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ARTICLE

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NUTRITIONAL AND NUTRACEUTICAL POTENTIAL OF UNDERUTILIZED WILD EDIBLE FRUITS USED BY TRIBAL PEOPLE OF KORAPUT, INDIA FOR HEALTH BENEFIT

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Wild edible fruits used as indigenous food and contribute significantly to nutritional security of several tribal people of Koraput. However, systematic investigation on nutritional and nutraceutical potential of these wild edible fruits are merger. Present study evaluated the proximate compositions, vitamins, phenol, flavonoid and antioxidant capacity in selected wildfruits of Koraput.The protein, carbohydrates and fat content in the wild fruits are varied from 5.54% to 19.51% and 25.54% to 66.52% and 0.7% to 8.11%, respectively. The wild fruits are rich in energy content which varied from 156.51 to 352.47 kcal100g^{-1}. The energy content was highest in Semecarpus anacardium followed by Aegle marmelos and Averrhoa carambola. The phenol, flavonoid and antioxidant capacity of the wild fruits were varied from 12.07 to 64.8mg 100g^{-1} dry weight, 1.07 to 6.25 µg 100g^{-1} dry weight and 10.98 to 97.56%, respectively.Based on the results, some wild fruits are rich in antioxidants should be promoted for the sources of natural antioxidants and beneficial for health.

Introduction

Wild plant resources played an important role in global food and nutrition security and also potential resources for sustainable food systems under climate change [1]. For tribal people and forest dwelling communitythe wild fruit plants are the important livelihood and are primesources of food and nutritionduring the period of food scarcity [2,3]. The term "wild edible" refers to plant species that are neither domesticated nor grown but are still available from their natural habitats and may be used for food [4]. In different geographical regions of the world, the edible fruits have been used as indigenous food by local people in supporting the global food basket as well as it offers a better income source to the tribal people[5]. Wild fruits are safe food sources and can be utilized for supplementary nutritional and medicinal properties by different tribal groups[5]. Now there is increasing interest in searching of nutrient rich underutilized, neglected and wild crops including wild fruits for better nutrition and health benefit[1]. These are not only important for their food value but also potential sources of various phytochemicals such as flavonoids, vitamins, and natural antioxidants[4,6]. Thus, the study of nutritional and nutraceutical potential of edible fruits is an important step for better understanding of their health benefits on human[6]. In spite of importance of wild fruits as indigenous food, little is known about their chemical composition and it's nutritional and nutraceutical profiling is essential in order to integrate them in developmental interventions[2,3]. Earlier Few studies have highlighted the health benefits and phytoconstituents of wild fruits in different geographical regions of the world[7], in India mostly from Western Ghats[8], Eastern Ghats[2,9] and

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Himalayan regions[3], Northeast India[10] in Kerala state[11]. However, there is dearth of documented information on nutritional and nutraceutical profiling of wild edible fruits from Koraput.

Koraput is one of biodiversity rich region situated in northern part of Eastern Ghats of India dominated by various tribal groups[1], The regionis the centres of diversity for many food crops and forest species.Recently our group highlighted several wild edible fruits, flowers and tubers of this region for tribal food and nutritional security[1,12]. However, systematic investigation on nutritional profiling of these high valued wild edible fruits aremerger. Therefore, the present study was attempted to characterize selected wild fruits used by tribal people of Koraput for nutritional bioactive compounds.The outcome of the study will help to develop baseline information on nutritional compositions of wild fruits of this region and helps for mass consumption and popularisation.

Materials and Methods

Sixteen differentwild edible fruits of wereused in our study (Fig. 1). The wild edible fruits were collected by the reconnaissance survey from different tribal pockets of Koraput district (18º 14¹ to 19º 14¹ N latitude and 82º 05¹ to 83º 25¹ E longitude) (Fig. S1). The data on consumption pattern of wild fruits were collected through questionnaire, focus group discussions and personal interviews with tribal people (Table 1). The fruit plants are identified using The Flora of Orissa by Saxena and Brahmam[13] and The Botany of Bihar and Orissa by Haines[14]. These fresh fruits were collected in polythene bags and taken into the laboratory and were then thoroughly cleaned and washed with running tap water for analysing the phytochemical and nutritional composition.

The proximate compositions (moisture, ash, protein, fat, carbohydrate and fibre) in wild fruit samples were determined following the procedure of AOAC [15]. The total

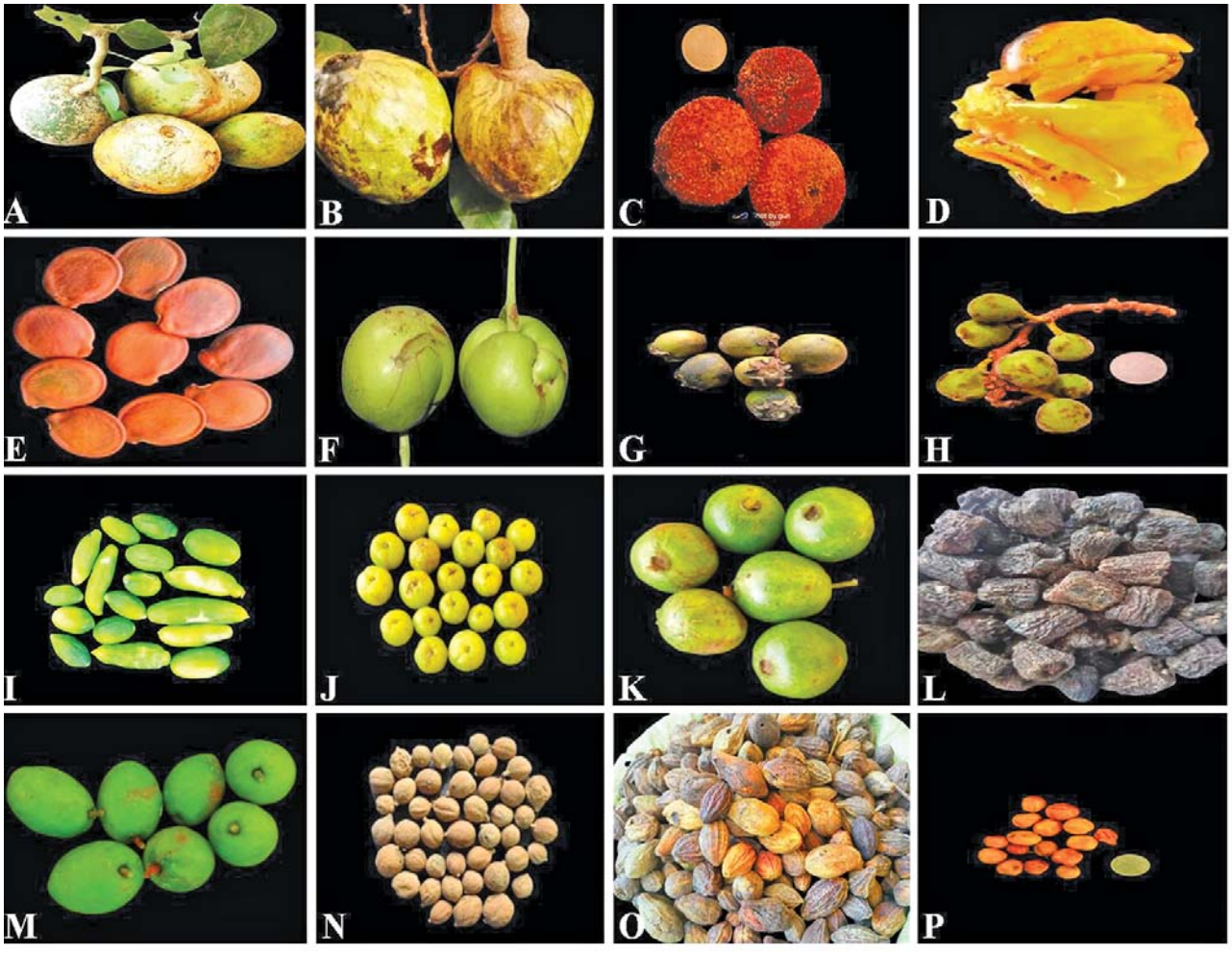

Fig. 1 Photograph of wild edible fruits used by tribal people of Koraput. A: *Aegle marmelos,* B: *Annona reticulata,* C: *Anthocephalus chinensis,* D: *Averrhoa carambola,* E: *Bauhinia vahlii,* F: *Dilleniaaurea,* G: *Diospyros melanoxylon,* H: *Ficus hispida,* I: *Melothria heterophylla,* J: *Phyllanthus emblica,* K: *Psidium guajava,* L: *Semecarpus anacardium,* M:*Spondias pinnata,* N: *Terminalia bellirica,* O: *Terminalia chebula,*P: *Ziziphus mauritiana*

Table 1 list of wild edible fruits used by tribal people of Koraput with their consumption pattern and ethnomedicinal value. (Source: Padhan and Panda 2015)

Fruit Species	Family	Local Name	English	Fruiting Season	Edible Part	Consumption Pattern	Ethnomedicinal Uses
Aegle marmelos (L.) Correa	Rutaceae	Bela	Stone apple	March-June	Fruits pulp and unripe fruits	Mucilaginous pulp eaten as sherbet.	Diabetes, digestive issues, heart problems
Annona reticulata L.	Annonaceae	Ramaphal	Custard apple	May-September	Fleshy part of fruit	Cream-colored, granular, aromatic pulp; directly taken as food.	Dysentery
Anthocephalus chinensis Walp.	Rubiaceae	Kadam phal	Bur flower	September-December	Fruits	Mature fruit consumed directly.	Mouth disorder and wounds
Averrhoa carambola L.	Oxalidaceae	Karamanga	Star fruit	Year around	Fruits	Ripe sweet and sour fruits are eaten fresh and used to make pickles and chutneys.	Used for Kidney stones, upset stomach
Bauhinia vahlii Wight & Arn.	Caesalpiniaceae	Siali	Kachnar	July-October	Seed	Roasted seed taken raw or after boiling.	Loose motion and gastric problem
Dilleniaaurea Smith	Dilleniaceae	Aou	Elephant apple	March-July	Fruits	Ripe fruits consumed directly, also used to make pickle.	Food poisoning
Diospyros melanoxylon Roxb.	Ebenaceae	Kendu phal	Malabar ebony	April-June	Ripe fruits	Ripe fruits are tasty and seeds of young fruits used as vegetable.	Rheumatoid arthritis and abdominal pain
Ficus hispida L.f.	Moraceae	Dumri	Gular tree	November-February	Ripe and unripe fruit	Young figs used as vegetable and ripe fruits occasionally eaten.	Gastric and abdominal pain
Melothria heterophylla (Lour.) Cogn.	Cucurbitaceae	Bana tundri	Kunduru	June-September	Fruits	Both raw and ripe fruits consumed directly.	Constipation
Phyllanthus emblica L.	Euphorbiaceae	Anla	Indian gooseberry	February-May	Mature fruits	Ripe and mature fruits are edible.	Abdominal discomfortand worm infection
Psidium guajava L.	Myrtaceae	Jamba	Guava tree	June-September	Fruits	Ripe fruits consumed directly.	Diarrhea, indigestion and gum problem
Semecarpus anacardium L.f.	Anacardiaceae	Bana bhalia	Marking nut	March-June	Fleshy thalamus, seed	Hypocarp is eaten when ripe.	Piles and cough
Spondias pinnata (L.f.) Kurz.	Anacardiaceae	Ambada	Hog plum	July-September	Mature fruits	Ripe fruit is directly edible and green fruits as vegetable.	Vomiting, dysentery and Diarrhea
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	Bahada	Bibhitaki	June-September	Fruit and nut	The kernel of fruit is consumed directly.	Cold, cough and indigestion
Terminalia chebula Retz.	Combretaceae	Harida	Ink nut	November-December	Mature fruits	Kernel of the fruit eaten directly.	Diarrhea, wound and cough
Ziziphus mauritiana Lam.	Rhamnaceae	Barakoli	Indian plum	October-December	Mature fruits	Fruits are edible. Ripen fruits are dried and then used for making chutney.	Anemia and headache

moisture content of the fruit was estimated by oven drying procedure of AOAC [15]. A known amount of sample was taken in a clean and dry petri plate and dried in a hot air oven at 100-105 ºC for 24 h until a constant weight was obtained. Ash content was determined by incineration of the moisture free samples in a muffle furnace by ignited at 600 ºC for 3 hours in a muffle furnace. The crude fat content of the fruit sample was estimated using soxhlet (*SOCS PLUS SCS-03E, Pelican*) extraction method.The crude fiber content in fruit was estimated by acid and alkali digestion method of AOAC [15]. The fat and moisture free fruit samples were used for crude fiber determination using H_2SO_4 and NaOH (1:25 %) extraction methods.

The crude protein content of fruit sample was measured by Kjeldahl method for nitrogen analysis and crude protein content of the sample was determined by using the following formula:Crude protein (%) = 6.25× %N

Total carbohydrate was evaluated by the difference after analysis of the following (AOAC 2012). Total carbohydrate = [100 - (% moisture + % protein + % crude fat + % crude ash + % crude fibre)]

The total energy content of sample (100 g dry weight) was calculated by taking fat, carbohydrate and protein contents by following equation of Rachkeeree et al.[16].

Total energy = [(4 x g protein sample) + (9 x g fat sample) + (4 x g carbohydrate sample)]

The ascorbic acid (Vitamin C) content was determined by the method of Omaye et al.[17] with some modification using 2, 4-dinitrophenylhydrazine-thiourea-copper sulphate (DTC) reagent and the colour intensity was measured at 520 nm in spectrophotometer. The phenol content was determined following Sadasivam and Manickam[18] with some modification using gallic acid as standard. Total flavonoid content of fruit sample was estimated by aluminium chloride spectrophotometric assay by following Chang et al.[19]. The total antioxidant capacity of the fruit sample was estimated by the procedure of Prieto et al.[20]

All the parameters reported in table and graphs are average values of triplicate determinations. One way analysis of variance (ANOVA). All the parameter were compared by the *Fisher's* LSD test.

Table 2 Proximate compositions in different wild edible fruits used by tribal people of Koraput. Data are the mean ± Standard deviation (n=3). Same Alphabets in a column are not significantly different at P<0.05.

Fruit plants	Moisture (%)	Ash (g $100g^{-1}$ dwt)	Fat (g $100g^{-1}$ dwt)	Fiber (g $100g^{-1}$ dwt)	Protein (g $100g^{-1}$ dwt)	Carbohydrate (g $100g^{-1}$ dwt)	Energy (Kcal $100g^{-1}$ dwt)
Aegle marmelos	61.05 ± 0.84^{d}	3.07 ± 0.11^{f}	3.87 ± 0.05^{c}	06.65 ± 0.01^{i}	13.59 ± 0.37^{d}	60.71 ± 2.12^{c}	331.9 ± 6.5^{b}
Annona reticulata	66.07 ± 1.01^{d}	4.66 ± 0.23^{d}	1.52 ± 0.01^{k}	35.08 ± 0.15^{b}	09.99 ± 0.16^{e}	51.94 ± 0.62^{d}	261.3 ± 1.9^{e}
Anthocephalus chinensis	76.44 ± 2.29^{b}	1.84 ± 0.28^{h}	3.71 ± 0.02^{d}	12.41 ± 0.08^{g}	05.63 ± 0.07^{f}	60.07 ± 0.25^{c}	296.2 ± 1.4^{d}
Averrhoa carambola	82.30 ± 0.65^{a}	7.15 ± 0.23^{a}	1.00 ± 0.04^{l}	08.01 ± 0.27^{h}	14.56 ± 0.16^{c}	63.43 ± 0.19^{b}	320.9 ± 0.2^{c}
Bauhinia vahlii	60.44 ± 6.36^{d}	3.84 ± 0.10^{e}	8.11 ± 0.01^{a}	05.77 ± 0.00^{i}	19.51 ± 2.67^{a}	34.69 ± 1.18^{g}	289.7 ± 5.5^{d}
Dillenia aurea	83.49 ± 0.08^{a}	2.81 ± 0.06^{f}	0.70 ± 0.02^{m}	36.04 ± 0.21^{a}	12.16 ± 0.16^{d}	42.25 ± 0.44^{f}	223.9 ± 2.2^{g}
Diospyros melanoxylon	71.53 ± 0.93^{c}	1.79 ± 0.04^{h}	2.27 ± 0.01^{i}	36.51 ± 0.71^{a}	09.59 ± 0.19^{e}	43.91 ± 0.90^{e}	234.4 ± 4.2^{f}
Ficus hispida	79.50 ± 0.64^{b}	5.44 ± 0.21^{c}	2.79 ± 0.02^{g}	22.14 ± 0.49^{c}	06.21 ± 0.34^{f}	31.41 ± 0.52^{h}	175.5 ± 0.8^{i}
Melothria heterophylla	75.17 ± 0.49^{b}	4.07 ± 0.06^{e}	2.60 ± 0.10^{h}	08.70 ± 0.05^{h}	11.34 ± 0.41^{d}	30.38 ± 0.03^{h}	190.2 ± 2.6^{h}
Phyllanthus emblica	77.95 ± 0.39^{b}	2.37 ± 0.11^{g}	1.45 ± 0.00^{k}	06.38 ± 0.47^{i}	11.21 ± 0.12^{d}	29.44 ± 0.12^{h}	175.6 ± 0.6^{i}
Psidium guajava	80.66 ± 0.76^{a}	2.83 ± 0.09^{f}	2.54 ± 0.02^{h}	08.25 ± 0.01^{h}	08.85 ± 0.53^{e}	51.50 ± 0.32^{d}	264.3 ± 3.2^{e}
Semecarpus anacardium	83.69 ± 0.79^{a}	3.34 ± 0.15^{f}	6.92 ± 0.02^{b}	13.47 ± 0.46^{f}	06.04 ± 0.44^{f}	66.52 ± 0.24^{a}	352.4 ± 2.9^{a}
Spondias pinnata	71.06 ± 0.07^{c}	4.23 ± 0.13^{e}	3.43 ± 0.05^{e}	04.37 ± 0.11^{j}	05.54 ± 0.12^{f}	28.38 ± 0.12^{hi}	166.4 ± 0.4^{i}
Terminalia bellirica	54.95 ± 1.05^{e}	6.02 ± 0.30^{b}	6.97 ± 0.04^{b}	21.01 ± 0.87^{d}	16.61 ± 0.37^{b}	32.13 ± 0.38^{h}	257.7 ± 0.3^{e}
Terminalia chebula	64.44 ± 0.58^{d}	2.76 ± 0.18^{f}	1.61 ± 0.04^{j}	19.91 ± 0.19^{e}	10.16 ± 0.37^{e}	25.34 ± 0.75^{i}	156.5 ± 1.9^{j}
Ziziphus mauritiana	79.07 ± 0.62^{b}	2.96 ± 0.18^{f}	2.96 ± 0.06^{f}	11.99 ± 0.69^{g}	06.01 ± 0.12^{f}	62.46 ± 0.65^{b}	300.5 ± 1.5^{d}
*LSD*P<0.05*	3.90	0.37	0.08	0.88	1.50	1.60	9.6

Results and Discussion

Proximate Composition and Total Energy in Wild Edible Fruits

The proximate compositions of wild edible fruits are reported in Table 2. The moisture content of fruit sample was varied from 54.95% to 83.69% with a mean value 72.98%. The fruit tissue of *Semecarpus anacardium* recorded maximum moisture content (83.69%) followed by *Dilleniaaurea* (83.49%). These results are within the ranges of moisture contents of commonly used vegetables 60 to 90%[3]. The higher moisture content in the plant products is the more likely to become perishable within short period [10]. The ash contents varied from 1.79 % to 7.15 % with an average value of 3.69 % in different wild fruits. Maximum ash content was reported in *Averrhoa carambola* (7.15%) and lowest was in *Diospyros melanoxylon* (1.79%). Amount of ash in different fruits indicates the levels of inorganic compounds and other essential and non-essential mineral elements [16]. The crude fat of the studied fruits samples ranged from 0.7 % to 8.1 1% and maximum was recorded in *Bauhinia vahlii* (8.11 %) followed by *Terminalia bellirica*(6.97 %) (Table 2). The studied fruits are rich source of dietary fibres and it ranged from 4.37% (*Spondias pinnata*) to 36.51% (*Diospyros melanoxylon*). This amount of fiber could be of immense importance in the digestive process of humans in controlling constipation[3].

The protein, carbohydrates and fat of the wild fruits are varied from 5.54% to 19.51%, 25.54% to 66.52% and 0.7% to 8.11% respectively. Maximum protein and carbohydrate content was reported in *Bauhinia vahlii*and *Semecarpus anacardium* respectively. Based on the results, the energy content in different wild fruits are ranged from 156.51 to 352.47 Kcal 100 g^{-1} dwt with a mean of 249.88 Kcal 100 g^{-1} dwt (Table 2). The fat content of edible fruits in the present study were all low in fat as earlier reported value of common leaf vegetables and also it is within the daily intake level [20]. It suggested that the consumption of these edible fruits could be recommended for human suffering from obesity[16]. More over carbohydrate and protein content were comparable with the other indigenous vegetables and fruits[21]. The exceptional rich in total energy content in *Semecarpus anacardium* followed by *Aegle marmelos* (331.99) and *Averrhoa carambola* (328.98) indicated its nutritional superiority than other and these fruits might be reliable food security crops for tribal people of the locality.

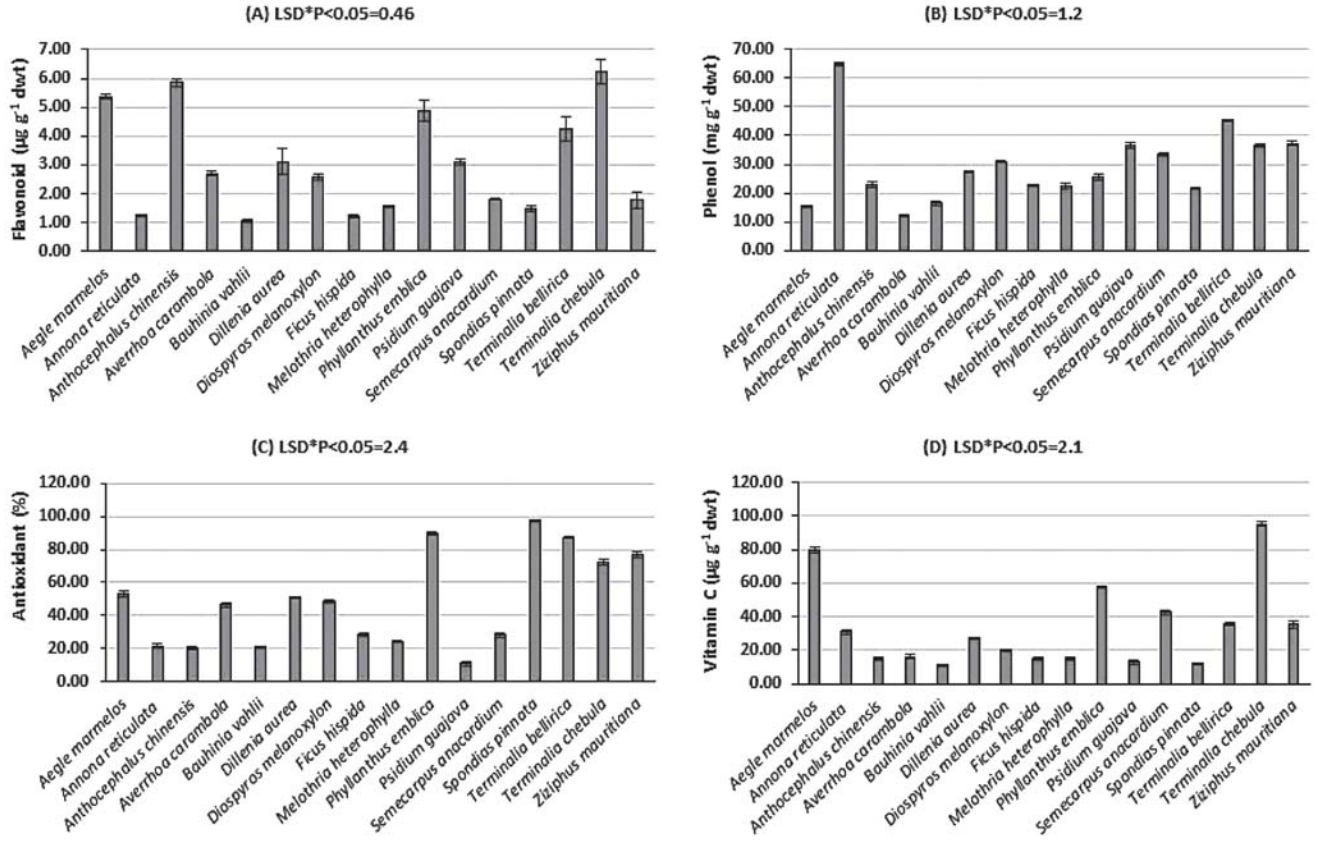

Fig. 2 Flavonoid, phenol, antioxidant and vitamin C content in different wild fruits used by tribal people of Koraput. Data are the mean of three replications with vertical bar represents standard deviation.

Nutraceutical Compositions in Wild Edible Fruits

The phenol content was varied significantly among wild fruits ranged from 12.07 to 64.8mg g^{-1} dwt, with a mean value of 29.53mg g^{-1} dwt (Fig. 2). Maximum phenol content was reported in *Annona reticulata* (64.8 mg g^{-1} dwt) among the studied fruits. Total flavonoid content varied significantly among fruits and ranged from 1.07 to 6.25 µgg^{-1}dwt with mean value of 4.89 µg$g^{-1}$of dwt (Fig. 2). Maximum flavonoid content was reported in *Terminalia chebula* followed by *Anthocephalus chinerisis*. Total antioxidant content varied from 10.98 to 97.56% among the studied fruits (Fig. 2). The total antioxidant capacity was found to be maximum in *Spondias pinnata* (97.56%) and minimum in *Psidium guajava* (10.98%). The phenols and flavonoids are both known as beneficial antioxidants which are particularly able to scavenge free radicals[22]. It has lots of health benefits such as anti-inflammatory activities, anticancer and are prone to reducing the risks of cardiovascular diseases[3,16]. Thus, the findings prove the efficacy of the traditional use of these wild fruitsmay be useful for oxidative stress[12,16]. The vitamin C content was found to be maximum in *Terminalia chebula* (95.36 µg g^{-1} dwt) followed by *Aegle marmelos*(79.76 µg g^{-1} dwt) (Fig. 2). The presence of good amount of vitamin C in these fruits can be promoted as a source of natural antioxidants.

Conclusion

The present study provides the baseline information on tribal use and nutritional compositions of 16 different wild edible fruits used by tribal people from Koraput. Results revealed that some wild fruits such as *Bauhinia vahlii, Semecarpus anacardium* and *Aegle marmelos* recoded high protein, carbohydrate and exceptional rich in total energy content indicated its nutritional superiority than other fruits. These wild fruits might be reliable food security crops for tribal people of Koraput. In addition, exceptional rich in antioxidants and vitamin C were recorded in *Spondias pinnata*, *Psidium guajava* and *Terminalia chebula*than the other species can be promoted as a source of natural antioxidants.These underutilized wild fruits might be popularized for different products as a good alternative source of food to alleviate hunger and malnutrition.

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