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Nutraceutical Potential of Some Wild Edible Fruits of Sikkim, Himalaya, India

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ABSTRACT Sikkim located in Himalayas, is a part of the Indo-Malayan Biodiversity Hotspot harbors with many wild fruit plants of nutritional potential. Fruit samples were collected randomly from different localities of Sikkim India to analyze their chemical properties and physical characteristics. *Ficus roxburghii* had heaviest fruits and *Rubus ellipticus* had lightest. *Castanopsis hystrix* was the least acidic (0.5%) while *Elaeocarpus sikkimensis* was the most (4.2%). *Diploknema butyraceae* had maximum TSS with 18^{o} Brix, while fruits of *Machilus edulis* had lowest (3.55^{o} Brix). The fruits of *Morus alba* were sweetest with total sugar content of twenty percent. The fat and carotenoids were in the range of 0.2-10.0 percent and 0.1-63.0 mg/100 g fresh weights. The analysis of nutritional properties and other bioactive compounds in wild fruits of Sikkim indicate potential to fulfill nutritional requirements locally and can find place in the global markets.

INTRODUCTION

Wild edible plants (WEPs) are the species that are neither cultivated nor domesticated however are available in their wild natural habitat and used as sources of food and socioeconomic wellbeing particularly for rural poor communities (Sundriyal et al. 2003; Sekeroglu et al. 2006; Mbuvi and Boon 2009; Beluhan and Ranogajec 2010; Abubakar et al. 2017; Bhatt et al. 2017). These plants play an important role in closing food gaps during periods of drought and scarcity for many people in developing countries (Afolayan and Jimoh 2009). Wild food plants even sometimes are reported to be nutritionally superior to some of the cultivated ones (Burlingame 2000).

Botanical explorations and literature highlights inventory, diversity and value of wild edible fruit plants from different parts of the world. However, untapped potential of about 3000 tropical fruits worldwide was reported (Mugnozza 1996). The Sikkim Himalayas, a part of Indo-Malayan Biodiversity Hotspot (Myers and Mittermeier 2000) harbors many fruit plants grown in wild habitats and indigenously utilized (Sundriyal and Sundriyal 2003). Their potential in nutritional, medicinal, therapeutic and industrial values is well recognized and utilized by the indigenous communities (Rai et al. 2005; Rawat et al. 2011). Perusal of literature reveals not much work has been done on this aspect. Therefore, a systematic attempt was made in the present study to analyze the physiochemical characteristics of some popular wild edible fruits of Sikkim Himalayas.

METHODOLOGY

Study Area

Fruit samples were collected randomly from localities of Rumtek, Sang, Nazitam, Tingbong, Gyathang, Lingdong, Geyzing, Namthang and Turung in Sikkim state of India. The climate of the state is tropical, temperate and alpine zones. Mean temperature in lower altitudinal zones varies from 4.5ºC to 18.5ºC, whereas at higher altitudinal zones it varies from 1.5ºC to 9.5ºC. Distribution of fruits is categorized into low, mid and higher hills, which cover all four districts of Sikkim.

Physiochemical Observations

Shape and color of fruits were visually recorded. Fresh weights were recorded immediately after harvest. Length and diameter was measured with a digital Vernier Caliper (Mitutoyo). Number of seeds set per fruit was counted and average of 10 fruits were recorded. Size was recorded visually as small, intermediate and large while position was recorded as terminal, auxiliary and both. Total soluble solids (TSS) of fruit were recorded with a hand refractometer calibrated in ^{o}brix at 20°C with the help of a temperature correction correlation chart (Mazumdar and Majumdar 2003). Total titrable acidity was determined by titration of a known weight of sample with NaOH using phenolphthalein as an indicator (Ruck 1969) and expressed in percent. Total and reducing sugar of fruits were estimated following Ranganna (1979) while non-reducing sugar was estimated as reported by Mazumdar and Majumdar (2003) and was expressed in percent.

Non-reducing sugar = (Total sugar – Reducing sugar) x 0.95

Ascorbic acid was estimated by volumetric method and expressed as mg per 100 g of fruit pulp (Mukherjee and Choudhury 1983). Protein was estimated and expressed in percent following Lowry et al. (1951). Chlorophyll and Carotenoid were extracted following the protocol formulated by Lichtenthaler and Wellburn (1987) and expressed as mg/100g. Anthocyanin content was determined using the pH differential method in which absorbance of anthocyanin extracts at pH 1.0 and 4.5 are determined (Rodriguez-Saona and Wrolstad 2001). The total anthocyanin content was expressed as mg Cyanidin 3-glucoside/100g fruit and calculated using its molar absorbance coefficient of 26900 $L^{-1} M^{-1} cm^{-1}$ (Wrolstad et al. 2005). Fat was estimated and expressed in percent following Thimmaiah (2009). Value for each sample was calculated as mean ± SD, coefficient of variation correlation and multiple regressions were tested employing the SPSS (version -17.0) software package. For statistical tests of physical characteristics, average value of descriptor per individual was used. Only ordinal and scale measured descriptors were used for statistical tests.

RESULTS AND DISCUSSION

Physical Features

The physical and chemical parameters of fruits are important indicators of their maturation, internal and external quality, and decisive factors for accomplishment of market demands that have encouraged a lot of researches under different conditions around the world. The fruit quality is related to some intrinsic characteristics (appearance, color, acids, sugars) and since they change during handling, research data can provide information on the way a product should be handled postharvest (Paull and Duarte 2011). In the present study three species were observed to have green to yellow fruits, two were green and remaining nine were rusty brown to green, orange yellow, green to red, pink to red, rusty brown to purple, red, green to purple and dark pink color. Fruits of seven species were oval, two were spherical and remaining five species were oblong. Average weight of fruits varied significantly among the different species. Maximum fruit weight was recorded for *Ficus roxburghii* (186.5 g) while the lowest at 2.46g/100 seeds was recorded for *Rubus ellipticus* (Table 1). Fruit size has a direct effect on the marketability and acceptance in both fresh market and processing plants. Traditionally, large fruits are preferred by consumers (Cahn et al. 1992; Moyer et al. 2002). Consumers demand high quality fruit that have an attractive appearance, high nutritional value, and good taste (Crisosto and Crisosto 2001; Koyuncu et al. 2004; Zatylny et al. 2005). Mean value of fruit size also indicated significant differences among the species. *Machilus edulis* and *Passiflora edulis* were recorded to be the largest fruits, while *Rubus ellipticus* and *Duchesnia indica* were smallest. Similar physical parameter studies of indigenous minor or wild edible fruits were also reported earlier (Bagra et al. 2006).

Chemical Constituents

Acidity, TSS and Sugar

Acidity of the fruits estimated varied significantly among species. *Castanopsis hystrix* had lowest acidity (0.5%) while *Elaeocarpus sikkimensis* with 4.2 percent *acidity* was highest, followed by *Terminalia chebula* and *Spondias axillaris* with four percent acidity. Acidity of remaining fruits ranged between one and three percent. Maximum TSS was recorded in fruits of *Diploknema butyraceae* (18^{o}Brix) and *Elaeocarpus sikkimensis* (17^{o}Brix) followed by *Eriolobus indica* and *Passiflora edulis* with 11^{o}Brix, and minimum TSS of 3°Brix was recorded for *Machilus edulis*. TSS for remaining fruits ranged from 4° to 8°Brix. Higher the TSS, the more is the sugar in pulp (Table 2). More the ripened fruits, more is amount of sugar in it. TSS determined for the fruits *Machilus edulis*, *Baccaurea*, *Passiflora*, *Eriolobus*, *Elaeocarpus*, *Bassia*, *Elaeagnus latifolia*, *Spondias axillaris* and *Diploknema butyracea* ranged between 4.66 and 21.0 percent reported from earlier studies (Sundriyal et al. 1998; Sundriyal and Sundriyal 2001). Mean total solids and soluble solids contents of chokeberry reported were 35.2 percent and 18.3 °Brix, respectively (Zatylny et al. 2005). The sugar (total, reducing and non-reducing) estimated varied significantly among species. Highest total sugar was recorded in fruits of *Morus alba* (20%) while *Machilus edulis*, *Spondias axillaris*, *Terminalia chebula*, *Castanopsis hystrix* and *Elaegnus latifolia* had the least total sugar (3% each). Total sugar of remaining fruits ranged from seven to thirteen percent. Similarly, highest amount of reducing sugar was also estimated for *Morus alba* (15%) followed by *Eriobolus indica* (12%) while minimum was recorded for *Spondias axillaris* and *Machilus edulis* (2.31% each). Reducing sugar of remaining fruits ranged from three to thirteen percent. Generally, sugar content of fresh fruits ranges between two to thirty percent (Norman, 1976). Non-reducing sugars in fresh fruits of different species varied from 0.1 to 6.0 percent. *Diploknema butyraceae* possessed maximum amount of non-reducing sugar followed by *Elaegnus latifolia* (5%) and *Morus alba* (4%) while minimum recorded for *Eriolobus indica*, *Ficus roxburghii* and *castanopsis hystrix*. Parmar and Kaushal (1982) reported total sugar content of 6.15 percent in *Ficus roxburghii* while reducing and non-reducing sugar of 6.12 and 0.03 percent, respectively. Similar findings related to chemical constituents on wild fruits were reported by Abubakar et al. (2017) and Bhatt et al. (2017).

Fat and Protein

Fat estimated in fruits varied significantly among species and highest amount of fat was found in *Machilus edulis* (21%), which was significantly higher than other species (Table 2). Lowest fat content was estimated for *Passiflora edulis* (0.2%) while in remaining fruits it ranged from 0.2 to ten percent. Protein content of different fruits ranged from two to ten percent, and varied significantly among species. The maximum protein content was estimated in *Prunus cerasoides* followed by *Morus alba* (9%) while minimum was estimated for *Duchesnia indica*, *Terminalia chebula* and *Eriolobus indica*. Maximum ascorbic acid was estimated in *Spondias axillaris* (32.0 mg/100g fresh weight) followed by *Passiflora edulis* (28 mg/100g fresh weight) and minimum 1 mg/100g of fresh fruit was estimated for *Castanopsis hystrix*. Ascorbic acid of remaining fruits ranged from 2 to 24 mg/100g of fresh fruit. In nature the main source of Vitamin C is from fruits and vegetables (Fox and Cameroon 1976). Wild fruits appeared to be rich in vitamin C and their consumption helps boost the body's immune system (Holford 1998). Fruits of *Morus spp*. were reported to have high ascorbic acid (286 mg/100g) followed by *Baccaurea sapida* (273.33 mg/100 g) and *Hippophae rhamnoides* with 263 mg/100g (Sundriyal and Sundriyal 2001).

Carotenoid, Anthocyanin and Chlorophyll

Carotenoid of fruits ranged from 0.1to 63.0 mg/100g fresh weight. *Machilus edulis* was estimated with highest carotenoid followed by *Elaeocarpus sikkimensis* (60 mg/100g fresh weight), *Terminalia chebula* (22 mg/100g fresh weight), *Duchesnia indica* (19 mg/100g fw) and *Castanopsis hystrix* (14 mg/100g fresh weight) while *Morus alba* was estimated with least carotenoid. Carotenoid of remaining fruits ranged from 0.2 to 8.0 mg/100g of fresh weight. Anthocyanin ranged from 0.1 to 3.8 mg/100g fresh weight. Highest concentration of anthocyanin was found in fruits of *Rubus ellipticus* followed by *Prunus cerasoides* (3.0 mg/100g fresh weight), while least was estimated for *Castanopsis hystrix* and *Duchesnia indica*. In remaining fruits estimated anthocyanin ranged from 0.4 to 0.9 mg/100g fresh weight (Table 2). Anthocyanin are polyphenolic pigments that belong to the flavonoids and are responsible for providing red, blue and violet colors found in most plant species (Nielsen et al. 2003). They have received considerable interest from health scientists and nutritionists due to potential protective effects against disease (Clifford 2000; Santos-Buelga and Scalbert 2000). Significant variation was estimated in fruit chlorophyll among the species. *Machilus edulis* with 2.3mg/100g fresh weight was estimated with highest chlorophyll followed by *Terminalia chebula* and *Elaeocarpus sikkimensis* with 2.1mg/100g fresh weight while least of 0.01mg/100g fresh weight was estimated for *Ficus roxburghii*.

In general, edible fruits contain various nutritive substances among which the most important are minerals, organic constituents, Vitamin C and growth substances (Malaisse 1997; Loura et al. 2000; Adebisi et al. 2012). In southern Yunnan, China 52 species of wild edible fruits were analyzed and reported to be a good source of sugar, titrable acid, crude fat, crude fiber, starch and soluble tannin (Jin et al. 1999). Earlier reports also indicated that the wild edible fruits found in Sikkim are a good source of fat, sugar, protein and antioxidants (Sundriyal and Sundriyal 2001, 2003; Rai et al. 2005). Indigenous minor or wild edible fruits of different areas were also reported having rich source of various constituents (Khan et al. 2011; Legwaila et al. 2011; Valvi et al. 2011; Mahapatra et al. 2012; Bhatt et al. 2013; Rawat et al. 2014). The chemical composition estimated clearly indicates that these wild edible fruits are a rich source of various constituents, which have not been explored so far. Though clinical study of these fruits has not been carried out, people strongly believe they have certain therapeutic values (Rai et al. 2005). Such fruits of Sikkim, if studied properly mainly on antioxidant properties and other bioactive compounds, may find place in the global markets.

CONCLUSION

All these fruits are a good source of fat, protein, sugars and antioxidants. These fruits are available round the year and have a great potential in ensuring food and nutritional security at times of food scarcity. Nutritional value of these fruits needs further study so as to determine how they compare nutritionally with the modern diet. Such documentation will benefit the community through the use of locally and freely available health giving foods, which will also help preserve their cultural pride.

Fruits like *Passiflora indica*, *Spondias axillaris* and *Elaegnus latifolia* have supplemented the family income through sale as fresh and processed. Processing the fruits has enhanced their utilization by reducing wastage, year-round availability and improved their marketing pros-

Table 1: Physical features of selected wild edible fruits

Scientific name and family	*Colour*	*Shape/type*	*Weight (g)*	*Length (cm)*	*Width (cm)*	*No. of seed*
Castanopsis hystrix Miq.Fagaceae	Light yellow brown	Ovoid/ Nut	1.25± 0.45**	1.82± 0.19	1.07± 0.02	One nut
D. butyraceae	Green to yellow when ripe	Oval/ Berry	11.24± 1.86	3.24± 0.07	2.8± 0.45	3
D. indica	Red	Spherical to oval/ Aggregate	3.02± 0.56	0.9± 0.28	0.45± 0.007	Many
E. indica	Green to yellow	Oval or pear shaped/ Berry	22.3± 7.13	4.5± 0.21	2.61± 0.04	15
E. latifolia	Dark pink	Oblong/ Drupe	9.47± 2.27	2.0± 0.56	1.6± 0.14	1
E. sikkimensis	Green	Oval/ Drupe	14.30± 2.41	3.52± 0.04	1.97± 0.05	1
F. roxburghii	Rusty brown to purple	Globose/ Cyconus	160.5± 19.1	3.8± 0.12	3.41± 0.14	Many
M. alba	Pink to red and black when ripe	Short cylindric/ Psorosis	3.47± 1.26	2.5± 0.27	1.3± 0.07	Many
M. edulis	Rusty brown to Green	Oval/ Drupe	26 ± 15.25	6.76± 0.38	2.52± 0.10	1
P. cerasoides	Green to red	Oval/ Drupe	2.94± 0.81	1.02± 0.03	1.01± 0.01	1
P. edulis	Green to purple with white specs	Oval/ Berry	7.79± 1.41	4.49± 0.04	4.48± 0.042	Many
R. ellipticus	Orange yellow	Spherical/ Aggregate, etaerio of berry	2.46± 0.47	1.5± 0.23	1.0± 0.01	Many
S. axillaris	Green to yellow	Oblong/ Drupe	12± 2.06	3.16± 0.09	2.43± 0.04	1
T. chebula	Green	Oval/ Drupe	4.86± 1.61	3.47± 0.19	1.80± 0.07	1

Table 2: Chemical characteristics of selected wild edible fruits

Species name	Fat (%)	Protein (%)	Ascorbic acid (mg 100 g^{-1} fresh weight	Carotenoids (mg 100g^{-1} fw)	Anthocyanin (mg 100g^{-1} fw)	Chlorophyll (mg 100g^{-1} fw)	Acidity (%)	Total soluble solid (°Brix)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)
C. hystrix	3.4±0.25*	3.5±0.02	0.7±0.2	14.4±0.7	0.06±0.01	0.90±0.37	0.47±0.45*	4.03±0.11	3.33±0.09	3.17± 0.07	0.14±0.02
D. butyraceae	1.1±0.01	3.9±0.03	24.3±3.1	7.6±0.3	0.6±0.02	0.1±0.002	1.13±0.06	18.50±0.58	12.21±0.03	5.98± 0.04	5.91±0.05
D. indica	1.1±0.15	1.8±0.30	2.54±0.3	19.4±0.4	0.07±0.01	0.44±0.27	1.46±0.45	6.53±0.25	7.52±0.15	3.55± 0.08	3.76±0.05
E. indica	0.4±0.002	2.1±0.02	7.5±0.4	0.3±0.4	0.5±0.01	0.02±0.001	1.81±0.04	11.53±0.57	13.04±0.05	12.90± 0.04	0.12±0.03
E. latifolia	0.8±0.03	6.2±0.01	11.2±1.9	5.8±0.02	1.81±0.03	0.05±0.01	3.18±0.06	6.92±0.08	3.03±0.02	2.72± 0.04	4.99±0.04
E. sikkimensis	0.3±0.02	6.5±0.03	10.0±2.0	59.7±0.4	1.5±0.05	2.1±0.013	4.15±0.03	17.03±0.03	7.26±0.03	5.10± 0.07	2.05±0.06
F. roxburghii	0.8±0.03	2.7±0.25	3.1±0.4	1.3±0.08	0.9±0.06	0.01±0.002	0.57±0.10	7.60±0.11	8.53±0.43	8.38± 0.39	0.13±0.04
M. alba	0.3±0.02	8.9±0.02	15.7±0.4	0.1±0.12	0.4±0.06	0.03±0.02	2.21±0.54	4.92±0.04	19.83±0.19	15.39± 0.63	4.21±0.45
M. edulis	21.5±0.02	5.6±0.01	5.0±1.0	62.9±0.5	0.4±0.03	2.29±0.06	3.34±0.53	3.55±0.59	3.03±0.01	2.31± 0.03	0.68±0.02
P. cerasoides	9.7±0.61	10.0±0.6	4.5±0.3	0.96±0.3	3.0±0.09	0.16±0.01	1.16±0.19	7.88±0.26	7.30±0.07	5.86± 0.03	1.33±0.06
P. edulis	0.2±0.02	5.6±0.01	27.7±4.2	0.38±0.1	1.29±0.22	0.13±0.02	2.45±0.09	11.34±0.60	13.11±0.02	7.85± 0.06	0.29±0.06
R. ellipticus	5.9±0.02	7.6±0.54	5.9±1.6	0.2±0.02	3.8±0.05	0.15±0.01	2.15±0.18	6.14±0.58	8.73±0.03	5.66± 0.07	2.90±0.06
S. axillaris	1.4±0.20	5.4±0.02	32.0±4.0	0.3±0.03	0.6±0.02	0.92±0.02	3.57±0.48	6.86±0.11	3.16±0.02	2.01± 0.07	1.11±0.05
T. chebula	1.5±0.02	2.2±0.03	7.3±0.2	22.4±0.4	0.7±0.05	2.14±0.02	3.85±0.02	3.98±0.19	3.20±0.02	3.00± 0.04	0.19±0.04

**Data represents the mean ± SD, significant at 0.01% level*

pects through value addition. In turn, this had led to better value recognition of these fruit species and also promoted their conservation. Indigenous minors or wild fruits have thus made a crucial contribution towards subsistence economy and livelihood of Sikkim.

RECOMMENDATIONS

These wild edible fruits can contribute towards subsistence economy and livelihood of Sikkim. Processing these fruits can enhance their utilization by reducing wastage, year-round availability and improved their marketing prospects through value addition. Nutritional value of these wild edible fruits and their value added products needs to be popularized and compared nutritionally with the modern diet. Use of these fruits also has the potential through selective conservation and domestication, which can contribute to the maintenance of plant biodiversity. There is a need to distinguish and recognize these fruits in terms of their nutraceutical values and their value added products in the local or national or international markets.

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