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Micronutrient content of selected green leafy vegetables dehydrated using different drying methods

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Abstract
North East India being blessed with a variety of natural surroundings, varying climates and seasons has a number of species of edible green leafy vegetables. Green leafy vegetables are highly perishable with shelf-life of only few days owing to higher moisture content. Drying is a simple, user-friendly technique which removes moisture of the product to an extent that increases the shelf life of the product. The present study intends to investigate nutritional and physical characteristics of six commonly consumed greens namely *Rumex vesicarius, Hibiscus sabdariffa, Diplazium esculentum, Polygonum microcephalum, Malva verticillata and Pogostemon benghalensis* after dehydration by using four different drying methods, i.e. sun drying, shade drying, cabinet dryer drying and microwave oven drying. Time required for dehydration of the greens till crispness was minimum in microwave drying and maximum in shade drying. Among the greens, *Rumex vesicarius* took maximum time irrespective of all drying methods. Yield obtained after dehydration of 100g of fresh greens was highest in shade drying for all the samples. Rehydration ratio was highest among microwave dried samples and lowest in shade dried samples. Moisture content was highest in shade dried samples. Among the nutritional parameters, total mineral content, iron, calcium, potassium, phosphorous and ascorbic acid content was found highest in cabinet dryer dried samples, followed by microwave dried samples. Among the greens, *Polygonum microcephalum* contained highest amount of iron (24.28 mg/100g), calcium (763.33 mg/100g) while phosphorous content was highest in *Pogostemon benghalensis* (466.34 mg/100g) and *Diplazium esculentum* contained highest potassium content (2175.65 mg/100g) in cabinet dried samples. Thus it can be concluded that the mineral content of all of the selected greens became concentrated after dehydration. These dehydrated leaves have good rehydration capacity for incorporation into various products to reduce micronutrient deficiency.

Keywords: micronutrients, greens, dehydration, drying methods

Introduction
Green leafy vegetables occupy an important place among the food crops as these promises supply of health protective factors as proteins and micro-nutrients like calcium, iron, vitamin A, vitamin C etc. (Sheela *et al.*, 2004) [10]. Green leafy vegetables have gathered interest worldwide as they exhibited multiple benefits for health of human beings. They form most readily available source of important vitamins, minerals, fibres and essential amino acids particularly in the developing countries where the daily diet is dominated by starchy staple foods (Poonia and Upadhayay, 2015) [6]. Green leafy vegetables are the cheapest of all the vegetables within the reach of poor man, being richest in their nutritional value. But these are highly perishable with shelf-life of only few days owing to higher amount of moisture due to which around 30 per cent of the produce gets rotten and spoilt, becomes inedible, rendering wastage of a huge amount of nutritious products. This calls for preservation and processing to prevent losses as well as make them available in the lean season at remunerative prices.
Dehydration is a simple user friendly, traditional technology which converts the vegetables in to crisp form, reducing in size to facilitate the utility throughout the year. Another added advantage of this method is that the dried vegetable powder can be then easily incorporate in to different traditional recipes (Gupta and Prakash, 2011) [3]. Dehydration makes green leafy vegetables a concentrated source of vitamins and minerals and thus they become a very suitable "natural fortificant" (Joshi and Mathur, 2010) [4]. To increase consumption of green leafy vegetables in a convenient way, an attempt was made to dehydrate few locally available greens of Assam to increase their shelf life and thus reducing wastage.

Materials and Methods

Six commonly available green leafy vegetables were selected and procured from the local market of Jorhat city, Assam. Selection of the green leafy vegetables was done on the basis of their availability and which are commonly grown in this region. After collection the edible portions were cleaned by removing the infested and diseased portion. The leaves were thoroughly washed in running tap-water and finally in distilled water and the surface moisture was removed. The samples were then dried using four drying methods, namely sun drying, shade drying, cabinet dryer drying and microwave oven drying. Moisture and ash was estimated by using standard method (AOAC 2000) [2], iron content was determined according to Wong's method described by Ranganna (1986) [8] and phosphorous content was determined according to the Fiske and Row's method described by Ranganna (1986) [8] by using spectrophotometer (Model No. 2513). Calcium and potassium was determined by using flame photometer (Model MM III) according to the method A.O.A.C. (1984) [1]. Ascorbic acid was determined by volumetric method.

Results and Discussion

a) Effect of moisture content of the greens after dehydration

In the present study, the moisture content of green leafy vegetables under different drying methods are presented in Table 1., which decreases up to 80-90% on drying. Microwave drying resulted in lower level of moisture content (3.59-4.66 g/100g) than other drying methods. Shade dried green leafy vegetables retained highest amount of moisture (5.34-6.87 g/100g) which may be due to high humidity content in air of this region.

Table 1: Effect of moisture content (g/100g) of the greens after dehydration

Botanical Name	Moisture content (g/100g)						
	Fresh greens	Sun drying	Shade drying	Cabinet drying	Microwave drying	CD (0.05)	S.Ed
Rumex vesicarius	94.73	4.76 [b]	6.11[a]	4.14[c]	3.90[c]	0.27	0.11
Hibiscus sabdariffa	89.54	4.33[b]	5.54[a]	3.75[c]	3.59[c]	0.19	0.08
Diplazium esculentum	91.23	5.05[b]	6.87[a]	4.86[c]	4.66[c]	0.22	0.09
Polygonum microcephalum	80.66	4.55[b]	5.34[a]	4.06[c]	3.94[c]	0.26	0.11
Malva verticillata	84.63	4.86[b]	5.77[a]	4.56[c]	4.32[c]	0.26	0.11
Pogostemon benghalensis	85.28	4.43[b]	5.86[a]	4.04[c]	3.86[c]	0.21	0.09

b) Effect of ash content of the greens after dehydration

In the present study, the ash content increases on dehydration as the moisture from the green leafy vegetables are reduced. Cabinet dried *Pogostemon benghalensis* ranked highest ash content of 11.81 g/100g and sun dried *Rumex vesicarius* showed lowest ash content of 6.05 g/100g. Ukegbu and Okereke (2013) [11] studied effect of sun and solar drying on the nutrient composition of *Amaranthus hybridus*, *Telferia occidentalis* and *Hibiscus esculentus* and results revealed that solar dried vegetables had significantly higher ($p< 0.05$) ash content than sun dried and fresh vegetables.

Table 2: Effect of ash content (g/100g) of the greens after dehydration

Botanical Name	Ash content (g/100g)						
	Fresh greens	Sun drying	Shade drying	Cabinet drying	Microwave drying	CD (0.05)	S.Ed
Rumex vesicarius	0.85	6.05[c]	6.84[b]	7.93[a]	7.71[a]	0.30	0.12
Hibiscus sabdariffa	0.91	6.77[c]	7.23[b]	8.04[a]	7.96[a]	0.32	0.13
Diplazium esculentum	1.58	9.34[c]	9.78[b]	10.52[a]	10.33[a]	0.31	0.12
Polygonum microcephalum	1.83	6.97[c]	7.45[b]	8.16[a]	7.88[a]	0.32	0.13
Malva verticillata	1.87	9.54[c]	9.95[b]	10.82[a]	10.53[a]	0.41	0.17
Pogostemon benghalensis	1.95	10.76[c]	11.21[b]	11.81[a]	11.63[a]	0.39	0.16

c) Effect of iron content of the greens after dehydration

In the present study, concentrated quantities of iron with multifold enhancement were observed in dehydrated form (Table 3). Cabinet dried green leafy vegetables showed higher iron content (ranged between 4.33 – 24.28 mg/100g) as compared to other drying methods; whereas sun dried greens were found with lower iron contents.

Table 3: Effect of iron content (mg/100g) of the greens after dehydration

Botanical Name	Iron content (mg/100g)						
	Fresh greens	Sun drying	Shade drying	Cabinet drying	Microwave drying	CD (0.05)	S.Ed
Rumex vesicarius	0.84	3.94[c]	4.06[b]	4.33[a]	4.21[a]	0.14	0.07
Hibiscus sabdariffa	2.12	10.23[c]	11.83[b]	12.40[a]	12.23[a]	0.27	0.10
Diplazium esculentum	4.82	18.94[c]	20.32[b]	21.52[a]	21.26[a]	0.31	0.12
Polygonum microcephalum	7.87	22.53[c]	23.67[b]	24.28[a]	23.97[a]	0.34	0.13
Malva verticillata	3.65	14.84[c]	15.32[b]	16.25[a]	16.05[a]	0.27	0.10
Pogostemon benghalensis	4.76	20.28[c]	21.89[b]	22.18[a]	22.06[a]	0.21	0.08

d) Effect of calcium content of the greens after dehydration

Cabinet dried green leafy vegetables were found with higher calcium content as compared to other drying methods; whereas sun dried green leafy vegetables showed lower calcium contents. Calcium content was found highest in cabinet dried *Polygonum microcephalum* (763.33 mg/100g) and lowest in sun dried *Rumex vesicarius* (361.85 mg/100g).

Calcium content of microwave dried and cabinet dried green leafy vegetables were on par, whereas sun dried and shade dried green leafy vegetables differ statistically. Rajeswari (2010) [7] reported that the calcium content of selected green leafy vegetables under cabinet drying and microwave drying as amaranthus 296.14% (cabinet dried) and 293.92% (microwave dried) and shepu 277.22% (cabinet dried) and 238.25% (microwave dried).

Table 4: Effect of calcium content (mg/100g) of the greens after dehydration

Botanical Name	Calcium content (mg/100g)						
	Fresh greens	**Sun drying**	**Shade drying**	**Cabinet drying**	**Microwave drying**	**CD (0.05)**	**S.Ed**
Rumex vesicarius	61.63	361.85^{c}	380.30^{b}	415.70^{a}	409.20^{a}	18.52	8.03
Hibiscus sabdariffa	147.63	644.38^{c}	664.98^{b}	717.57^{a}	702.78^{a}	13.94	6.04
Diplazium esculentum	66.38	389.98^{c}	401.80^{b}	443.33^{a}	424.30^{a}	21.82	9.46
Polygonum microcephalum	183.06	698.90^{c}	743.50^{b}	763.33^{a}	757.80^{a}	9.62	4.17
Malva verticillata	68.24	389.54^{c}	397.43^{b}	428.80^{a}	412.60^{a}	14.64	6.34
Pogostemon benghalensis	73.79	489.64^{c}	511.32^{b}	573.70^{a}	567.34^{a}	18.25	7.91

e) Effect of phosphorous content of the greens after dehydration

Cabinet dried green leafy vegetables showed higher phosphorous content as compared to other drying conditions; whereas sun dried greens showed lower phosphorous contents. Sun dried and shade dried green leafy vegetables exhibited phosphorous content in the range of 94.10 – 402.13 mg/100g and 103.20 – 445.72 mg/100g respectively. Phosphorous content was found highest in cabinet dried *Pogostemon benghalensis* (466.34 mg/100g) and lowest in sun dried *Diplazium esculentum* (94.10 mg/100g). Joshi and Mehta (2010) conducted a study on the effect of dehydration on the nutritive value of drumstick leaves. Fresh drumstick leaves had a phosphorus content of 70 mg/100g where as the phosphorous content of the leaf powder prepared by different methods of dehydration (sun, shade and oven) was estimated to be 203 mg/100g (Sun dried), 218 mg/100g (shadow dried) and 215 mg/100g (oven dried) respectively. The phosphorous content was 64 - 68% more than their fresh counter parts. The maximum retention was observed in oven drying technique.

Table 5: Effect of phosphorous content (mg/100g) of the greens after dehydration

Botanical Name	Phosphorous content (mg/100g)						
	Fresh greens	**Sun drying**	**Shade drying**	**Cabinet drying**	**Microwave drying**	**CD (0.05)**	**S.Ed**
Rumex vesicarius	21.28	102.35^{c}	133.46^{b}	141.50^{a}	137.60^{a}	6.36	2.75
Hibiscus sabdariffa	34.95	157.34^{c}	186.60^{b}	205.88^{a}	194.59^{a}	10.36	4.49
Diplazium esculentum	17.01	94.10^{c}	103.20^{b}	114.40^{a}	109.60^{a}	7.53	3.26
Polygonum microcephalum	64.05	178.60^{c}	184.32^{b}	214.87^{a}	203.55^{a}	12.82	5.56
Malva verticillata	58.56	287.53^{c}	305.40^{b}	355.45^{a}	342.60^{a}	13.93	6.04
Pogostemon benghalensis	61.67	402.13^{c}	445.72^{b}	466.34^{a}	453.80^{a}	14.72	6.38

f) Effect of potassium content of the greens after dehydration

Potassium content was found highest in cabinet dried *Spinacia oleracea* (2546.45 mg/100g) and lowest in sun dried *Talinum triangulare* (403.87 mg/100g). The potassium content of cabinet dried and microwave dried greens were at par and ranged from 478.67 – 2546.45 mg/100g and 463.42 – 2526.30 mg/100g respectively. Sun dried greens exhibited significant lower level of potassium. This observation may probably be due to potassium being cationic element that does not polarize easily in heating but forms oxides when exposed to light and air.

Liman *et al. (*2014) [5] reported the potassium content of drumstick leaves in sun dried (8.83 mg/100g), oven dried sample (8.50 mg/100g) and samples dried in moisture analyzer (7.83 mg/100g). As for bitter leaf (*vernonia amygdalina),* potassiun content is found in oven dried sample with 20.58 mg/100g followed by that for sun dried sample with 20.08 mg/100g then the least is seen for moisture analyzer with 18.92 mg/100g.

Table 6: Effect of potassium content (mg/100g) of the greens after dehydration

Botanical Name	Potassium content (mg/100g)						
	Fresh greens	**Sun drying**	**Shade drying**	**Cabinet drying**	**Microwave drying**	**CD (0.05)**	**S.Ed**
Rumex vesicarius	227.40	1021.53^{c}	1087.24^{b}	1156.68^{a}	1145.63^{a}	17.10	7.41
Hibiscus sabdariffa	186.67	643.29^{c}	695.20^{b}	754.62^{a}	742.82^{a}	25.24	10.94
Diplazium esculentum	487.80	2064.40^{c}	2116.13^{b}	2175.65^{a}	2153.30^{a}	22.74	9.86
Polygonum microcephalum	152.20	587.30^{c}	614.72^{b}	652.53^{a}	644.70^{a}	18.37	7.96
Malva verticillata	317.90	1474.56^{c}	1496.23^{b}	1557.38^{a}	1543.80^{a}	19.31	8.37
Pogostemon benghalensis	376.32	1578.20^{c}	1603.60^{b}	1623.57^{a}	1615.50^{a}	11.73	5.08

g) Effect of ascorbic acid content of the greens after dehydration

From the Table 7, it can be seen that ascorbic acid was found reduced during different drying methods as compared to fresh condition. Ascorbic acid is a heat labile water soluble vitamin which decreases in heat treatment. Sun drying caused maximum loss in ascorbic acid and shade dried samples showed better retention of ascorbic acid which may be due to absence of heat treatment. Ascorbic acid of sun dried and shade dried greens were in the range of 0.58 – 9.87 mg/100g and 2.16 – 13.87 mg/100g respectively. After shade drying, microwave dried greens showed good retention of ascorbic acid (ranged between 2.02 – 13.96 mg/100g). Effect of sun and solar drying on the nutrient composition of *Amaranthus*

hybridus, *Telferia occidentalis* and *Hibiscus esculentus w*as reported by Ukegbu and Okereke in 2013 [11]. The study revealed that solar dried vegetables had significantly higher ascorbic acid content than sun dried vegetables. Ascorbic acid content of *Amaranthus hybridus was* 33.44 mg/100g (solar dried) and 17.61 mg/100g (sun dried), *Telferia occidentalis* 29.16 mg/100g (solar dried) and 28.12 mg/100g (sun dried) and *Hibiscus esculentus* are 19.70 mg/100g (solar dried) and 18.83 mg/100g (sun dried). In all the samples, ascorbic acid was most depleted in sun dried vegetables which is in accordance with the present study. This could be attributed to oxidative destruction in the presence of heat, light, oxygen, moisture and metal ions (Russel and McDowell, 1989) [9].

Table 7: Effect of ascorbic acid content (mg/100g) of the greens after dehydration

Botanical Name	Ascorbic acid content (mg/100g)						
	Fresh greens	Sun drying	Shade drying	Cabinet drying	Microwave drying	CD (0.05)	S.Ed
Rumex vesicarius	32.11	7.55^{d}	11.52^{a}	8.23^{c}	9.68^{b}	0.13	0.06
Hibiscus sabdariffa	21.21	4.26^{d}	6.55^{a}	5.21^{c}	5.48^{b}	0.12	0.05
Diplazium esculentum	12.60	0.85^{d}	2.43^{a}	1.92^{c}	2.07^{b}	0.09	0.04
Polygonum microcephalum	36.07	9.87^{d}	13.87^{a}	12.26^{c}	13.54^{b}	0.11	0.05
Malva verticillatae	13.43	0.58^{d}	2.67^{a}	1.93^{c}	2.13^{b}	0.09	0.04
Pogostemon benghalensis	12.57	0.65^{d}	2.16^{a}	1.82^{c}	2.02^{b}	0.13	0.06

Conclusion

Green leafy vegetables are treasure trove of micronutrients. Judicious combination of green leafy vegetables might serve as richer source of specific micronutrients. Dehydrated green leafy vegetables will serve as an instant food ingredient to be used without laborious pre-processing. Dehydration also increases shelf-life of the greens. Dehydrated green leafy vegetables can be efficiently utilized for processing of value added products. Consumption of dehydrated green leafy vegetables incorporated products in daily diet will ensure micronutrient security.

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