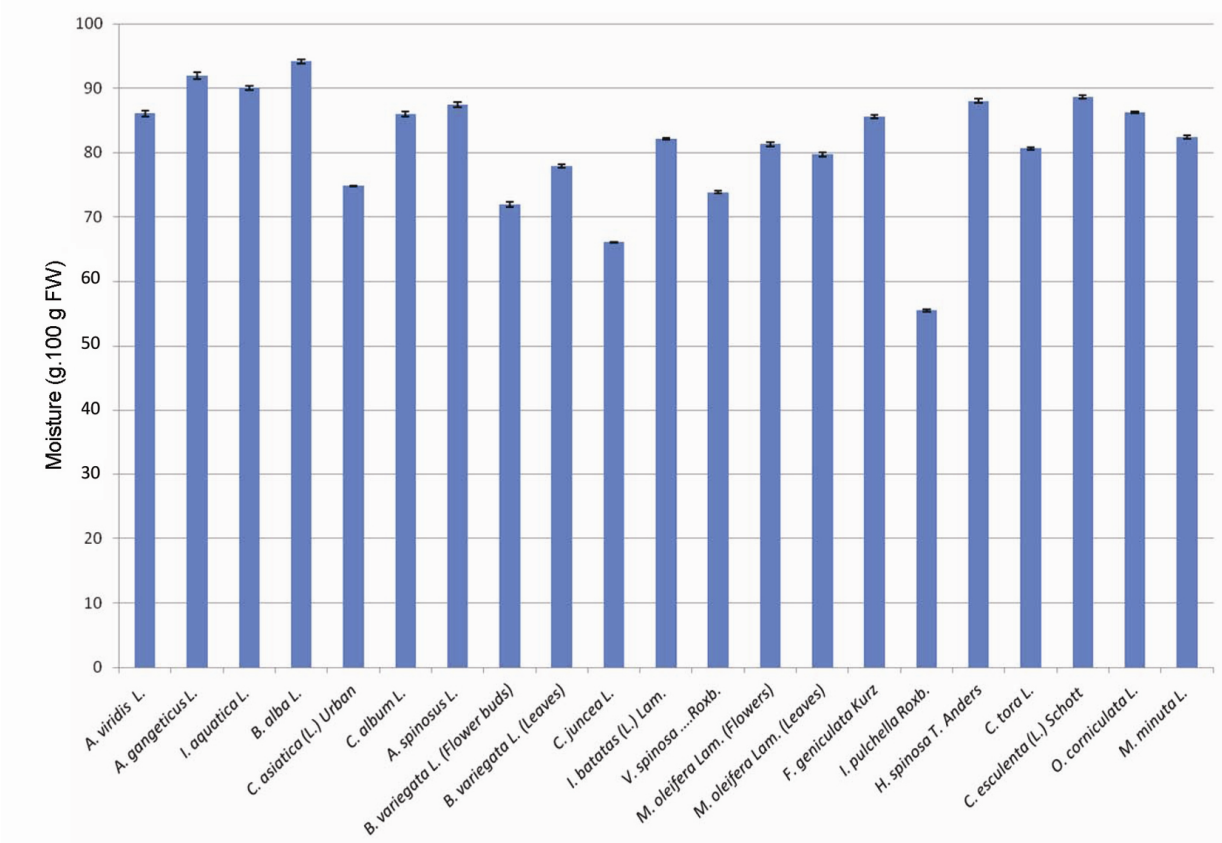

Figure 6. Moisture content of potential underutilized leafy vegetables of Jharkhand.

C. asiatica, *B. alba* and *C. juncea* also contained higher amounts of phosphorus (336.8 ± 4.6, 325.8 ± 3.8, 311.8 ± 4.4 and 256.6 ± 3.1 mg/100 g FW respectively). However in another study, *M. oleifera* (leaves) was reported to contain the highest P content (109 ± 20.7 mg/100 g) amongst 34 species of leafy vegetables analysed[27]. Magnesium content varied from 254.3 ± 5.2 mg/100 g in flowers of *M. oleifera* to 1233.7 ± 8.1 mg/100 g FW in *A. spinosus*. The results are in conformity with other studies that reported *A. spinosus* to contain the highest amount of magnesium compared to other leafy vegetables analysed[27,34]. Besides, in the present study, *A. gangeticus*, *I. batatas*, *B. alba* and *A. viridis* also contained higher amounts of magnesium (1227.1 ± 13.2, 1076.9 ± 5.9, 1074.2 ± 7.9 and 1073.1 ± 22.6 mg/100 g FW respectively). Dietary deficiency of magnesium, which is linked with ischaeamic heart disease, could be prevented by the regular consumption of these vegetables as they are a good source of the mineral.

Sodium content in these leafy vegetables varied from 189.6 ± 1.7 mg/100 g FW in the leaves of *B. variegata* to 473.3 ± 3.9 mg/100 g FW in *I. aquatica*. These values match favourably with those reported in five medicinally important leafy vegetables of Kamrup district, Assam (146.0–358.0 mg/100 g)[35] and were higher compared to those reported in 34 leafy vegetables grown in India (9.34 ± 2.11–111 ± 34.1 mg/100 g)[27]. The potassium content of the leafy vegetables varied from 98.5 ± 4.5 mg/100 g FW in *B. alba* to 4516.1 ± 18.2 mg/100 g FW in *C. album*. Similarly in another study also, *C. album* was found to contain the highest potassium content amongst four wild leafy vegetables of South Africa[36]. Besides these, species like *C. asiatica*, *A. viridis*, *A. spinosus* and *C. juncea* also contained higher amounts of potassium (3017.3 ± 11.3, 2954.6 ± 19.6, 2809.0 ± 11.1 and 2289.2 ± 21.1 mg/100 g FW respectively). The high potassium content coupled with low sodium content, as observed in almost all the leafy vegetables analysed in this study, has been reported to be protective against many diseases[37]. These indigenous vegetables could therefore meet the daily requirements of potassium for an adult, and may be useful in the management of hypertension and other cardiovascular diseases. Sulphur content of the leafy vegetables analysed varied from 52.0 ± 2.4 mg/100 g FW in *I. pulchella* to 840.6 ± 7.5 mg/100 g FW in flowers of *M. oleifera*.

Iron content in the local underutilized leafy vegetables in the present study varied from 7.2 ± 0.3 mg/100 g FW in the leaves of *B. variegata* to 61.3 ± 4.1 mg/100 g FW in *A. gangeticus*. However, a comparatively lower range of Fe (2.2–19.9 mg/kg) has been reported in 15 species of lesser known wild leafy vegetables of Dumka district,

Table 3. Minerals content (mg/100 g FW) of potential underutilized leafy vegetables of Jharkhand*

Scientific name	Macrominerals (mg/100g FW)**						Microminerals (mg/100g FW)**			
	Ca	Mg	P	S	K	Na	Fe	Zn	Cu	Mn
A. viridis	1025.1 ± 21.6^{g}	1073.1 ± 22.6^{b}	336.8 ± 4.6^{b}	253.2 ± 3.7^{e}	2954.6 ± 19.6^{c}	249.4 ± 3.1^{g}	38.4 ± 3.3^{c}	5.1 ± 0.2^{d}	0.6 ± 0.1^{fg}	4.3 ± 0.3^{gh}
A. gangeticus	1041.7 ± 12.1^{f}	1227.1 ± 13.2^{a}	525.3 ± 5.2^{a}	159.8 ± 6.7^{i}	2169.4 ± 15.2^{f}	222.6 ± 3.2^{i}	61.3 ± 4.1^{a}	5.2 ± 0.3^{d}	0.9 ± 0.1^{def}	5.1 ± 0.3^{fg}
I. aquatica	396.5 ± 5.1^{n}	444.2 ± 4.8^{e}	174.4 ± 1.9^{i}	204.3 ± 3.3^{f}	545.2 ± 5.6^{s}	473.3 ± 3.9^{a}	52.8 ± 1.3^{b}	4.4 ± 0.4^{e}	1.1 ± 0.1^{cde}	5.3 ± 0.3^{f}
B. alba	704.5 ± 7.2^{j}	1074.2 ± 7.9^{b}	311.8 ± 4.4^{d}	181.0 ± 2.9^{g}	98.5 ± 4.5^{t}	205.5 ± 4.9^{k}	16.4 ± 2.2^{g}	9.9 ± 1.3^{a}	0.9 ± 0.1^{def}	4.8 ± 0.3^{fg}
C. asiatica	1189.1 ± 9.3^{d}	398.5 ± 3.3^{f}	325.8 ± 3.8^{c}	209.3 ± 3.7^{f}	3017.3 ± 11.3^{b}	179.3 ± 2.2^{m}	7.9 ± 0.6^{k}	6.6 ± 0.5^{b}	1.1 ± 0.2^{cde}	1.6 ± 0.2^{kl}
C. album	985.7 ± 5.3^{h}	1034.4 ± 6.1^{c}	241.0 ± 3.9^{f}	172.7 ± 3.2^{h}	4516.1 ± 18.2^{a}	232.3 ± 3.3^{h}	37.0 ± 2.5^{c}	6.6 ± 0.5^{b}	4.8 ± 0.3^{a}	11.1 ± 0.6^{d}
A. spinosus	1737.8 ± 9.2^{a}	1233.7 ± 8.1^{a}	237.8 ± 2.7^{f}	162.8 ± 2.0^{i}	2809.0 ± 11.1^{d}	204.5 ± 2.5^{k}	37.1 ± 1.2^{c}	6.0 ± 0.4^{bc}	4.9 ± 0.3^{a}	19.9 ± 0.8^{b}
B. variegata (flowers)	616.3 ± 6.6^{k}	348.8 ± 4.6^{g}	231.1 ± 2.8^{g}	96.5 ± 3.9^{m}	1976.7 ± 16.8^{g}	279.1 ± 4.6^{e}	12.9 ± 0.9^{hi}	2.9 ± 0.2^{gh}	4.9 ± 0.3^{a}	1.9 ± 0.2^{jk}
B. variegate (leaves)	262.2 ± 1.9^{q}	280.9 ± 1.8^{j}	83.2 ± 1.2^{m}	151.9 ± 3.1^{j}	711.3 ± 5.2^{op}	189.6 ± 1.7^{l}	7.2 ± 0.3^{k}	3.9 ± 0.2^{ef}	1.1 ± 0.1^{cde}	0.9 ± 0.1^{l}
C. juncea	224.9 ± 4.5^{r}	407.2 ± 5.6^{f}	256.6 ± 3.1^{e}	107.1 ± 2.1^{l}	2289.2 ± 21.1^{e}	294.6 ± 4.2^{c}	14.8 ± 1.7^{gh}	3.0 ± 0.5^{gh}	5.1 ± 0.8^{a}	2.2 ± 0.3^{jk}
I. batatas	1329.6 ± 7.2^{c}	1076.9 ± 5.9^{b}	212.5 ± 4.1^{h}	96.7 ± 3.9^{m}	1813.2 ± 11.5^{h}	256.6 ± 4.1^{f}	26.0 ± 1.8^{d}	2.8 ± 0.2^{h}	4.7 ± 0.2^{a}	4.3 ± 0.3^{gh}
V. spinosa	552.4 ± 7.8^{m}	409.1 ± 4.8^{f}	209.7 ± 2.7^{h}	68.3 ± 3.1^{n}	1714.3 ± 12.2^{i}	276.2 ± 2.7^{e}	22.9 ± 1.6^{e}	2.6 ± 0.2^{hi}	4.9 ± 0.4^{a}	12.4 ± 0.9^{c}
M. oleifera (flowers)	125.8 ± 3.1^{t}	254.3 ± 5.2^{k}	103.3 ± 2.3^{k}	840.6 ± 7.5^{a}	859.1 ± 7.3^{l}	211.6 ± 4.2^{j}	15.3 ± 1.5^{gh}	2.0 ± 0.3^{ij}	0.5 ± 0.1^{fg}	1.8 ± 0.3^{kl}
M. oleifera (leaves)	1114.2 ± 9.1^{e}	566.0 ± 4.1^{d}	55.2 ± 3.2^{op}	652.8 ± 6.1^{b}	585.0 ± 3.3^{r}	190.7 ± 1.8^{l}	9.6 ± 0.1^{jk}	1.5 ± 0.2^{j}	0.5 ± 0.1^{fg}	2.8 ± 0.2^{ij}
F. geniculata	157.3 ± 3.9^{s}	321.6 ± 5.5^{h}	119.8 ± 2.8^{j}	95.8 ± 2.1^{m}	770.5 ± 7.2^{m}	205.5 ± 4.1^{k}	7.3 ± 0.8^{k}	3.5 ± 0.2^{fg}	1.3 ± 0.1^{cd}	1.9 ± 0.2^{jk}
I. pulchella	285.5 ± 4.3^{op}	296.3 ± 4.8^{i}	26.7 ± 1.6^{r}	52.0 ± 2.4^{op}	669.4 ± 6.2^{q}	222.6 ± 3.1^{i}	12.9 ± 1.2^{hi}	1.7 ± 0.3^{j}	1.4 ± 0.2^{c}	3.6 ± 0.3^{hi}
H. spinosa	978.5 ± 9.3^{h}	347.8 ± 3.2^{g}	42.4 ± 2.4^{q}	379.9 ± 6.5^{e}	895.2 ± 6.6^{k}	462.3 ± 3.1^{b}	9.2 ± 0.6^{jk}	5.6 ± 0.2^{cd}	2.2 ± 0.1^{b}	5.0 ± 0.3^{fg}
C. tora	1454.6 ± 13.1^{b}	397.7 ± 3.6^{f}	85.8 ± 2.1^{m}	134.4 ± 2.2^{k}	776.5 ± 5.1^{m}	205.5 ± 3.2^{k}	11.0 ± 1.2^{ij}	4.3 ± 0.2^{e}	0.7 ± 0.1^{efg}	4.2 ± 0.1^{gh}
C. esculenta	583.5 ± 4.2^{l}	317.3 ± 2.3^{h}	91.8 ± 1.6^{l}	187.2 ± 2.6^{g}	1021.2 ± 10.2^{j}	201.3 ± 2.3^{k}	11.0 ± 0.7^{ij}	5.2 ± 0.4^{d}	1.4 ± 0.1^{c}	80.7 ± 2.0^{a}
O. corniculata	794.8 ± 7.2^{i}	343.7 ± 3.3^{g}	73.7 ± 1.2^{n}	138.9 ± 1.3^{k}	655.2 ± 6.5^{q}	288.8 ± 2.8^{d}	13.7 ± 0.4^{h}	2.0 ± 0.2^{ij}	0.6 ± 0.2^{fg}	4.3 ± 0.1^{gh}
M. minuta	233.8 ± 2.1^{r}	274.0 ± 3.1^{i}	241.7 ± 3.8^{f}	264.4 ± 0.5^{d}	746.5 ± 5.1^{n}	220.4 ± 2.2^{i}	19.1 ± 0.3^{f}	2.7 ± 0.2^{h}	0.4 ± 0.1^{g}	10.0 ± 0.5^{e}

*Means in a column with common superscript are not significantly different at the 0.05 level of probability by Duncan's multiple range test. **Five samples were pooled from different markets for each leafy vegetable and the analysis was done in triplicate.

Jharkhand[6]. In the present study, *A. gangeticus*, *I. aquatica*, *A. viridis*, *A. spinosus* and *C. album* were found to be rich in iron (61.3 ± 4.1, 52.8 ± 1.3, 38.4 ± 3.3, 37.1 ± 1.2 and 37.0 ± 2.5 mg/100 g FW respectively), and thus may help overcome some of the nutritional problems associated with iron deficiency. Zinc content varied among the leafy vegetables analysed, from 1.5 ± 0.2 mg/100 g FW in leaves of *M. oleifera* to 9.9 ± 1.3 mg/100 g FW in *B. alba* and copper content varied from 0.4 ± 0.1 mg/100 g FW in *M. minuta* to 5.1 ± 0.8 mg/100 g FW in *C. juncea*. These values are higher compared to those of Zn (0.3–1.2 mg/100 g) and Cu (0.1–0.9 mg/100 g) reported in 21 wild vegetables traditionally consumed in Northeast India[38]. Manganese content of the underutilized leafy vegetables varied from 0.9 ± 0.1 mg/100 g FW in the leaves of *B. variegata* to 80.7 ± 2.0 mg/100 g FW in *Colocasia esculenta.* These values are higher compared to those reported in 15 species of lesser known wild leafy vegetables of Dumka district, Jharkhand (0.29–17.9 mg/100g)[6].

Summary and conclusion

The present study has identified some of the potential underutilized leafy vegetables in Jharkhand which are popular, widely consumed, nutritionally rich, easy to cultivate and market. The potential underutilized fresh leafy vegetables based on their availability as well as antioxidative and nutritional value were found to be *A. gangeticus* L., *A. viridis* L., *A. spinosus* L., *I. aquatica* L., *C. album* L. and *B. alba* L., whereas those which are sold in dried form were *C. tora* L., *I. batatas* (L.) Lam. and *V. spinosa* (Roxb. ex Link) Roxb. The results indicate the potentiality of these inexpensive, easily accessible, but lesser known leafy vegetables as a source of unconventional food. There is good potential to include other popular species identified in this study in the cropping pattern and home gardens of tribal farmers of the state. These vegetables are nutritionally and culturally important, but wider cultivation is curtailed by lack of information on appropriate agronomic practices, supply of quality seeds and organized marketing in the city markets. Consumption of such valuable vegetables should be encouraged through awareness, so that a larger section of the population could include them in the dietary menu to get nutritional as well as health benefits. Moreover, the value-added products based on these leafy vegetables can be popularized among the urban people and can also provide livelihood security to the resource-poor farmers.

1. Subasinghe, S., Cultivation of medicinal fruits trees. *Daily News*, Srilanka, 2014.
2. Wada, L. and Ou, B., Antioxidant activity and phenolic content of Oregon cranberries. *J. Agric. Food Chem*., 2002, **50**, 3495–3500.
3. Vanpoppel, G., Kardinaal, A. F. M., Princen, H. M. G. and Kok, F. J., Antioxidant and coronary heart disease. *Ann. Med*., 1994, **26**, 429–434.
4. Gopalan, C., Ramasastri, B. V., Balasubramanian, S. C., Rao, B. S. N., Deosthale, Y. G. and Pant, K. C., Nutritive value of Indian foods. National Institute of Nutrition, ICMR, Hyderabad, 2004.
5. Kumari, B. and Kumar, S., A checklist of some leafy vegetables used by tribes in and around Ranchi. Jharkhand. *Zoos' Print J.*, 2001, **16**, 442–444.
6. Thakur, S., Kumar, S. and Kumar, A., Potential of some wild leafy vegetables as natural source for supplementation of micronutrients in vegetarian diets of Santhal Pargana area of Jharkhand. *Indian J. Fundam. Appl. Life Sci*., 2012, **2**, 65–67.
7. Sharma, H. P. and Rawal, A. K., Health security in ethnic communities through neutraceutical leafy vegetables. *J. Environ. Res. Develop*., 2013, **7**, 1423–1429.
8. Dasgupta, N. and De, B., Antioxidant activity of some leafy vegetables of India: a comparative study. *Food Chem.*, 2007, **101**, 471–474.
9. Routray, R., Sahu, R. K. and Kar, M., Evaluation of antioxidant potential in selected leafy vegetables of Odisha. *Int. J. Pharm. Sci.*, 2013, **5**, 232–235.
10. Arora, S., Kumar, D. and Shiba, Phytochemical, antimicrobial and antioxidant activities of methanol extract of leaves and flowers of *Ipomoea cairica*. *Int. J. Pharm. Sci*., 2013, **5**, 198–202.
11. Zakaria, Z. A., Rofiee, M. S., The, L. K., Salleh, M. Z., Sulaiman, M. R. and Somchit, M. N., *Bauhinia purpurea* leaves' extracts exhibited *in vitro* antiproliferative and antioxidant activities. *Afr. J. Biotechnol*., 2011, **10**, 65–74.
12. Sirappuselvi, S. and Chitra, M., *In vitro* antioxidant activity of *Cassia tora* Lin. *Int. Res. J. Biol. Sci*., 2012, **1**, 57–61.
13. Ghosh, T. K., Studies on flora of Ranchi district, Dissertation, Ranchi University, 1971.
14. Haines, H. H., *The Botany of Bihar and Orissa I–IV*, Botanical Survey of India, Calcutta, 1921–1925.
15. Singh, N. P. *et al*., *Flora of Bihar, Analysis*, Botanical Survey of India, Calcutta, 2001.
16. Katalinic, V., Milos, M., Kulisic, T. and Jukic, M., Screening of 70 medicinal plant extracts for antioxidant capacity and total phenols. *Food Chem*., 2006, **94**, 550–557.
17. Thaipong, K., Boonprakob, U., Crosby, K., Cisneros-Zevallos, L. and Byrne, D. H., Comparison of ABTS, DPPH, FRAP and ORAC assays for estimating antioxidant activity from guava fruit extracts. *J. Food Compost. Anal.*, 2006, **19**, 669–675.
18. Kang, H. M. and Saltveit, M. E., Antioxidant capacity of lettuce leaf tissue increases after wounding. *J. Agric. Food Chem*., 2002, **50**, 7536–7541.
19. Benzie, I. F. F. and Strain, J. J., The ferric reducing ability of plasma (FRAP) as a measure of antioxidant power: the FRAP assay. *Anal. Chem.*, 1996, **239**, 70–76.
20. AOAC, *Official Methods of Analysis*, Association of Official Analytical Chemists. Washington, DC, USA, 1990.
21. Lichtenthaler, H. K. and Wellburn, A. R., Determinations of total carotenoids and chlorophylls *a* and *b* of leaf extracts in different solvents. *Biochem. Soc. Trans*., 1983, **11**(3), 591–592.
22. Jackson, M. L., *Soil Chemical Analysis*, Prentice Hall of India, New Delhi, 1973.
23. Hesse, P. R., *A Textbook of Soil Chemical Analysis*, John Murray Publishers, London, UK, 1971.
24. Shah, P. and Modi, H. A., Comparative study of DPPH, ABTS and FRAP assays for determination of antioxidant activity. *Int. J. Res. Appl. Sci. Eng. Technol.*, 2015, **3**(6), 636–641.
25. Sahu, R. K., Kar, M. and Routray, R., DPPH free radical scavanging activity of some leafy vegetables used by tribals of Odisha, India. *J. Med. Plants Stud.*, 2013, **1**, 21–27.
26. Kshirsagar, A. D., Ingale, K. G., Vyawahare, N. S. and Thorve, V. S., *Hygrophila spinosa*: a comprehensive review. *Pharmacogn. Rev.*, 2010, **4**(8), 167–171.
27. Longvah, T., Ananthan, R., Bhaskarachary, K. and Venkaiah, K., *Indian Food Composition Tables*, National Institute of Nutrition, ICMR, Hyderabad, 2017, pp. 3–168.

28. Ogunlesi, M., Okiei, W., Azeez, L., Obakachi, V., Osunsanmi, M. and Nkenchor, G., Vitamin C contents of tropical vegetables and foods determined by voltammetric and titrimetric methods and their relevance to the medicinal uses of the plants. *Int. J. Electrochem. Sci.*, 2010, **5**, 105–115.
29. Tanumihardjo, S. A., Food-based approaches for ensuring adequate vitamin A nutrition. *Comp. Rev. Food Sci. Food Saf.*, 2008, **7**, 373–381.
30. Krinsky, N. I., Actions of carotenoids in biological systems. *Annu. Rev. Nutr.*, 1996, **13**, 561–587.
31. Rodriguez-Bernaldo de Quiros, A. and Costa, H. S., Analysis of carotenoids in vegetable and plasma samples. *J. Food Compos. Anal.*, 2006, **19**(2–3), 97–111.
32. Rajyalakshmi, P., Venkatalaxmi, K., Venkatalakshmamma, K., Jyothsna, Y. and Balachandramani Devi, K. and Suneetha, V., Total carotenoid and beta-carotene contents of forest green leafy vegetables consumed by tribals of south India. *Plant Foods Hum. Nutr.*, 2001, **56**, 225–238.
33. Akubugwo, I. E., Obasi, N. A., Chinyere, G. C. and Ugbogu, A. E., Nutritional and chemical value of *Amaranthus hybridusn* L. leaves from Afikpo, Nigeria. *Afr. J. Biotechnol.*, 2007, **6**, 2833–2839.
34. Barminas, J. T., Charles, M. and Emmanuel, D., Mineral composition of non-conventional leafy vegetables. *Plant Foods Hum. Nutr.*, 1998, **53**, 29–36.
35. Gogoi, P. and Kalita, J. C., Proximate analysis and mineral components of some edible medicinally important leafy vegetables of Kamrup district of Assam, India. *Int. J. Pharm. Biol. Sci.*, 2014, **5**, 451–457.
36. Afolayan, A. J. and Jimoh, F. O., Nutritional quality of some wild leafy vegetables in South Africa. *Int. J. Food Sci. Nutr.*, 2009, **60**, 424–431.
37. Arlington, V. A., Arbeit, M. L., Nicklas, T. A. and Berenson, G. S., Considerations of dietary sodium potassium energy ratios of selected foods. *J. Am. Coll. Nutr.*, 1992, **11**, 210–222.
38. Saikia, P. and Deka, D. C., Mineral content of some wild green leafy vegetables of North-East India. *J. Chem. Pharm. Res*., 2013, **5**, 117–121.

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