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Nutritional Contribution by Wild Plants as Novel Food to the Ethnic Tribes of Arunachal Himalaya, India

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Abstract: *Nutritional value was determined for six wild edible plants namely, Polygonum runcinatum, Pilea bracteosa, Elatostema platyphyllum, Gynura bicolor, Plantago erosa and Diplazium esculentum which were widely consumed as vegetables by the ethnic tribes of Arunachal Pradesh, India. Proximate analysis revealed rich nutrient levels in all the six wild plants compared to the common vegetables. Moisture, protein and phosphorus content were highest in Polygonum runcinatum with lowest sodium content, whereas, Pilea bracteosa was rich in lysine and proline. Ash, calcium and magnesium content were highest in Elatostema platyphyllum and it was also rich carbohydrate, crude protein and fat with high energetic value. Crude fat, tryptophan and potassium content were highest in Gynura bicolor with rich lysine, proline and other minerals. Proline and sodium content was highest in Plantago erosa, whereas, Diplazium esculentum was richest in fibre and carbohydrate content fetching greatest energy value with rich minerals. All the six wild edible plants made a significant contribution to the nutraceutical requirements of the ethnic tribal communities of Arunachal Pradesh, India particularly tryptophan, magnesium, calcium and potassium as per the daily-recommended dietary allowances prescribed by the Indian Council of Medical Research.*

Keywords*: wild edibles, nutritional value, dietary fibre, lysine, minerals*

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I. Introduction

Wild edible plants represent all plant resources that grow in the wild or as associates of cultivated crops in the form of weeds, but have great importance from edible and livelihood point of view. There are more than 3000 edible plants known to the mankind, where only 30 cultivated crops contribute to more than 90% of the world's calorie intake, and around 120 crops are economically important for their nutritional value[1]. It shows that several hundreds of plants with high nutritional values remained unattended or unnoticed. The consumption of wild plants as major food and food supplement is very common in food insecure areas as well as among the ethnic communities all over the world, which also contribute to the economy of millions of households[2]. In India, most of the ethnic communities in the rural areas depend on wild resources to meet their food requirements. Nutrients derived from plants are important for human health and complement other food sources[3]. Leaves of many plants are aromatic, sour, sweet, bitter or tasteless but are among the readily available sources of proteins, vitamins, minerals, and essential amino acids[4]. The quality of food depends upon the presence or absence of relative concentration of various nutrients such as, carbohydrates, proteins, enzymes, fats, amino acids, vitamins, minerals and anti-nutritional parameters. It is widely accepted that identification, introduction and propagation of highly nutritional wild plants in addition to the existing domestic crops are important to overcome malnutrition[5]. The ethnic tribes in Arunachal Pradesh of Eastern Himalayas, India are living an intricate life and mostly dependent on wild edible plants. Knowledge of the ethnic people on such plants and their properties are immense. Innumerable numbers of wild plants are consumed in raw form or after cooking or roasting which compensate the daily calorie requirements in addition to other essential nutrients. Most of those plants are sold in the local markets with high demand. Although immense ethno-botanical survey was made, very few works has been done on the nutritional value of wild edible plants available in Arunachal Pradesh[6-7]. This study has attempted to determine the nutritional values of six socially and commercially important and most commonly consumed wild edible plants namely, *Polygonum runcinatum, Pilea bracteosa, Elatostema platyphyllum, Gynura bicolor, Plantago erosa* and *Diplazium esculentum* which grow as wild in Papum Pare district of Arunachal Pradesh, India (Plate1&2). All the six wild edible plants were consumed after proper cooking and roasting, where, *Polygonum runcinatum* and *Pilea bracteosa* were also consumed in raw form as salads.

II. Materials And Methods

Sample collection and identification

Randomly sampled fresh edible parts of the six selected wild plants were collected from their natural habitats in Toru circle of Papum Pare district of Arunachal Pradesh, India during March 2014. Collected plant specimens were identified by consulting taxonomic literatures[8,9] and comparing with the herbarium specimens of Botanical Survey of India, Itanagar (ARUN), State Forest Research Institute, Itanagar and online database of Royal Botanic Gardens, Kew. Prepared herbarium specimens were deposited to the herbaria of Forestry Department, North Eastern Regional Institute of Science & Technology (Deemed University), Arunachal Pradesh. Plant specimens with their respective voucher number and reference number are as follows:

Polygonum runcinatum Buch.-Ham. ex D. Don; Voucher no: Papum Pare (Toru) B/1A (15/03/2014), NERIST herbaria; Ref: Chowdhery *et al*., Mat. Fl. Ar. Pradesh 2: 315. 2008. Specimen examined: Kurung Kumey (Nyapin), 21.02.2010, S.S. Dash 31673, BSI (ARUN)); Kurung Kumey (Satey), 14.09.2009, S.S. Dash 31431, BSI (ARUN); Kurung Kumey (Nyapin), 6.04.2009, S.S. Dash 31080, BSI (ARUN).

Pilea bracteosa Wedd; Voucher no: Papum Pare (Toru) B/2A (08/03/2014), NERIST herbaria; Ref: Chowdhery *et al*., Mat. Fl. Ar. Pradesh 2: 418. 2008. Specimen examined: Lower Subansiri (Doimukh), 13.11.1978, G.D. Pal 70243, BSI (ARUN); Lower Subansiri (Yazali), 11.11.1980, G.D. Pal 65969, BSI (ARUN); Changlang (Namdapha), 29.09.1994, G.D.Pal 7343, BSI (ARUN).

Elatostema platyphyllum Wedd; Voucher no: Papum Pare (Toru) B/3A (08/03/2014), NERIST herbaria; Ref: Chowdhery *et al*., Mat. Fl. Ar. Pradesh 2: 415. 2008. Specimen examined: Upper Siang (Yingkiong), 15.11.2002, B. Tam 13556, BSI (ARUN); Upper Siang (Yingkiong), 12.03.2004, R.K. Choudhary 16237, BSI (ARUN); Upper Siang (Yingkiong), 12.03.2004, R.K. Choudhary 16238, BSI (ARUN); Upper Siang (Yingkiong), 12.03.2004, R.K. Choudhary 16240 (BSI (ARUN).

Gynura bicolor (Roxb. Ex Willd) DC; Voucher no: Papum Pare (Toru) B/4A (15/03/2014), NERIST herbaria; Ref: Chowdhery *et al*., Mat. Fl. Ar. Pradesh 2: 28. 2008. Specimen examined: Kurung Kumey (Lee to Satey), 14/09/2009, S.S. Dash 31427, BSI (ARUN); Kurung Kumey (Lee to Satey), 14/09/2009, S.S. Dash 31428, BSI (ARUN); West Siang (Menchuka to Tato), 13/11/2010M. Bhaumik 25159 BSI (ARUN); India, 1821, N. Wallich 3152, Royal Botanic Garden Kew; Thailand, 11.04.1914, A.F.G. Kerr 3195, Royal Botanic Garden Kew; India, 1832.

Plantago erosa Wall. In Roxb; Voucher no: Papum Pare (Toru) B/5A (08/03/2014), NERIST herbaria; Ref: Chowdhery *et al*., Mat. Fl. Ar. Pradesh 2: 299. 2008. Specimen examined: Kurung Kumey, S.S. Dash 32483 A, BSI (ARUN); Kurung Kumey (Buyang-Ratey), S.S. Dash 32689, BSI (ARUN); Kurung Kumey (Palin), S.S. Dash 32921, BSI (ARUN); Kurung Kumey (Palin), S.S. Dash 32683, BSI (ARUN); Kurung Kumey (Palin), S.S. Dash 32118, BSI (ARUN).

Diplazium esculentum (Koenig ex Retz.); Voucher no: Papum Pare (Toru) B/6A (08/03/2014), NERIST herbaria; Ref: Singh and Panigrahi, Ferns and Fern-Allies of Ar. Pradesh 1: 161, 2005. Specimen examined: Arunachal Pradesh, S.S. Bhatti 369, SFRI (Itanagar); Arunachal Pradesh, S.S. Bhatti 274, SFRI (Itanagar); Indonesia, 20.06.1979, E. Hennipma 5955, Royal Botanic Garden Kew; Malaysia, 18.02.1986, P.J. Edwards 2029, Royal Botanic Garden Kew; Malaysia, 01.07.1993, H. Christensen 1141, Royal Botanic Garden Kew.

Sample preparation and their chemical analysis

The plant samples collected were thoroughly washed with distilled water and oven dried using paper envelop at 70 ± 5 ^{0}C for a week. Dried samples were ground into fine powder using an electric grinder and stored in room temperature in airtight container for detail chemical analysis. Moisture content, ash, crude fat, crude fibre and crude protein in the plant samples were determined following standard methods[10]. Ash content was determined in silica crucibles by incineration in a muffle furnace at 600˚C for 4 hours. Crude fat was determined through soxhlet extraction method using petroleum ether. Crude fibre was determined by acid-base digestion method using sulphuric acid and sodium hydroxide at standard conditions. Crude protein content was computed through multiplying total nitrogen content by 6.25, where nitrogen content was determined by Kjeldahl method using KEL PLUS Nitrogen Analyzer (PELICAN, India). Total carbohydrate content was determined by anthrone method, and concentration of tryptophan, lysine and proline was determined following standard methods[11]. Plant samples were digested in tri-acids for analyzing minerals as per standard methods[12]. Phosphorus content was determined through molybdenum blue method; potassium, calcium and sodium content was determined through flame photometry and magnesium content was determined through EDTA titration method. The energetic value of the plants was determined by summing up the values obtained after multiplying the protein, fat and carbohydrate content by 4.0, 9.0 and 4.0, respectively[13]. All the data were analyzed on dry tissue basis and the results were expressed on fresh tissue basis. Analyses were carried out in triplicates and the data were statistically analyzed using one-way ANOVA for their significant levels.

III. Results

Moisture, fibre and ash contents in the six wild plants were significantly different ($p < 0.01$), where moisture content was within a very narrow range from 87.1-89.9 g/100g edible portions, whereas, fibre content and ash content ranged from 0.78-1.81% and 1.47-2.73 g/100g edible portions, respectively (Table 1). Fibre content was highest in *Diplazium esculentum* and lowest in *Polygonum runcinatum*, whereas, ash content was highest in *Elatostema platyphyllum* and lowest in *Polygonum runcinatum.* Total carbohydrate, crude protein and fat content in these plants were also significantly different ($p< 0.01$) (Table 1). Total carbohydrate ranged from 5.23-6.91 g/100g edible portions, where highest value was recorded in *Diplazium esculentum* and lowest in *Polygonum runcinatum.* Crude protein ranged from 1.74-2.50 g/100g edible portions and it was highest in *Polygonum runcinatum* and lowest in *Gynura bicolor*, whereas, fat content ranged from 0.12-0.20 g/100g edible portions with highest content in *Gynura bicolor* and lowest in *Diplazium esculentum*. Energetic value of the six plants ranged from 31.0-37.7 kcal/100 g edible portions, which was highest in *Diplazium esculentum* and lowest in *Gynura bicolor*. Among the amino acids analyzed, lysine, tryptophan and proline content in the six plants were also significantly different ($p<0.01$), where lysine content ranged from 170-242 mg/g N and was highest in *Pilea bracteosa* and lowest in *Diplazium esculentum* (Table 1). Tryptophan and proline content ranged from 138-206 mg/g N and 197-321 mg/g N, respectively, where, tryptophan was highest in *Gynura bicolor* and lowest in *Pilea bracteosa*, whereas, proline was highest in *Plantago erosa* and lowest in *Elatostema platyphyllum*.

The concentration of all the minerals considered for this study was significantly different among the six plants ($p<0.01$) (Table 2). Sodium and potassium content ranged from 3.85-7.88 mg/100 g edible portions and 332-617 mg/100 g edible portions, respectively. Sodium content was highest in *Plantago erosa* and lowest in *Polygonum runcinatum*, whereas, potassium content was highest in *Gynura bicolor* and lowest in *Plantago erosa.* Calcium and magnesium content ranged from 48.6-179.4 mg/100 g edible portions and 115.4-207.5 mg/100 g fresh tissue, where both minerals were significantly highest in *Elatostema platyphyllum* and lowest in *Diplazium esculentum.* Phosphorus content ranged from 20.4-32.7 mg/100 g fresh tissue, where it was highest in *Polygonum runcinatum* and lowest in *Gynura bicolor*.

Table 3 presents the per cent contribution of neutraceutical parameters when consumed 100 g of the wild plants as a component of daily food items to the Recommended Daily Allowances[14]. This study revealed that, all the six wild edible plants made a significant contribution of neutraceutical requirements, particularly tryptophan, magnesium, calcium and potassium to both adult man and woman as per the daily-recommended dietary allowances prescribed by the Indian Council of Medical Research. These six wild plants could fulfill 20-40.9% lysine and 112-275% tryptophan of the daily-required quantity on the consumption of 100 g of edible parts as vegetable. Highest contribution for magnesium and calcium to the daily requirement was also made by *Elatostema platyphyllum* followed by *Pilea bracteosa* and *Polygonum runcinatum*, whereas *Gynura bicolor* made highest contribution for potassium followed by *Diplazium esculentum* and *Elatostema platyphyllum*. Although, very poor fraction of the required quantity was fulfilled for rest nutraceutical parameters by all the six wild plants, such as daily required energy, protein, phosphorus and sodium.

IV. Discussion And Conclusions

Moisture and fiber content in the six wild edible plants were close to the range of commonly consumed conventional vegetables as reported[15]. High moisture content in all the six wild edible plants revealed their better post-harvest stability since moisture content of any food is an index of stability with greater activity of water-soluble enzymes and co-enzymes[16]. High fibre content of the six wild edibles considered in this study may contribute significantly in regulating the intestinal transit by increasing fecal matter consistency and in slashing down the cholesterol level[17]. High ash content recorded in these wild plants depicted their rich mineral contents[18]. Carbohydrate and protein content in these wild plants were comparable with most commonly consumed vegetables and even higher than many of them, such as, cabbage, spinach, cucumber, bottle gourd, amaranth, potato and brinjal as reported[15], suggesting that these vegetables may be substituted by the wild edible plants considered for this study. Lysine content was close to amaranth, cabbage and ladies finger whereas tryptophan content was found to be higher than the conventional vegetables. Contribution to the Recommended Dietary Allowance of adult man and woman by the six wild plants was fairly high for tryptophan and lysine content. Tryptophan acts as a precursor for serotonin, a brain neurotransmitter theorized to suppress pain[19], whereas, lysine is needed to produce antibodies, hormones, enzymes, collagen formation as well as repair of tissue[20]. Moderate energy value with high potassium, calcium, magnesium and phosphorus but low sodium content of the six wild plants also permits them to be accepted as among the best vegetables with balanced nutrients. Highest mineral contribution to the Recommended Dietary Allowance of adult man and woman was made by magnesium followed by calcium, potassium and phosphorus. It is a known fact that excess sodium consumption may enhance hypertension, whereas, potassium helps in maintaining body weight and regulating water and electrolyte balance in the blood and tissues[21]. Both calcium and magnesium play a key role in the

formation of bones and teeth, blood clotting, muscle contraction and synaptic transmission of nerve impulses, regulating many circulatory diseases[22], whereas, phosphorus plays an important role in normal kidney functioning and transfer of nerve impulse[23].The present study has revealed that all the six wild edible plants which were consumed by the ethnic tribes of Arunachal Pradesh in the Eastern Himalayas, India were rich in essential nutrients required for human health especially protein, important amino acids and minerals and needs their recognition for domestication and commercialization. It was evident that, the ethnic people of the study area who survived on these wild edible plants in addition to other domestic foods and vegetables might have fulfilled most of the essential nutrients with less chances of malnutrition-related diseases. Further, studies are anticipated to determine other important nutritional and medicinal facts especially the natural amino acids, trace elements, vitamins, antioxidants and active metabolites of such wild edibles consumed in the region.

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Plate 1:(A) Polygonum runcinatum, (B) Pilea bracteosa, (C) Elatostema platyphyllum, (D) Gynura bicolor, (E) Plantago erosa and (F) Diplazium esculentumin the natural habitats.

Plate 2:(A) Polygonum runcinatum, (B) Pilea bracteosa, (C) Elatostema platyphyllum, (D) Gynura bicolor, (E) Plantago erosa and (F) Diplazium esculentum sold in the market places.

Table 1. Comparative account of various nutrients present in the edible portions of six wild plants(Mean ± SD) and some common vegetables*

Plant species	Moisture (g/100g)	Crude Fibre (g/100g)	Ash (g/100g)	Total Carbohydrate (g/100g)	Crude Protein (g/100g)	Crude Fat (g/100g)	Energy (kcal/100g)	Lysine (mg/g N)	Tryptophan (mg/g N)	Proline (mg/g N)
Polygonum runcinatum	89.9±1.5	0.78±0.10	1.47±0.06	5.23±0.25	2.50±0.29	0.15±0.01	32.3±0.6	214±7	151±9	213±8
Pilea bracteosa	89.3±0.5	1.03±0.14	2.01±0.02	5.65±0.13	1.81±0.14	0.16±0.01	31.3±0.8	242±8	138±5	275±6
Elatostema platyphyllum	87.3±0.4	1.52±0.22	2.73±0.07	5.92±0.15	2.36±0.15	0.17±0.01	34.7±0.6	195±4	188±11	197±7
Gynura bicolor	89.1±0.5	1.17±0.06	2.28±0.08	5.56±0.09	1.74±0.20	0.20±0.02	31.0±0.9	238±5	206±5	272±3
Plantago erosa	88.8±0.6	1.45±0.11	1.74±0.13	5.85±0.17	1.99±0.09	0.13±0.01	32.6±0.4	231±2	204±3	321±14
Diplazium esculentum	87.1±0.3	1.81±0.13	1.84±0.13	6.91±0.09	2.24±0.10	0.12±0.01	37.7±0.1	170±8	146±9	205±10
*WINTER VEGETABLES										
Amaranthus gangeticus (Amaranth)	85.7	1.0	1.5	6.1	1.0	0.5	45	250	100	-
Brassica oleracea var. *botrytis* (Cauliflower)	80.0	2.0	1.0	7.6	5.9	1.3	66	360	90	-
Brassica oleracea var. *capitata* (Cabbage)	91.9	1.0	0.7	4.6	1.8	0.1	27	240	70	-
Spinacea oleracea (Spinach)	92.1	0.6	1.7	2.9	2.0	0.7	26	400	100	-
Solanum tuberosum (Potato)	74.7	0.4	1.1	22.6	1.6	0.1	97	320	100	-
*SUMMER VEGETABLES										
Abelmoschus esculentus (Ladies finger)	89.6	1.2	1.1	6.4	1.9	0.2	35	210	40	-
Cucumis sativus (Cucumber)	96.3	0.4	0.4	2.5	0.4	0.1	13	270	50	-
Lagenaria siceraria (Bottle gourd)	96.1	0.6	0.4	2.5	0.2	0.1	12	350	30	-
Solanum melongena (Brinjal)	92.7	1.3	0.8	4.0	1.4	0.3	24	330	60	-

*Source-Ref.[15]; '-'data not available

Table 2. Comparative account of mineral elements (mg/100g) present in the edible portions of six wild plants (Mean ± SD) and some common vegetables

Plant species	Sodium	Potassium	Calcium	Magnesium	Phosphorus
Polygonum runcinatum	3.85±0.19	379.2±14.8	63.9±1.5	127.0±12.4	32.7±2.73
Pilea bracteosa	5.68±0.20	334.4±2.4	116.3±26.9	143.6±3.7	30.4±2.21
Elatostema platyphyllum	6.61±0.37	418.6±4.0	179.4±20.7	207.5±13.0	27.3±1.09
Gynura bicolor	6.26±0.21	617.3±3.9	82.3±4.8	117.5±2.0	20.4±1.87
Plantago erosa	7.88±1.33	332.5±2.7	91.4±14.7	124.8±5.0	28.4±1.74
Diplazium esculentum	5.40±0.74	502.3±22.6	48.6±4.3	115.4±7.9	29.7±3.02
***WINTER VEGETABLES**					
Amaranthus gangeticus (Amaranth)	230.0	341	397	122	83
Brassica oleracea var. *botrytis* (Cauliflower)	53.0	138	626	18	107
Brassica oleracea var. *capitata* (Cabbage)	-	-	39	31	44
Spinacea oleracea (Spinach)	58.5	206	73	64	21
Solanum tuberosum (Potato)	11.0	247	10	30	40
***SUMMER VEGETABLES**					
Abelmoschus esculentus (Ladies finger)	6.9	103	66	53	56
Cucumis sativus (Cucumber)	10.2	50	10	14	25
Lagenaria siceraria (Bottle gourd)	1.8	87	20	26	10
Solanum melongena (Brinjal)	3.0	200	18	15	47

*Source- Ref.[15]; '-' data not available

Table 3. Per cent contribution of nutritional parameters by six wild edible plants to the Recommended Dietary Allowances as per ICMR (2010) when consumed 100g of each plant as vegetable (fresh weight).

Nutritional parameters	*Polygonum runcinatum* (%)		*Pilea bracteosa* (%)		*Elatostema platyphyllum* (%)		*Gynura bicolor* (%)		*Plantago erosa* (%)		*Diplazium esculentum* (%)		RDA 2010 (Units/day)	
	AM	AW	AM	AW	AM	AW	AM	AW	AM	AW	AM	AW	AM	AW
Energy	1.2	1.5	1.2	1.4	1.3	1.6	1.1	1.4	1.2	1.5	1.4	1.7	2730 Kcal	2230 Kcal
Protein	4.2	4.6	3.0	3.3	3.9	4.3	2.9	3.2	3.3	3.6	3.7	4.1	60 g	55 g
Lysine	40.9	29.7	37.8	27.5	32.4	23.6	37.5	27.3	37.7	27.4	27.5	20.0	1800 mg	2475 mg
Tryptophan	248	180	155	112	232	169	218	158	275	200	192	140	240 mg	330 mg
Calcium	10.7	10.7	19.4	19.4	29.9	29.9	13.7	13.7	15.2	15.2	8.1	8.1	600 mg	600 mg
Magnesium	37.4	41.0	42.3	46.3	61.0	67.0	34.6	37.9	36.7	40.3	33.9	37.2	340 mg	310 mg
Phosphorus	5.5	5.5	5.1	5.1	4.6	4.6	3.4	3.4	4.7	4.7	5.0	5.0	600 mg	600 mg
Sodium	0.2	0.2	0.3	0.3	0.3	0.4	0.3	0.3	0.4	0.4	0.3	0.3	2092 mg	1902 mg
Potassium	10.1	11.8	8.9	10.4	11.2	13.0	16.5	19.1	8.9	10.3	13.4	15.6	3750 mg	3225 mg

Body weight for Adult man (AM): ~60kg

Body weight for Adult woman (AW): ~55kg