Indian Journal of Traditional Knowledge
Vol 23(5), May 2024, pp 478-488
DOI: 10.56042/ijtk.v23i5.11041

Estimation of phytochemical constituents and antioxidant potential of underutilized ethnobotanically important wild edible fruits of Manipur

Mayanglambam Bidyalakshmi Devi & Ashalata Devi*
Department of Environmental Science, Tezpur University, Tezpur, Napaam 784 028, Assam, India
*E-mail: ashalatadevi12@gmail.com

Received 20 August 2021; revised & accepted 01 February 2024

This paper presents investigation on ethnobotany, phytochemicals constituents and antioxidant potential of six selected wild edible fruits (WEFs) of Manipur. Ethnomedicinal data collected through a semi-structured questionnaire shows that there are different therapeutic possibilities of WEFs, practised by the local people. Phytochemical estimation observed *Rhus semialata* was the most acidic fruit (4.67 pH) with 0.73% of titratable acidity and lowest solubility (20%). A strong negative and significant association was observed between pH and titratable acidity, $r = -0.900$, $p<0.010$, while a moderate positive relationship between titratable acidity and solubility, $r = 0.590$, $p<0.010$ and no significant relationship was observed between pH and solubility. The calorific value was found within the range of 198-459 kcal/100 g. The phytochemical content was foremost in *Phyllanthus emblica*, including the antioxidant potential and vitamin C, exceptfortannin. Meanwhile, tannin was found highest in *Spondias pinnata* (67.63±0.97mg/g). Least total phenolic and tannin content was recorded in *Vangueria spinosa*. *P. emblica* shows the highest reducing capacity in both the analysis, *i.e.,* total *in vitro* antioxidant activity (159.06±4.10 AAE mg/g) and FRAP assay (42.57±0.05 AAE mg/g). In *in vitro* antioxidant activity, *S. pinnata* (11.82±1.54 AAE mg/g) shows the lowest antioxidant activity. The inhibition percentage of the DPPH assay was in order of *Phyllanthus emblica>Spondias pinnata>Rhus semialata>Elaeocarpus floribundus>Microcos paniculata>Vangueria spinosa.* The fruit samples exhibit diverse antioxidant activity indicating an active response to the radical. The finding specifies the overall primary and secondary metabolites, and antioxidant properties of these underutilized wild edible fruits and validates their therapeutic values and prospects. Value-added food products of the WEFs plant species may be promoted within and outside the state while assuring nutrient content and availability of products. Moreover, it will help improve the economic conditions of local people, aiding financial condition by selling fruits and value-added products.

Keywords: Antioxidant, Manipur, Phytochemicals, Wild edible fruits

IPC Code: Int Cl.[24]: A61K 36/00, A61K 47/36

Different wild edible plants are known for their significant value in the history of humankind in all geographical regions of the world. In India, many ethnobotanists have documented several wild edible plants including fruits used by tribal and rural communities to fulfil their diverse requirements such as food, medicines, and source of income. Wild edible plants are the plants that grow naturally in self-maintaining populations in natural or semi-natural ecosystems, which differ from the cultivated plants that arise through the breeding or selection process[1]. Apart from the traditional use as food, wild edible fruits (WEFs) offer numerous advantages, including medicinal properties and antioxidant effects[2]. Hence, fruits have become the crucial ingredients in human diets. Fruits provide an adequate level of nutrition for humankind and rich in vitamins and minerals, especially vitamin C, in addition to protein and energy[3]. The importance of chemical constituents of different fruit species was recognised by various researchers around the globe. However, limited study was undertaken in the north-eastern region of India, particularly in the state Manipur. Some recent reports on traditional knowledge and phytochemical constituents to be mentioned from Manipur are Hazarika and Singh[4], Sharma *et al*.[5], Khomdram *et al*.[6], and Khomdram and Devi[7].

In Manipur, several indigenous people largely depend on their traditional agricultural products and the forest-based resources which they also considered as the primary means of livelihood for centuries. Varieties of wild edible fruit plants are widely distributed in different natural habitats, especially in forest areas. These wild edible fruits play a significant role in providing nutrient, food supplements and a source of income for people living in remote villages.

*Corresponding author

Besides their nutritional and therapeutic values, some value-added products are also prepared and contribute significantly to improve their socio-economic livelihood, health, and food security. But minimal factual data are available on the occurrence, availability, utilization, and market value of these wild edible fruit species.

Moreover, the people of Manipur have a traditional system of dietary culture. They naturally intend to consume varieties of wild edible plants and fruits in their traditional lifestyle, which help in their well-being. In recent years, it has been observed that plant-based medicines or phytochemicals are used for treatment of various health ailments and illnesses. Likewise, since the ancient periods, these wild edible plants are used to cure many ailments and diseases like arthritis, stone problems, malaria, jaundice, etc. by the local healers (medicine men) of Manipur known as *Amaiba/Amaibi* in the Manipuri dialect. It has been shown that plants generally contain secondary metabolites which reveal their specific character and contribute to pharmacological properties. Among the secondary metabolites present in fruits, notable examples include Quercetin, which had been associated with antioxidant, anti-inflammatory, and anti-cancerous properties[8]. Additionally, Tannins, identified as polyphenolic compounds found in certain wild edible fruits, possess astringent attributes and may exhibit antioxidant and anti-inflammatory effects[9]. Moreover, Phenolic acids, a class of polyphenolic compounds found in wild edible fruits, also exhibit antioxidant and anti-inflammatory properties[10]. The nature and efficacy of the medicines prepared from plant parts depend on multiple factors such as parts use, required quantity and the quality of the secondary metabolite present in raw drugs. Hence, it is imperative to investigate and validate the medicinal properties of such traditionally known wild edible fruit plants of Manipur. Subsequently, the qualitative and quantitative phytochemical screening will help to understand the characteristics of biochemical constituents present in the fruits. Therefore, the present study aimed to investigate ethnobotanical values and estimation of the phytochemical compositions and antioxidant property of six selected wild edible fruits of Manipur. The outcome of the study will help to establish any potential quality of the species relevant to pharmacognosy and fruit-based industry.

Methodology

Study area

The study was conducted in two villages of Machi block in Tengnoupal district of Manipur (Fig. 1). Geographically, the state is located in temperate and tropical rain forest zone within the 23°47'-25°41'N latitude and 93°61'-94°48'E longitude bordering Myanmar to the east, China and Nepal to the north[11]. The two villages are Machi village (24°30'30.80" N to 094°08'29.96" E, 1443m amsl) and Laiching Minou village (24°30'28.14" N to 094°02'18.81" E, 1021m amsl). Laiching Minou village and Machi village are approx. 28 km and 49 km respectively, from the head quarter of Tengnoupal district. While distance between Machi village and Laiching Minou village is approx. 29 km. Tengnoupal district is dominated by Maring Naga tribe and both the selected villages are inhabited by this tribe. They conserved forest as a community forest to support their livelihoods. The main occupation of the Maring Naga tribe is cultivation and bamboo crafting. However, now-a day's young generation of the community prefer to opt for a better opportunity towards a stable job.

Materials and Methods

Sample plants, collection of fruits and ethnomedicinal data

A total of six wild edible fruits (WEFs) namely, *Elaeocarpus floribundus* Bl., *Microcos paniculata* L, *Phyllanthus emblica* L., *Spondias pinnata* (L. f.) Kurz, *Vangueria spinosa* (Roxb. ex Link) Roxb., and *Rhus semialata* Murr. (Fig. 2) were selected for the purpose of study. The plants were carefully identified referring taxonomic characteristics of the species and other relevant taxonomic literature. Scientific nomenclature of the plant species was checked with The Plant List (www.theplantlist.org), and herbarium specimens for each species were prepared for voucher sample record with specified number (601-606), which are housed in the Tezpur University Herbarium House, Department of Environmental Science. The fruits were procured from various locations (such as local markets and community forests) of the study areas. The medicinal information of these fruits was obtained from local healers (*Amaiba /Amaibi*) and other knowledgeable elderly local people using a suitable pre-structured questionnaire. Further relevant secondary information, literature on regional floras was also studied.

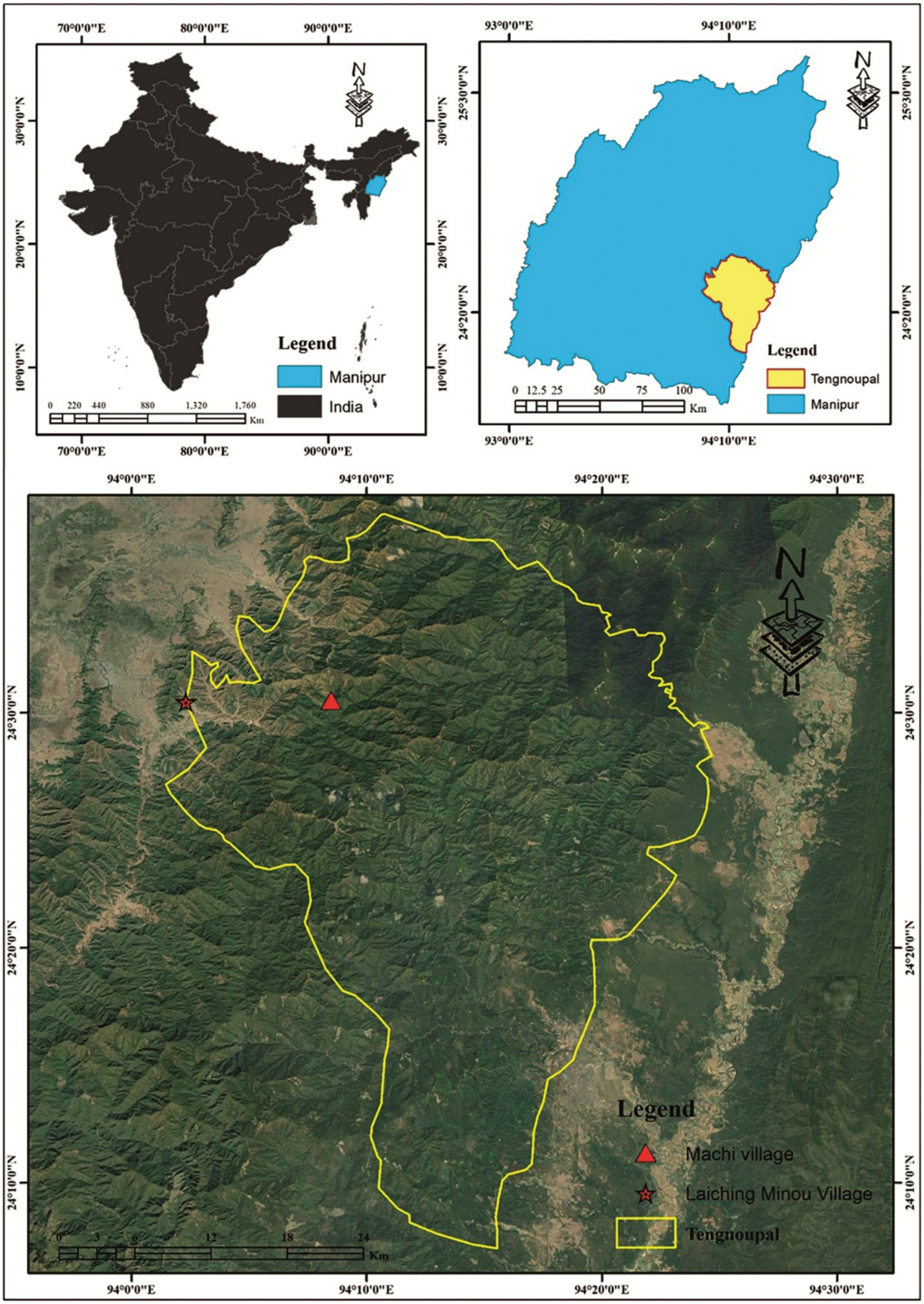

Fig. 1 — Map of Tengnoupal District, Manipur showing the study areas (generated using ArcMap)

Experimental design

Mature, healthy, and unaffected fruits were collected and brought to the laboratory for sample processing. The fruits were thoroughly washed with running tap water then oven-dried (below 50°C). Fresh juice was extracted for vitamin C estimation. The oven-dried sample was then pulverized using a mechanical grinder and stored in an airtight container for further analysis. The extraction of the sample was prepared using aqueous and ethanol as a solvent for further analysis.

Chemical used

2, 2-Diphenyl-1-picrylhydrazyl (DPPH), 2,4,6-tris(2-pyridyl)-s- triazine (TPTZ), ferric chloride hexahydrate, L-ascorbic acid, gallic acid, quercetin, tannic acid, aluminium chloride, GR-grade methanol and ethanol, and Folin-Ciocalteu's reagents were used

Fig. 2 — Photographic representation of the selected six wild edible fruits, (A) *Elaeocarpus floribundus* (B) *Microcos paniculata* (C) *Phyllanthus emblica* (D) *Spondias pinnata* (E) *Vangueria spinosa* and (F) *Rhus semialata*

for analysis of physiochemical, phytochemical and antioxidant properties.

Physiochemical properties

pH and titratable acidity of the selected fruits were analysed using the standard protocols given by the Association of Official Agricultural Chemists[12]. The solubility was determined according to the method described by Chau *et al.*[13]. Auto Bomb Calorie meter (Make: Changsha Kaiyuan Instrument Co. Ltd; Model: 5E-1AC/ML) was used for determination of calorific value of the dried sample.

Qualitative phytochemical investigation

The phytochemical components of the plant extracts (both aqueous and ethanol) such as protein, carbohydrate, tannin, phenol, flavonoid, saponin, alkaloid, terpenoid, steroid, cardiac glycoside, phlobatannin, anthocyanin, and quinone were screened qualitatively by using standard methods as described by Harborne[14], Sofowora[15] and Evans[16].

Quantitative phytochemical analysis

The quantitative phytochemical analysis was performed using suitable standard methods. Total carbohydrate was determined by Phenol sulphuric acid method[17]. Lowry's method[18] was followed for estimation of total protein. Total phenol content was determined by Folin-Ciocalteu's method[19]. Total flavonoids content was measured with the aluminium chloride colorimetric assay[20]. Tannins were determined following modified Folin-Ciocalteu's method[21]. Vitamin C was evaluated using titration method following University of Canterbury[22]. The total *in vitro* antioxidant capacity was estimated by the Ferric reducing antioxidant power method[23]. DPPH (2, 2-Diphenyl-1-picrylhydrazyl) free radical and FRAP (ferric reducing antioxidant power) assay were performed to determine the total antioxidant activity of the extract by the method given by Brand-Williams *et al.*[24] and Benzie and Strain[25], respectively. Percentage of scavenging effect has been calculated for DPPH using the following formula.

$$\% \text{ Scavenging effect} = \frac{A0\text{-}A1}{A0} \times 100$$

Where, A0 = absorbance of control; A1 = absorbance of test sample

While, *in vitro* antioxidant capacity and FRAP value was expressed in ascorbic acid equivalent (AAE) mg/g extract.

Statistical analysis

The statistical analysis of each parameter was done using triplicate value and the data were presented as mean±standard deviation (SD). The correlation was performed in SPSS software (Version 12). The line graph for DPPH assay was plotted using Origin pro software (Learning edition version).

Result and Discussion

Ethnobotanical values

Ethnobotanical information was collected through informal conversation from a total of 10 informants who were involved in herbal practices and the collection of medicinal plants. It has been recorded that the fruit of the selected species has an essential source of nutrition and played a vital role in preparing therapeutic medicine to treat several ailments. These fruits are used to treat diarrhoea, dysentery, haemorrhage, anaemia, jaundice, kidney trouble, urinary complaints, intestinal worm, bleeding gums and piles. Both fresh and dried fruit parts are utilised for the preparation of medicine. Oral application is a common mode of administration, while the dose for administration varied for children and adults. It has been reported that the efficiency of the medicine administered differs from person to person. The record of the ethnomedicinal importance of the selected six fruits is enumerated in Table 1 and are comparable with the study of Singh *et al.*[26] and Hazarika and Singh[4]. In addition to the medicinal values, Hazarika and Singh[4] also reported the formulation of the medicines. Most of the wild edible fruits were collected from natural habitats by the villagers and sold in local markets in fresh and dried forms. Such activities of villagers catalysed as a small entrepreneur during the season of availability and also in the off season. It was observed that other than the traditional medicinal value, all the fruits are mainly dried and process for pickles, which brings substantial benefits to small entrepreneurs, mainly during the offseason. A similar result was observed in the study conducted by Ahivar *et al.*[27].

Physiochemical properties

The physiochemical characteristics like pH, solubility, titratable acidity, and calorific value of these fruits are presented in Table 2. The pH indicates the strength of the acids, while titratable acidity measures the total acidity but not the strength of the acids. *R. semialata* was the most acidic fruit

Table 1 — Ethnobotanical importance of the studied six wild edible fruit plant species

Scientific name (Family) [Voucher number]	Vernacular Name (Maring/Meitei)	English/ Common name	Uses	Health benefits and ailments
Elaeocarpus floribundus Bl. (Elaeocarpaceae) [601]	Chorphon/ Chorphon	Indian Olive	Fruits are eaten raw and cooked for decoction. Used for pickles and chutney.	Fruits are used as antiseptic and in constipation and indigestion. Young leaves are used in pile treatment.
Microcos paniculata L. (Tiliaceae) [602]	Heituk/ Heitup	Wild Apple	Fruits are used for pickles and candy.	Fruits are used in indigestion, dysentery, mouth ulcer and typhoid.
Phyllanthus emblica L. *(*Phyllantheceae) [603]	Puklu/ Heikru	Goose berry	Fruits are eaten raw as well as pickle. And are boiled with rice water for hair cleanser.	Fruits are given in diarrhoea, dysentery, haemorrhage, anaemia and jaundice. Fruits are used in cough, constipation, bleeding gums, piles and also used as brain and nerve tonic in blood diseases.
Spondias pinnata (L. f.) Kurz (Anacardiaceae) [604]	Totoihei/ Heining	Indian Hog Plum	Ripe and unripe fruits are used for pickles and chutney.	Bark extract is taken against dysentery and diarrhoea. Fruit pulp is good for indigestion.
Vangueria spinosa (Roxb. ex Link) Roxb. (Rubiaceae) [605]	Theibi/ Heibi	Muyna	Young leaves are ingredient of traditional salad (singju) and hair cleanser.	Cooked leaf used for intestinal worm. Leaf paste is used for local application on head in hoarseness.
Rhus semialata Murr. (Anacardiaceae) [606]	Khupmai/ Heimang	Chinese Sumac/ Chinese gall	Matured and dried fruits are used for brown sugar candy and powdered pickles. Decoction is used as hair cleansers.	Kidney trouble, urinary complain, antiviral, antibacterial, diarrhoea, constipation, antioxidant activities, and as a digestive.

Table 2 — pH, solubility, titratable acidity and calorific value of fruit sample of studied species

Plant species	pH	Solubility (%)	Titratable acidity (%)	Calorific Value (kcal/100 g)
1 *Elaeocarpus floribundus*	5.67	46.7	1.06	323.64
2. *Microcos paniculata*	6.91	50.0	0.46	365.68
3. *Phyllanthus emblica*	5.9	40	0.82	306.68
4. *Spondias pinnata*	4.88	26.7	0.94	298.80
5. *Vangueria spinosa*	5.05	53.3	0.53	198.48
6. *Rhus semialata*	4.67	20.0	0.73	458.59

(4.67 pH) among the six selected fruits with 0.73% titratable acidity. The solubility of the fruits was found highest in *V. spinosa* (53.3%) and lowest in *R. semialata* (20%). The highest calorific value was found in *R. semialata* (458.59 kcal/100 g). The fruit of *R. semialata* is a small drupe, dried when mature and has a skinny layer of the soluble part. A scientific paper reported the energy content of five wild edible fruits of Meghalaya, India, found to be in the range between 342.15±0.13 to 419.09±0.06 kcal/100 g[28]. The calorific value found in *R. semialata* was similar to 364.6 kcal/100 g given by Sen *et al.*[29] and comparatively higher than the 75.38 kcal/100 g given by Sharma *et al.*[5]. A strong negative and significant association was observed between pH and titratable acidity, r = -0.900, $p<0.010$, while a moderate positive relationship between titratable acidity and solubility, r = 0.590, $p<0.010$ and no significant relationship was observed between pH and solubility.

Phytochemical properties

Qualitative analysis

In qualitative analysis, parameters like proteins, carbohydrates, tannins, phenols, flavonoids, saponins, alkaloids, terpenoids, steroids, cardiac glycosides, phlobatannins, anthocyanins, betacyanins and quinones were screened using aqueous and ethanol extracts. The degree of presence or absence of an active compound is represented by the symbols *viz,* '+++' present in high concentration, '++' present in a moderate concentration, '+' present in small concentration, and '-' absent as shown in Table 3. The presence of these phytochemical bioactive compounds implies the potential medicinal value of the fruits. These phytochemicals exhibit significant variability in their structure, mode of action, and biological activities, bestowing them with diverse medicinal

Table 3 — Phytochemical constituents recorded inaqueous extract (Aq.) and ethanol extract (E.) of fruit sample of the studied species

Chemical test	Fruits	*Elaeocarpus floribundus*		*Microcos paniculata*		*Phyllanthus emblica*		*Spondias pinnata*		*Vangueria spinosa*		*Rhus semialata*	
	Solvents	Aq.	E.	Aq.	E.	Aq.	E.	Aq.	E.	Aq.	E.	Aq.	E.
Proteins	Million's Test	-	-	-	-	-	-	-	-	-	-	-	+
	Ninhydrin Test	-	-	-	-	-	-	-	+	-	-	-	-
	Copper Sulphate Test	+	+	+	+	+	+	+	+	+	+	+	+
	Xanthoproteic Test	-	-	-	-	-	+++	+	+	+++	+	-	-
Carbohydrates	Fehling's Test	+	+	+	+	+	+++	+	+	+	+	+	+
	Benedict's Test	+	+	+	+	+	+	+	+	+	+	+	+
	Molisch's Test	+	+	+	+	+	+	+	+	+	+	+	-
Tannins	Alcoholic Ferric Chloride Test	+	+	+	+	+	+	+	+++	-	+	+	+
Phenols	Aqueous Ferric Chloride Test	+	+	+	+	+	+	+	+++	-	+	+	+
Flavanoids	Alkaline reagent Test	+	-	+	+	+++	+	+++	+	+	+	+	-
	Lead Acetate Test	+	+	+	+	+	+	+	+	-	+	+	+
Saponins	Foam Test	-	+	-	+++	+	-	+	+	-	+	-	-
Alkaloids	Mayer's Test	-	-	-	+	-	-	-	-	-	-	-	+
	Wager's Test	-	-	-	-	-	-	-	+	-	+	-	-
Terpenoids	Salkawski Test	-	+	+	+	-	+	-	+	+	+	-	-
Steroids	Salkawski Test	-	-	-	-	-	-	-	-	-	-	+	-
Cardiac glycosides	Keller-Killiani Test	+	+	+	+	+	+	+	+	+	+	-	+
Phlobatannins	Hydrochloric Test	-	+	-	+	-	+	-	-	-	+	-	-
Anthocyanins	Sodium hydroxide Test	-	-	-	-	-	-	-	-	-	-	-	-
Betacyanins	Sodium hydroxide Test	+	-	+	-	-	-	+	+	+	+	+	-
Quinones	Sulphuric acid test	-	-	-	+	-	+	+++	+	+++	+	-	-

properties, including anthelmintic, antioxidant, antimicrobial, and other biological activities[30].

The presence of protein in the WEFs was analysed using four preliminary tests: Million's test, Ninhydrin test, Copper Sulphate test, and Xanthoproteic test. Based on the analysis, it was observed that only the copper sulphate test showed positive responses in both the extracts (*i.e.,* aqueous and ethanol) for the entire sample studied, while observed negative responses to Million's test and Ninhydrin's test except the ethanol extract of *R. semialata* and *S. pinnata*, respectively. In the case of carbohydrate test, the entire test showed positive response except for *R. semialata* of ethanol extract. Only aqueous extract of *V. spinosa* showed negative reactions for both tannin and phenol test. The presence of flavonoid was exhibited in all the test samples, and saponin was found to be absent only in *R. semialata*. The presence of alkaloids was shown in ethanol extract of *M. paniculata*, *S. pinnata, V. spinosa* and *R. semialata*. Terpenoids were found in all the WEFs, except *R. semialata.* However, *R. semialata* was the only sample that showed positive reactions in the steroid test. Test for cardiac glycosides showed positive results in all the tested samples. Phlobatannins were absent in *S. pinnata* and *R. semialata*. Unexpectedly, anthocyanins were absent in all the tested samples. Betacyanins were present in the entire sample except for *P. emblica*. Lastly, quinones were absent in *E. floribundus* and *R. semialata.* Notably, the ethanol extract contained a higher concentration of active components compared to the aqueous extract, consistent with previous findings[31]. The present analysis reveals the presence of secondary metabolites such as phenol, tannins, flavonoids, alkaloids, saponins, phlobatannins, steroids, terpenoids, anthraquinones, and cardiac glycosides. Plants containing these secondary metabolites are responsible for the medicinal property of plant such as anti-cancer, anti-inflammatory, anti-diabetic, cardiovascular protective effects, antioxidant and other chronic diseases[30,32].

Quantitative analysis

The present work showed that *P. emblica* contain 36.39% of total carbohydrate, 11.66 g/100 g of total protein, 5.25 mg GAE/g of total phenol, and 183.90 mg QE/g of flavonoid which is the highest among the six selected fruits (Table 4). *S. pinnata* showed the maximum tannin concentration (67.63 mg/g) among them. The least carbohydrate, protein, phenol, flavonoid, and tannin content was observed in *M.*

Table 4 — Test result of quantitative phytochemical analysis of fruit sample of studied species

Plant species	Total Carbohydrate (%)	Total Proteins (g/100 g)	Total Phenol (mg GAE /g)	Total Flavanoid (mg QE/g)	Total Tannin (mg/g)	Total in vitro-antioxidant (AAE mg/g)	FRAP (AAE mg /g)	Vitamin C (mg/100 g)
E. floribundus	15.68±1.78	0.70±0.14	2.10±0.03	6.93±0.05	36.37±0.10	13.26±0.79	6.89±0.01	15.25±0.51
M. paniculata	14.98±0.86	1.20±0.07	4.23±0.11	11.50±0.07	33.85±1.04	43.08±4.14	6.15±0.04	58.08±0.88
P. emblica	36.39±1.83	11.66±0.20	5.25±0.09	183.90±4.47	54.70±1.93	159.06±4.10	42.57±0.05	340.85±6.60
S. pinnata	22.24±0.80	7.39±0.17	2.75±0.25	87.74±1.82	67.63±0.97	11.82±1.54	19.48±0.03	207.97±2.69
V. spinosa	34.56±2.68	3.61±0.12	0.93±0.04	11.25±0.20	33.72±0.13	38.83±0.78	3.87±0.02	109.71±1.02
R. semialata	23.08±2.57	4.50±0.29	4.92±0.21	26.53±1.27	38.51±1.25	66.48±1.84	28.92±0.02	134.93±1.83

Note: Each value in the table is expressed as Mean ± SD

paniculata (14.98%), *E. floribundus* (0.70 g/100 g), *V. spinosa* (0.93 mg GAE/g), *E. floribundus* (6.93 mg QE/g), and *V. spinosa* (33.72 mg/g), respectively. The estimated range of total carbohydrate in the fruits was lower than that of Western Himalaya (74.29 to 80.71 g/100 g)[33] and wild edible fruits of Meghalaya (47.03% to 85.83%)[28,34]. However, the present findings are consistent with findings of Khomdram[7].

In the conducted study, it was found that the total flavonoid content in the examined fruits was notably higher compared to lesser-known edible fruits from the Western Ghats of India[35] with *P. emblica* exhibiting the highest amount at 183.90 mg QE/g, showing significant differences when compared to the other fruits in terms of total flavonoid content. Total phenolic content among the fruits was found in the order of *P. emblica*>*R. semialata*>*M. paniculata*>*S. pinnata*>*E. floribundus*>*V. spinosa*. The range of phenolic compounds in the fruit samples was similar to that reported in some wild edible plants, which ranged from 0.87 to 7.02 mg/g[36]. However, total tannin content was found in the order of *S. pinnata*>*P. emblica*>*R. semialata*>*E. floribundus*>*M. paniculata*>*V. spinosa*. The investigated wild edible fruits of Manipur were found to contain significant amounts of tannin, comparable to most common fruits of Algeria[37], but lower than the 16 wild edible fruits of Odisha[38]. The present study indicates the concentration of phytochemicals was highest in flavonoids followed by tannin and phenol.

The current study reveals that among the examined fruits, *P. emblica* exhibited the highest vitamin C content (340.85 mg/100 g), followed by *S. pinnata* (207.97 mg/100 g), *R. semialata* (134.93 mg/100 g), *V. spinosa* (109.71 mg/100 g), *M. paniculata* (58.08 mg/100 g) and *E. floribundus* (15.25 mg/100 g indicating significantly higher levels of ascorbic acid in wild edible fruits compared to commonly consumed fruits like kiwi (75 mg/100 g), mango (45 mg/100 g), orange (70 mg/100 g), papaya (85 mg/100 g), strawberries (95 mg/100 g), and apple juice (50 mg/100 g)[39]; since Vitamin C is a vital nutrient supplied by fruits and vegetables in human diets, incorporating these seasonal wild edible fruits into our daily consumption can meet the minimum requirements for a healthy life, particularly crucial in the current pandemic situation, as it plays a vital role in absorbing and neutralizing free radicals, thus safeguarding the body from harmful effects[40].

P. emblica shows the highest reducing capacity in both the analysis, *i.e.,* total *in vitro* antioxidant activity (159.06 AAE mg/g) and FRAP assay (42.57 AAE mg/g) while *S. pinnata* (11.82 AAE mg/g) shows the lowest antioxidant activity. Whereas, in FRAP analysis, *V. spinosa* (3.87 AAE mg/g) exhibit the least capacity. In a study conducted by Dasgupta *et al*.[41], unlike the present finding, they observed the maximum concentration of the total antioxidant capacity in *S. pinnata* (50.10 AAE mg/100 g). However, they found a similar observation of FRAP assay with the present study giving a maximum of 72.6 AAE mg/100 g. The FRAP reducing power observed in this study was significantly higher than that reported for other wild fruits from eastern Himalaya (3.63 to13.82 mg AAE/g)[42]. Additionally, similar to our findings, *P. emblica* displayed the greatest FRAP value amongst thirteen fruits of Assam[43]. The inhibition percentage of the DPPH assay was found to be in the order of *P. emblica*>*S. pinnata*>*R. semialata*>*E. floribundus*>*M. paniculate* >*V. spinosa* (Fig. 3). *S. pinnata* has demonstrated potential as an antioxidant with activities similar to those of *P. emblica*, similar observation was made by Dasgupta *et al*.[41]. The total antioxidant activity of the fruit samples is widely diverse and showed an active response to the radical. The antioxidant potential of *P. emblica* and *S. pinnata* was comparable with the standard (ascorbic acid) antioxidant activity.

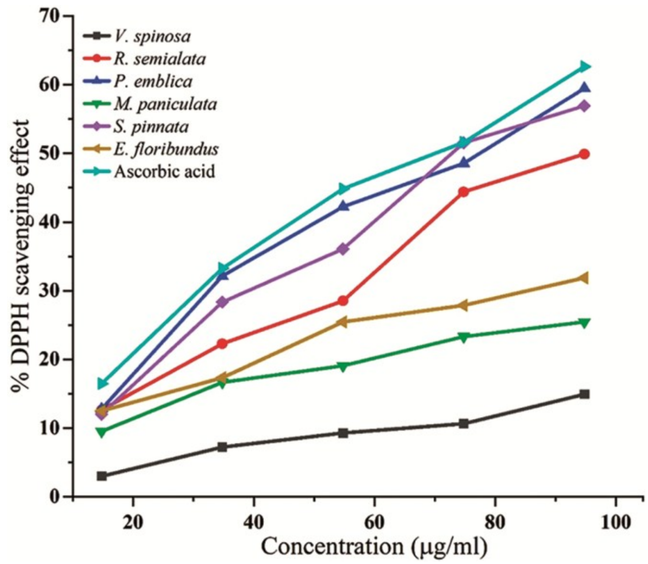

Fig. 3 — Percentage inhibition of DPPH radical of the six wild edible fruits

Pearson's correlation analysis revealed that there were no statistically significant relationships among carbohydrates, phenols, and tannins with other parameters in the study. However, protein content exhibited significant positive correlations with flavonoids ($r = 0.956$) and vitamin C ($r = 0.996$) at the $p<0.010$ level. Additionally, a strong positive correlation was observed between protein and FRAP (Ferric Reducing Antioxidant Power) with a coefficient of 0.862 at the $p<0.050$ level. Flavonoids also displayed significant correlations with FRAP ($r = 0.845$, $p<0.050$) and vitamin C ($r = 0.957$, $p<0.010$). Notably, a strong positive correlation was found between *in vitro* antioxidant and FRAP ($r = 0.818$, $p<0.050$). Similarly, FRAP and vitamin C also exhibited a strong positive and significant correlation with a coefficient of 0.863 at the $p<0.050$ level. These positive correlations indicate potential relationships and interactions between the various biochemical constituents in wild edible fruits. Particularly noteworthy is the statistically highly significant correlation between flavonoids and FRAP, as well as vitamin C, which suggests a major role of flavonoids in the antioxidant activity of the fruits. The correlation between protein and antioxidant activity in fruits can be attributed to the presence of enzymatic antioxidants, antioxidant peptides, metal-chelating properties, protein-bound antioxidants, and antioxidant-rich protein sources, which collectively contribute to the overall antioxidant capacity of the fruit. Moreover, the positive correlation between antioxidant activity and vitamin C can be attributed to vitamin C's role as a powerful antioxidant that neutralizes free radicals and reactive oxygen species, protects cells and tissues, regenerates other antioxidants, enhances enzymatic antioxidant defences, and works synergistically with other antioxidants. These findings are consistent with the findings of Liu *et al*.[44] and Silva and Sirasa[45].

Conclusion

The studied six wild edible fruits are ethnobotanically important and are used for treatment of various health ailments. These fruits contain rich bioactive nutrients and antioxidant potential thus provides health benefits in terms of nutrition and medicine. *Phyllanthus emblica* showed maximum phytochemicals content and antioxidant potential which was comparable with *Spondias pinnata*. Commercialization of value-added products of these fruits can serve as a reliable income for many people of the village to support their livelihood. These wild edible fruits play a significant role in food, medicine, and economic aspects of local people of Manipur especially for the rural people.

Acknowledgement

The authors are thankful to the local people of Machi block, Tengnoupal district, Manipur, especially the village head and knowledgeable local elders, for their kind cooperation and assistance during the fieldwork. The authors are thankful to Bijay Thakur, a research scholar for helping in generating the study area map. The authors are also thankful to the Department of Environmental Science, Tezpur University, Assam for providing the necessary facilities to carry out the research work.

Declaration

Prior informed consent was obtained from all the informants.

Conflict of Interest

Authors declare that they do not have any conflict of interest.

Author Contributions

MBD: Field visit, Data collection, Experimental investigation, Formal analysis, Writing – original draft; and AD: Overall supervision, Methodology, Writing – review & editing.

References

1 Termote C, Van Damme P & Djailo B D, Eating from the wild: Turumbu, Mbole and Bali traditional knowledge on non-cultivated edible plants, District Tshopo, DRCongo, *Genet Resour Crop Evol*, 58 (4) (2011) 585-618.

2 Hazarika T K, Lalramchuana & Nautiyal B P, Studies on wild edible fruits of Mizoram, India used as ethno-medicine, *Genet Resour Crop Evol*, 59 (8) (2012) 1767-1776.

3 Akubugwo I E, Obasi A N & Ginika S C, Nutritional potential of the leaves and seeds of black nightshade - *Solanum nigrum* L. Var virginicum from Afikpo-Nigeria, *Pakistan J Nutr*, 6 (4) (2007) 323-326.

4 Hazarika T K & Singh T S, Wild edible fruits of Manipur, India: associated traditional knowledge and implications to sustainable livelihood, *Genet Resour Crop Evol*, 65 (1) (2018) 319-332.

5 Sharma P B, Handique P J & Devi H S, Antioxidant properties, physico-chemical characteristics and proximate composition of five wild fruits of Manipur, India, *J Food Sci Technol*, 52 (2) (2015) 894-902.

6 Khomdram S, Arambam S & Shantibala D G, Nutritional profiling of two underutilized wild edible fruits *Elaeagnus pyriformis* and *Spondias pinnata*, *Ann Agric Res*, 35 (2) 2014 129-135.

7 Khomdram S & Devi G S, Determination of antioxidant activity and vitamin C of some wild fruits of Manipur, *Fruits*, 5 (3) (2010) 501-504.

8 Hazarika T K, Varte L, Mathipi V, Khawlhring L, Lalruatsangi E, *et al*., Phytochemicals constituents, antioxidant activities and cytotoxicity assays of few wild edible fruits of North-East India, *Int J Food Prop*, 26 (1) (2023) 1020-35.

9 Nieto G, Martínez-Zamora L, Peñalver R, Marín-Iniesta F, Taboada-Rodríguez A, *et al*., Applications of plant bioactive compounds as replacers of synthetic additives in the food industry, Foods, 13 (1) (2023) 47.

10 Tischer B, Pangloli P, Nieto-Veloza A, Reeder M & Dia V P, Bioactive compounds, antioxidant capacity and anti-inflammatory activity of native fruits from Brazil, Plos one, 18 (5) (2023) e0285625.

11 Singh H B K, Singh P K & Elangbam V D, Indigenous bio-folklores and practices - their role in biodiversity conservation in Manipur, *J Hill Res*, 9 (2) (1996) 359-362.

12 Horwitz W, Official methods of analysis of the association of official analytical chemists, *Anal Chim Acta*, 242, 1991, 302.

13 Chau C F, Wang Y T & Wen Y L, Different micronization methods significantly improve the functionality of carrot insoluble fibre, *Food Chem*, 100 (4) (2007) 1402-1408.

14 Harborne J B, Phytochemical methods: A guide to modern tecniques of plant analysis, Third Edition, *Chapman Hall*, (1998) p. 58.

15 Sofowora A A, Medicinal plants and traditional medicine in West Africa, John Willey and Sons Ltd, *New York*, (1993) p. 289.

16 Evans W C, Trease and evans, *Pharmacogn 9th Ed Publ by Saunders Elsevier*, (2002) p. 553.

17 Dubois M, Gilles K A, Hamilton J K, Rebers P A & Smith F, Colorimetric Method for determination of sugars and related substances, *Anal Chem*, 28 (3) (1956) 350-356.

18 Lowry O H, Rosebrough N J, Farr A L & Randall R J, Total protein estimation by Lowry's method, *J Biol Chem*, 193 (1951) 265.

19 Patel V R, Patel P R & Kajal S S, Antioxidant activity of some medicinal plants of western region of India, *Adv Biol Res* , 4 (1) (2010) 23-26.

20 Satishkumar T, Baskar R, Shanmugam S, Rajasekaran P, Sadasivam S, *et al*., Optimization of flavonoids extraction from the leaves of *Tabernaemontana heyneana* Wall. Using L16 ortho design, *Nat Sci*, 6 (3) (2008) 10-21.

21 Prabhavathi R M, Prasad M P & Jayaramu M, Studies on qualitative and quantitative phytochemical analysis of *Cissus quadrangularis*, *Adv Appl Sci Res*, 7 (4) (2016) 11-17.

22 Canterbury University, Determination of Vitamin C Concentration by Titration Determination of Vitamin C Concentration by Titration, *Coll Sci Univ Canterbury*, (2016) 5-7.

23 Patel S, Patel J K & Patel R K, To study proximate analysis & biological evalution of *Triphala guggulu* formulation, *Int J Pharm Tech Res*, 4 (4) (2012) 1520-1526.

24 Brand-Williams W, Cuvelier M-E & Berset C, Use of a free radical method to evaluate antioxidant activity, *LWT-Food Sci Technol*, 28 (1) (1995) 25-30.

25 Antolovich M, Prenzler P D, Patsalides E, McDonald S & Robards K, Methods for testing antioxidant activity, *Analyst*, 127 (1) (2002) 183-198.

26 Singh S R, Phurailatpam A K, Wangchu L, Ngangbam P & Chanu T M, Traditional medicinal knowledge of underutilized minor fruits as medicine in Manipur, *Int J Agric Sci*, 4 (8) (2014) 241-247.

27 Ahirvar B P, Verma M, Vishwakarma R & Chaudhry S, Potentials and prospects of wild edible fruits in central India, *Int J Curr Adv Res*, 6 (12) (2017) 8561-8565.

28 Seal T & Chaudhuri K, Ethnobotanical importance and nutritional potential of wild edible fruits of Meghalaya state in India, *J Chem Pharm Res*, 5 (4) (2014) 359-364.

29 Sen S, Passah T, Thubru K & Chakraborty R, Comparative evaluation of nutritive value of some fruits available in North-East India, *J North East India Stud*, 6 (1) (2016) 88-94.

30 Oh Y S, Bioactive compounds and their neuroprotective effects in diabetic complications, *Nutrients*, 8 (8) (2016) 472.

31 Prasannan P, Jeyaram Y, Pandian A, Raju R & Sekar S, A review on taxonomy, phytochemistry, pharmacology, threats and conservation of *Elaeocarpus L.* (*Elaeocarpaceae*), Volume 86 (3-4) (2020) 298-328.

32 Pandey K B & Rizvi S I, Plant polyphenols as dietary antioxidants in human health and disease, *Oxid Med Cell Longev*, 2 (2009) 270-278.

33 Tiwari O P & Krishan R, Determination of nutritional potential of five important wild edible fruits traditionally used in Western Himalaya, *Int J Life Sci*, 6 (1) (2018) 79-86.

34 Seal T, Pillai B & Chaudhuri K, Nutritional potential of wild edible fruits, traditionally used by the local people of Meghalaya state in India, *Indian J Nat Prod Resour*, 5 (4) (2014) 359-364.

35 Karuppusamy S, Muthuraja G & Rajasekaran K M, Antioxidant activity of selected lesser known edible fruits from Western Ghats of India, *Indian J Nat Prod Resour*, 2 (2) (2011) 174-178.

36 Aberoumand A & Deokule S S, Studies on nutritional values of some wild edible plants from Iran and India, *Pak J Nutr*, 8 (1) (2008) 26-31.

37 Djenidi H, Khennouf S & Bouaziz A, Antioxidant activity and phenolic content of commonly consumed fruits and vegetables in Algeria, *Prog Nutr*, 22 (1) (2020) 224-235.

38 Rout P & Basak U C, Evaluation of antinutritional factors in sixteen wild edible fruits of Odisha, India, *Int J Curr Sci*, 13 (2014) 34-42.

39 Padayatty S J, Katz A, Wang Y, Eck P, Kwon O, *et al*., Vitamin C as an antioxidant: Evaluation of its role in disease prevention, *J Am Coll Nutr*, 22 (1) (2003) 18-35.

40 Prakash D, Upadhyay G, Gupta C, Pushpangadan P & Singh K K, Antioxidant and free radical scavenging activities of some promising wild edible fruits, *Int Food Res J*, 19 (3) (2012) 1109.

41 Dasgupta S, Pandya M & Patel N, Antioxidant activities of some less utilized edible fruits, *Int J Curr Pharm Res*, 9 (5) (2017) 28-31.

42 Rymbai H, Verma V K, Talang H, Assumi S R, Devi M B, *et al*., Biochemical and antioxidant activity of wild edible fruits of the eastern Himalaya, India, *Front Nutr*, 10 (2023) 1039965.

43 Saikia S, Mahnot N K & Mahanta C L, Phytochemical content and antioxidant activities of thirteen fruits of Assam, India, *Food Biosci*, 13 (2016) 15-20.

44 Liu H, Cao J & Jiang W, Evaluation and comparison of vitamin C, phenolic compounds, antioxidant properties and metal chelating activity of pulp and peel from selected peach cultivars, *Lwt*, 63 (2) (2015) 1042-1048.

45 Silva K D R R & Sirasa M S F, Antioxidant properties of selected fruit cultivars grown in Sri Lanka, *Food Chem*, 238 (2018) 203-208.