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Nutritional and sensory quality of micronutrient-rich traditional products incorporated with green leafy vegetables

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Abstract: The study was aimed to formulate micronutrient rich products with dried greens. 'Keerae' (*Amaranthus paniculatus*) and 'shepu' (*Peucedanum graveolens*) greens were steam blanched after chemical pretreatment and dried in hot air oven. Dried greens were analyzed for proximate constituents, vitamins, minerals, antinutrients and dialyzable minerals. Dehydrated greens were incorporated into '*Mathri*' – a wheat flour based deep fried product and '*Thalipeeth*' – a mixed cereal based shallow fried product at 4, 8 and 12 % levels. The products were evaluated for sensory quality in comparison to control (without greens) by an untrained panel numbering 80. Analysis of chemical composition showed no significant losses in proximate, mineral and antinutrient contents of dehydrated greens. Results of sensory analysis revealed that products incorporated with 4% dehydrated greens were similar to control in texture, taste and overall quality. However, acceptability scores reduced with increasing concentration of greens. Addition of dehydrated greens increased nutrient density of all products.

Keywords: ***Amaranthus paniculatus*, *Peucedanum graveolens*, dehydration, sensory analysis, value addition**

Introduction

Multiple micronutrient deficiencies are more common than single deficiencies in developing countries and the cause for their high prevalence is low dietary intake by populations and poor bioavailability of micronutrients. Vitamin A deficiencies are estimated to cause 600,000 deaths whereas zinc deficiencies cause 400,000 deaths annually. Iron deficiency is the most common nutritional problem worldwide, and contributes to maternal deaths in pregnancy and parturition. The principle manifestation of iron deficiency is anemia; iron deficiency also compromises the immune system and is associated with limited cognitive development in children. Among pre-school aged children worldwide, 23% suffer from iron deficiency anemia (Gegios *et al*., 2010). In developing countries these nutritional problems are more severe, however, people in developed countries also suffer from different forms of these nutritional problems. In India, 79% of children between 6 to 35 months and women between 15 to 49 years of age are anemic (Krishnaswamy, 2009).

The most sustainable approaches to increasing the micronutrient status of populations are food-based strategies, which include food production, dietary diversification and food fortification. Food-based interventions focus on food - natural, processed, fortified, or in combination - as the primary tool for improving the quality of diet and for overcoming and preventing malnutrition and nutritional deficiencies. The basis of this approach is to increase the production and consumption of foods, especially those rich in micronutrients, as well as their absorption and utilization in the body (Allen, 2006).

The food based approach for combating micronutrient malnutrition, is difficult and of a long duration, although its effect is predicted to be long lasting. Green leafy vegetables (GLV) are micronutrient dense nature's gift to mankind that provides more vitamins per mouthful than any other food. GLV are known to be rich sources of micronutrients such as vitamin A, iron, β-carotene, etc. and utilizing them is one way of ensuring the micronutrient intake. They also contain certain amounts of antinutritional substances (dietary fiber, oxalic acid, tannins, etc.) that are known to interfere in mineral absorption *in vivo*. They also contain an immense variety of bioactive, non-nutritive health enhancing factors such as antioxidants, phytochemicals, essential fatty acids and dietary fiber. GLV are inexpensive sources of micronutrients, however their utilization seems to be limited either due to ignorance or the inability to use them in many

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products.

GLV are seasonal and also highly perishable due to the high water content in their plant tissues. There is a need to preserve the nature's storehouse of nutrients through convenient processing techniques. Therefore dehydration seems to be the simplest technology for preserving greens especially when they are abundantly available. Greens can be utilized in multiple ways by incorporating into existing products and formulation of health foods using techniques of dehydration. There are no processed foods that are available, which incorporate greens. In fact, the consumption of green leafy vegetables in Indian population is limited to 5 - 10 g per day (NNMB, 1997) as against the recommendation of 100 g by Indian Council of Medical Research (ICMR, 1998). The basic idea is to find novel methods by which consumption of greens can be increased. This study was therefore planned with an objective to study the changes in composition of GLV on dehydration and utilize the dehydrated GLV to enhance the nutritional quality of traditional products.

Methodology

Materials

Two GLV namely Keerae (*Amaranthus paniculatus*) and Shepu (*Peucedanum graveolens*) were selected to study the changes in composition on dehydration and utilize them in product formulation. GLV, wheat flour (*Triticum aestivum*), maize flour (*Zea mays*), Bengal gram flour (*Cicer arietinum*), fine semolina (*Triticum aestivum*), refined sunflower oil (*Helianthus annuus*), red chilli powder (*Capsicum annuum*), cumin powder (*Cuminum cyminum*), ajwain (*Trachyspermum ammi*), salt, onions (*Allium cepa*) and tomatoes (*Lycopersicon esculentum*) were procured in one lot from the local market for formulation of products.

The GLV were separated from roots and washed under running water to remove the adhering mud particles followed by double glass-distilled water and drained completely. One set of samples was dried (unblanched) in an oven at 60°C, powdered and stored in air tight containers in a refrigerator and used for further analysis. The other set of greens were steam blanched for 5 min after chemical treatment with a solution of 0.1% magnesium oxide +0.1% sodium bicarbonate and 0.5% potassium metabisulphite. They were drained after blanching and spread on steel trays for drying in an oven at 60°C for 8 - 10 h. After drying, the GLV were powdered in a mixer and stored in an airtight container in refrigerator.

Compositional analysis

The washed and drained fresh greens were used for analysis of moisture (AOAC, 1999), ascorbic acid, total and β-carotene (Ranganna, 1986), thiamine (Raghuramulu *et al*., 2003), oxalates (Baker, 1952) and *in vitro* bioavailable iron and calcium by dialysis method (Luten *et al*., 1996). The dialysates were analyzed for iron by colorimetric method using α - α bipyridyl (AOAC, 1965) and calcium by Raghuramulu *et al*. (2003). The dried samples (unblanched) were used for analysis of protein, fat, ash, minerals - iron and calcium (Ranganna, 1986), dietary fiber (Asp *et al*., 1983) and tannins (Burns, 1971). The blanched and dehydrated greens were subjected to compositional analysis using the methods as mentioned above.

The dehydrated *Peucedanum graveolens* and *Amaranthus paniculatus* (unblanched and blanched as mentioned above) were used for moisture sorption study. Moisture sorption isotherms were investigated for these GLV using salts which represent different relative humidities (Labuza *et al*., 1976). Double glass-distilled water was used for preparation of reagents used in the entire analysis. All chemicals used for the study were of analytical grade.

Product formulation

Two products namely '*Mathri*' and '*Thalipeeth*' were selected for incorporating *Amaranthus* paniculatus and *Peucedanum graveolens* respectively. *Mathri* is a wheat flour based deep fat fried product, which is generally eaten as a snack. Wheat flour (70 g), wheat semolina (14 g), shortening (14 g), salt (2g), ajwain (1 g), chilli powder (2 g), and cumin seed powder (2 g) were all mixed together. Water (luke warm- 100 ml) was added and kneaded well to make stiff dough. The dough was kept aside for 10 min, kneaded again and divided into small portions. The dough was rolled to about 4 mm thick and cut into small circles using a cutter. *Mathri* was deep fried in oil for 5 min until they were golden brown in color. The thickness of the fried *mathri* was about 5 mm. Flour was replaced with dehydrated *Amaranthus* paniculatus at 4, 8 and 12% levels.

Thalipeeth is a mixed cereal and legume based pancake like product. Bengal gram flour (25 g), maize flour (25 g), fine semolina (25 g) and whole wheat flour (25 g) were mixed together. Onions (40 g), tomatoes (20 g), half a green chilli (finely chopped), ajwain (1 g), cumin seed powder (1 g) and salt (3 g) were added to the flour mixture and made into a batter of pouring consistency with water. The batter was spread on a non-stick pan like a pancake to have a diameter of about 5 inches and allowed to cook with a lid covered. Oil (5 ml) was smeared and the pancake was turned upside down so that it was cooked on both sides. The thickness of the cooked *thalipeeth* was 4 - 5 mm. It was served with tomato sauce as a carrier. The mixture of flours was replaced with dehydrated *Peucedanum graveolens* at 4, 8 and 12% levels.

Sensory analysis

The formulated products were subjected to sensory analysis by panel members (n = 80) with the help of a score card. The product without green leafy vegetable served as control. The score card was developed using a 10-point scale for appearance, color, texture, taste and overall quality (Gridgeman, 1967). The products were presented in an order. The control was placed first followed by the samples with increasing amounts of dehydrated greens incorporated in the products, i.e., 4%, 8% and 12%. The panelists were also asked to indicate presence or absence of greens aroma in the formulated products. The data was compiled and analyzed statistically.

Statistical analysis

Standard deviation and t-test were performed on the compositional analysis data. The sensory analysis data was subjected to ANOVA and Duncan's multiple range tests to determine the statistically significant differences among the products that were developed. The statistical packages used for the above analysis are MS - Excel and Minitab 11.0.

Results and Discussion

Dehydration involves removal of water normally present in tissues by evaporation. Vegetable dehydration is generally done either for preserving the perishable raw commodity against deterioration or to reduce the cost of packaging, handling, storing and transporting. However, in our study we wanted to utilize dehydration technology with a different perspective. GLV are rich sources of micronutrients and therefore dehydrating them can provide us a concentrated source of micronutrients. Utilizing these micronutrient-rich GLV in a dehydrated form can be a food-based approach to combat the micronutrient deficiency prevalent in our populations.

The necessity for blanching vegetables for improved product quality prior to dehydration has been recognized for long. Blanching is necessary to prevent the formation of off-flavors, odors and colors. Though blanching is a prerequisite to inactivate enzymes, it is deleterious to the vegetables causing vitamin losses by thermal degradation, diffusion and leaching (Negi and Roy, 2000). It also results in some degree of chlorophyll degradation with the subsequent formation of pheophytin, which can be prevented by the addition of an alkalizing agent like magnesium carbonate during blanching (Maharaj and Sankat, 1996). In the present study we analyzed the influence of dehydration on the nutritive value of GLV and incorporated the dried greens in products. The results of the study are presented in Tables 1 - 4. The composition data is presented on fresh weight basis to correct for differences in the moisture content.

Nutritional composition

The moisture content of the fresh *Amaranthus paniculatus* and *Peucedanum graveolens* was 86.5 and 90.4% whereas dehydrated GLV contained 4.9 and 7.4 % respectively (Table 1). Ether extract in fresh and dried *Amaranthus paniculatus* was 0.41 and 0.78 g/100g and in *Peucedanum graveolens* it was 0.49 and 0.70 g/100g respectively. The difference between the fresh and dehydrated samples were statistically significant for *Amaranthus paniculatus* which could be attributed to a better extraction in dried samples because they undergo mild heat treatment while drying. However the differences were found to be insignificant for *Peucedanum graveolens*. When the ash content of the fresh and dehydrated *Amaranthus paniculatus* was considered, no significant differences were found. In *Peucedanum graveolens* ash content was 1.35 and 1.27 mg/100g respectively in fresh and dried greens. As per student's t-test, significant differences were observed in the ash content on dehydration, however the real differences in actual values are too small to consider.

In fresh *Amaranthus paniculatus* the iron and calcium content were 5.46 mg/100g and 221.9 mg/100g respectively while in *Peucedanum graveolens* it was 3.63 mg/100g and 73.2 mg/100g respectively (Table 1). Dehydration does not seem to have much effect on the iron content of the GLV. Similar observations have been reported by Kawashima and Valente Soares (2003) on cooking of leafy vegetables consumed in Brazil. Though there were variations in the iron content of dehydrated GLV when compared to the fresh, no significant differences were seen on application of t-test. The calcium contents of fresh and dehydrated GLV were found to be similar, slight variations observed were found to be statistically insignificant.

Ascorbic acid, thiamine, total and β-carotene were the vitamins that were analyzed in both fresh and dehydrated GLV. Ascorbic acid, the most water-soluble and heat labile vitamin was found to be lost in large quantities on dehydration. As can be seen from

Table 1, fresh GLV has good amounts of ascorbic acid -65.4 and 58.3 mg/100g in *Amaranthus paniculatus* and *Peucedanum graveolens* respectively. On dehydration in *Amaranthus paniculatus*, it reduced to 3.0 mg/100g (fresh weight basis) whereas *Peucedanum graveolens* contained 22.9 mg of ascorbic acid per 100 g of dry vegetable (fresh weight basis). Statistically significant differences were observed when Student's t-test was used to find out the effect of dehydration on ascorbic acid content. Fresh *Amaranthus paniculatus* contained 0.05 mg thiamine /100 g fresh vegetables out of which only 50% was retained on dehydration. *Peucedanum graveolens* contained 0.14 mg/100g of fresh vegetable which was reduced to 0.04 mg/100g on dehydration. Dehydration did result in losses of thiamine. Statistical analysis showed significant differences between the thiamine content of fresh and dehydrated greens.

Total carotene content of the GLV was also affected by dehydration (Table 1). It decreased from 43.47 to 25.25 mg/100 g in *Amaranthus paniculatus* and 29.33 to 16.96 mg/100g in *Peucedanum graveolens*. Statistically significant differences were observed in total carotene on dehydration. β-carotene, which is a precursor of vitamin A was also analyzed. *Amaranthus paniculatus* had higher β-carotene content in comparison to *Peucedanum graveolens*. On drying, statistically significant losses were observed; the β-carotene decreased from 5.60 to 3.76 mg/100 g in *Amaranthus paniculatus* whereas, in *Peucedanum graveolens* it reduced from 3.29 to 2.60 mg/100g fresh vegetable.

When we consider the amount of ascorbic acid that was retained on dehydration, *Peucedanum graveolens* retained 39.4% of its initial ascorbic acid content whereas *Amaranthus paniculatus* retained only 4.54% of its original ascorbic acid. In comparison with ascorbic acid, thiamine was better retained on dehydration. Almost 48% retention was seen in *Amaranthus paniculatus*, whereas *Peucedanum graveolens* retained 34% of thiamine on dehydration. Similarly Mosha *et al*. (1995) have reported significant losses of ascorbic acid and thiamine on traditional processing practice of sun drying in Tanzanian vegetables. Among the vitamins, total and β-carotene were better retained on dehydration. Fifty eight percent of total carotene was retained in both the GLV analyzed. A high retention of β-carotene was seen in *Peucedanum graveolens* (79%), whereas *Amaranthus paniculatus* retained 67% of the initial β-carotene content. Negi and Roy (2000) have reported that blanching in water followed by potassium metabisulphite dip and drying at low temperature had the least drastic effect on ascorbic acid and β-carotene content of the GLV studied. Mdziniso *et al*. (2006) reported high retention of β-carotene in collard greens on solar drying. Recently Zhang *et al*. (2009) have reported that ascorbic acid and β-carotene were better retained in freeze dried samples in comparison to oven-dried bitter melon leaf. From the above results, it can be said that vitamins are more prone to destruction on dehydration while there seems to be little effect on the proximate constituents.

Table 1. Nutrient composition of fresh and dehydrated green leafy vegetables[#]

Nutrient	*Amaranthus panicualtus*			*Peucedanum graveolens*		
	Fresh	Dehydrated	P-value	Fresh	Dehydrated	P-value
Moisture (%)	86.5 ± 0.59	4.9 ± 0.11	-	90.4 ± 0.32	7.4 ± 0.30	-
Ether extract (g/100g)	0.41 ± 0.00	0.78 ± 0.05	0.030*	0.49 ± 0.01	0.70 ± 0.05	0.056ns
Ash (g/100g)	2.28 ±0.00	2.30 ±0.04	0.328ns	1.35 ±0.01	1.27 ±0.01	0.004**
Iron (mg/100g)	5.46 ± 0.90	4.91 ± 0.39	0.162 ns	3.63 ± 0.56	4.37 ± 0.71	0.078ns
Calcium (mg/100g)	221.9 ± 26.84	231.5 ± 3.33	0.264 ns	73.2 ± 11.33	63.4 ± 3.18	0.098 ns
Ascorbic acid (mg/100g)	65.4 ± 0.50	3.0 ± 0.22	0.000***	58.3 ± 13.63	22.9 ± 0.15	0.007**
Thiamine (mg/100g)	0.04 ± 0.01	0.02 ± 0.01	0.038**	0.14 ± 0.04	0.05 ± 0.01	0.005**
Total carotene (mg/100g)	43.47 ± 2.31	25.25 ± 0.27	0.000***	29.33 ± 0.73	16.96 ± 0.86	0.000***
β-carotene (mg/100g)	5.60 ± 0.39	3.76 ± 0.57	0.002**	3.29 ± 0.13	2.60 ± 0.25	0.004**

- All values are reported on fresh weight basis, values are means of four replicates.
* - Significant at P ≤ 0.05, ** - Significant at P ≤ 0.01, ***- Significant at P ≤ 0.001, ns- not significant.

Antinutrients and dialyzable minerals

Tannins, total and soluble oxalates, insoluble and soluble dietary fiber were the antinutrients analyzed in fresh and dehydrated greens (Table 2). In fresh samples, tannin content (expressed as catechin equivalents) was found to be lesser in

Peucedanum graveolens (130.4 mg/100g) and higher in *Amaranthus paniculatus* (238.9 mg/100g). There was a slight increase in tannin content of dehydrated greens which could be due to dehydration and pre-treatment before dehydration resulting in increased solubility and extraction. Differences in tannin content of fresh and dehydrated GLV were found to be statistically insignificant for *Amaranthus paniculatus* whereas they were significant for *Peucedanum graveolens*.

in statistical insignificance in case of SDF whereas in case of IDF the differences were found to be statistically significant. Some studies have reported the effect of processing on dietary fiber. Khanum *et al*. (2000) have reported a significant increase in SDF fraction with a concomitant decrease in the IDF fraction upon cooking. Conversely no significant effect of processing/cooking on IDF and SDF content of GLV has been reported by Punna and Rao (2004).

Table 2. Antinutrient content and dialyzable iron and calcium in fresh and dehydrated green leafy vegetables[#]

Antinutrients and bioavailable minerals	*Amaranthus paniculatus*			*Peucedanum graveolens*		
	Fresh	Dehydrated	P-value	Fresh	Dehydrated	P-value
Tannins[a] (mg/100g)	238.9 ± 12.12	249.0 ± 30.26	0.285^{ns}	130.4 ± 9.13	176.8 ± 9.66	0.000^{***}
Total oxalates (mg/100g)	928.1 ± 94.85	902.6 ± 34.97	0.319^{ns}	63.4 ± 19.22	65.3 ± 22.15	0.452^{ns}
Soluble oxalates (mg/100g)	372.3 ± 28.60	205.9 ± 21.14	0.000^{***}	13.8 ± 2.10	20.5 ±6.25	0.055^{ns}
Insoluble Dietary fiber (g/100g)	3.58 ± 0.00	3.63 ± 0.18	0.383^{ns}	2.76 ± 0.03	2.41 ± 0.06	0.040^{*}
Soluble Dietary fiber (g/100g)	0.37 ± 0.04	0.55 ± 0.06	0.029^{*}	0.36 ± 0.00	0.38 ± 0.01	0.148^{ns}
Dialyzable iron (mg/100g)	1.55 ± 0.23	0.25 ± 0.04	0.001^{***}	0.98 ± 0.16	0.23 ± 0.14	0.000^{***}
Dialyzable calcium (mg/100g)	19.23 ± 4.33	7.19 ± 2.45	0.002^{***}	57.93 ± 5.97	25.75 ± 6.29	0.000^{***}

#- All values are reported on fresh weight basis, values are means of four replicates,
a - expressed as catechin equivalents.
* - Significant at P ≤ 0.05, ***- Significant at P ≤ 0.001, ns- not significant.

Total oxalate content of *Peucedanum graveolens* was found to increase on dehydration while in *Amaranthus paniculatus* it decreased (Table 2). However these differences were very small to be statistically significant. A similar trend was seen in soluble oxalate content of the dehydrated greens. Soluble oxalate was seen to increase in *Peucedanum graveolens* on dehydration, while in *Amaranthus paniculatus* dehydration seems to have reduced the soluble oxalate content. The differences between the soluble oxalate content of fresh and dehydrated greens were found to be statistically significant for *Amaranthus paniculatus* whereas it was insignificant for *Peucedanum graveolens*. To the best of our knowledge, there are no studies on the effect of dehydration on the tannins and oxalate content of GLV in literature.

When we consider the insoluble dietary fiber content (IDF), a slight increase from 3.58 g/100g to 3.63 g/100g was seen in *Amaranthus paniculatus*. A similar trend was also observed for soluble dietary fiber (SDF) content. These differences in IDF content in fresh and dehydrated GLV were found to be statistically insignificant according to Student's t-test whereas they were significant for SDF. In case of *Peucedanum graveolens*, a marginal increase in both IDF and SDF was seen on dehydration. The differences in actual values are vey small, resulting

The effect of dehydration on dialyzability of iron and calcium measured by *in vitro* technique was also studied. In fresh *Amaranthus paniculatus* the dialyzable iron content was 1.55 mg/100g fresh vegetable whereas on dehydration it reduced to 0.25 mg/100 g. When *Peucedanum graveolens* was considered, the fresh vegetable had 0.98 mg of dialyzable iron /100g vegetable which declined to 0.23 mg/100 g on drying. The differences in dialyzable iron in the fresh and dried greens were found to highly significant. A sharp decline in the dialyzable iron of dried greens was observed. When percent dialyzable iron was considered, it reduced from 28.43% and 26.86% in fresh to 5.13% and 5.25% in dried *Amaranthus paniculatus* and *Peucedanum graveolens* respectively. Different workers have reported varying values for percent dialyzability from green leafy vegetables. Chawla *et al*. (1988) in one of the earliest studies determined the *in vitro* availability of iron and related constituents in six green leafy vegetables (amaranth, colocasia, drumstick, fenugreek, shepu and spinach) and found it to be between 2.8 - 4.6%. Lucarini *et al*. (2000) studied the dialyzable iron content from artichoke, asparagus, broccoli, cabbage, cauliflower, kale, carrot, tomato and potato and reported it to be in the range of 10.7 - 23.1% in vegetables with the exception of artichoke and asparagus. The *in vitro* iron bioavailability in the uncommon greens from the Uttaranchal region of India ranged between 4.62 - 6.20% (Raghuvanshi *et al*., 2001). These differences in the bioavailable iron content of the vegetables can be attributed to the samples themselves, the organic acid content of vegetables and the presence of the antinutrients in these vegetables. However, we have not found any study on the effect of dehydration on the bioavailable iron content of the GLV. The decrease in dialyzability on dehydration could be attributed to the fact that during the process of dehydration, iron could have been bound to other constituents of the vegetables thus reducing the solubility, which in turn influences the dialyzability of the mineral. Also, ascorbic acid which is a promoter of iron bioavailability is destroyed during dehydration. The change in the food matrices on dehydration of GLV may also affect the contents of dialyzable minerals.

The absolute amount of dialyzable calcium was found to be 19.23 and 57.93 mg/100g in *Amaranthus paniculatus* and *Peucedanum graveolens* respectively. When dehydrated greens were considered, we found a decline in their dialyzable calcium content with respect to fresh greens. In *Amaranthus paniculatus*, dialyzable calcium content reduced by more than half to 7.19 mg/100g of dried greens while in *Peucedanum graveolens* to 25.75 mg/100g of dried greens. The percent dialyzable calcium reduced from 8.67% and 79.18% in fresh to 3.10% and 40.60% in dried *Amaranthus paniculatus* and P*eucedanum graveolens* respectively. Differences in dialyzable calcium in fresh and dried greens were found to be highly significant. Raghuvanshi *et al*. (2001) reported that inspite of high oxalate content of uncommon GLV from Uttaranchal regions of India, the in vitro calcium bioavailability ranged between 7.30 - 63.48%. Conversely, Kamchan *et al*. (2004) reported high levels of dialyzable calcium (20 - 39%) in kale, celery, collard, pak-chee-lao (*Anethum graveoleus*, L.), Chinese cabbage and soybean sprouts. Medium levels of dialyzable calcium (11 - 18%) were found in Indian mulberry and sesbania leaves. Pak-paw (*Polygonum odoratum*, L), amaranth and wild betel exhibited low calcium dialyzability. The differences in the calcium dialyzability as reported by Raghuvanshi *et al*. (2001) and Kamchan *et al*. (2004) could be attributed to the different methods used for estimation of in vitro dialyzable calcium. Recently Charoenkiatkul *et al*. (2008) have reported that calcium bioavailability of ivy gourd (a GLV) was relatively good as compared to milk and could be recommended to public as a source of calcium.

Moisture sorption studies

Amaranthus paniculatus and *Peucedanum graveolens* were steam blanched after chemical pretreatment and dried in an oven and evaluated for moisture sorption. Dried greens were used in formulation of products to increase the utilization of GLV in our diets. Unblanched dried greens were also used for moisture sorption study. Moisture uptake of unblanched and blanched *Amaranthus paniculatus* ranged from 1.75-5.25% and 1.78-5.2% respectively at relative humidities ranging from 22-93%. Moisture uptake was 2.6% for unblanched greens and 3% for blanched and dried greens at relative humidity of 60%. The moisture uptake of unblanched and blanched *Peucedanum graveolens* ranged from 1.35-6.7% and 1.35-6.8% respectively at relative humidities ranging from 22-93%. The moisture uptake was 2.7% for unblanched greens and 2.6% for blanched and dried greens at relative humidity of 60%. Moisture sorption isotherms were similar for blanched and unblanched greens. The results of the moisture sorption study indicate that the dehydrated GLV powders were stable at high relative humidities.

Incorporation in product and sensory evaluation

Blanched and dehydrated Amaranthus paniculatus were incorporated into *'Mathri*', which is a wheat flour based deep fat fried product generally eaten as a snack. It was prepared by replacing 4, 8 and 12% of the base ingredients with dehydrated *Amaranthus paniculatus*. Product without GLV served as control. Products were evaluated for sensory quality by a panel size of 80. Results of sensory analysis are presented in Table 3. The control sample was given scores ranging from 7.74 to 8.42 for different quality attributes. These were the maximum scores given for all sensory attributes among the products evaluated. Addition of dehydrated *Amaranthus paniculatus* brought down the scores of all the samples with respect to appearance, color, texture, taste and overall quality in comparison to control. Incorporation of dehydrated greens at 8 and 12% levels lowered the scores of all the attributes of the product. The quality of appearance received the lowest score of 5.7 for 12% greens incorporated product. ANOVA revealed significant differences in all the attributes of the products. When Duncan's multiple range tests was applied to check for differences in between the samples, we found that 4 and 8% greens incorporated samples were similar in appearance. The 8 and 12% greens incorporated products were found to be similar in all the other sensory attributes except appearance. However, the 4% greens incorporated product was found to be similar to control in terms of texture,taste and overall quality although significant differences

Table 3. Mean scores of sensory attributes of mathri incorporated with different levels of dehydrated *Amaranthus paniculatus* and *thalipeeth* incorporated with different levels of dehydrated *Peucedanum graveolens**

Variation	Appearance	Color	Texture	Taste	Overall Quality	Greens Aroma (Y)
Mathri* incorporated with dehydrated *Amaranthus paniculatus						
Control	8.21^{a} ± 1.42	8.14^{a} ± 1.68	7.74^{a} ± 1.71	8.13^{a} ± 1.79	8.42^{a} ± 1.46	-
4%	7.29^{be} ± 1.67	7.23^{b} ± 1.78	7.41^{a} ± 1.78	7.81^{a} ± 1.89	7.97^{a} ± 1.55	57
8%	6.63^{ce} ± 1.82	6.33^{ce} ± 2.01	6.57^{bd} ± 1.70	6.44^{bd} ± 1.89	6.99^{bd} ± 1.70	72
12%	5.70^{d} ± 2.37	5.51^{de} ± 2.52	6.43^{cd} ± 1.97	6.25^{cd} ± 2.44	6.57^{cd} ± 2.24	77
F-ratio	**26.05*** **	**25.25*** **	**10.6*** **	**17.68*** **	**18.82*** **	-
Thalipeeth* incorporated with dehydrated *Peucedanum graveolens						
Control	7.56^{a} ± 1.59	7.50^{a} ± 1.67	7.20^{ad} ± 1.46	7.44^{a} ± 1.78	7.66^{a} ± 1.45	-
4%	7.38^{a} ± 1.50	7.46^{a} ± 1.53	7.36^{a} ± 1.30	7.71^{a} ± 1.59	7.89^{a} ± 1.46	56
8%	6.59^{b} ± 1.64	6.54^{b} ± 1.71	6.76^{bde} ± 1.73	6.66^{b} ± 1.76	6.96^{bd} ± 1.55	66
12%	5.75^{c} ± 2.06	5.75^{c} ± 2.05	6.39^{ce} ± 1.87	5.89^{c} ± 2.18	6.34^{cd} ± 2.05	73
F-ratio	**18.78*** **	**18.30*** **	**6.04*** **	**16.03*** **	**14.58*** **	-

Total sensory responses = 80.
* Means in the same columns with different superscripts are significantly different from each other.
*** - Significant at $P \leq 0.001$.

Table 4. Nutritive value of *mathri* and *thalipeeth* incorporated with dehydrated *Amaranthus paniculatus* and *Peucedanum graveolens* respectively per 100 g product*

Nutrients	*Mathri*				*Thalipeeth*			
	Control	**4%**	**8%**	**12%**	**Control**	**4%**	**8%**	**12%**
Protein (g)	9.85	10.51	11.17	11.83	14.26	14.80	15.31	15.87
Fat (g)[#]	32.28	35.92	39.89	38.60	13.01	13.18	13.35	13.52
Dietary fiber (g)	5.75	6.84	7.92	9.01	14.4	15.03	15.67	16.30
Iron (mg)	2.39	3.91	5.58	6.93	3.90	5.62	7.35	8.99
Calcium (mg)	43.14	93.97	144.80	195.63	60.86	79.55	98.24	116.93
Total carotene (μg)	35	7538	15041	22544	8	13	15	22
β – carotene (μg)	-	1118	2236	3354	118	1193	2267	3342
Serving size	*6 **mathri** (25g)*				*2 **thalipeeth** (120g)*			

* Nutrient content is based on analyzed values for GLV. For nutrient content of other ingredients, Food Composition table (Gopalan *et al*., 2004) was used.
# Analyzed by Soxhlet extraction for *Mathri*

were seen in appearance and color.

Thalipeeth is a mixed cereal and legume based pancake like product, which is generally consumed as a breakfast item. It was incorporated with three levels of dehydrated *Peucedanum graveolens* and subjected to sensory evaluation by a panel of 80 members. The product without greens served as control. The results of the sensory evaluation are presented in Table 3. The control product was given a similar rating ranging from 7.20 - 7.66 for all quality attributes. As can be seen from the table 3, addition of greens brought down the scores of all the sensory attributes. Low scores ranging from 5.75 - 6.39 were observed for 12% *Peucedanum graveolens* incorporated thalipeeth. ANOVA revealed significant differences in all the attributes of the products. On application of Duncan's test, the differences in between the samples were much clearer. No significant differences were observed in the appearance, color, texture, taste and overall quality of the control and 4% *Peucedanum graveolens* incorporated *thalipeeth*. Though the 8% and 12% *Peucedanum graveolens* incorporated thalipeeth were similar in texture and overall quality, the differences in appearance, color and taste were statistically significant. From the above results, it can be said that though control and 4% *Peucedanum graveolens* incorporated *thalipeeth* were similar, the 8% *Peucedanum graveolens* incorporated *thalipeeth* was also acceptable.

Products incorporated with greens showed a remarkable increase in all their micronutrient content (Table 4). The iron content of *mathri* was found to increase from 2.39 mg in control to 6.03 mg/100g for the 12% greens incorporated product. The calcium content almost doubled by addition of 4% dried greens to the product. The total and β-carotene content also increased extraordinarily. A serving size of 25 g of *mathri* can provide the daily requirement of β-carotene for an individual. When the nutritive value of the *Peucedanum graveolens* incorporated *thalipeeth* was evaluated, we found a marginal increase in the dietary fiber content in comparison with the control. The iron content almost doubled in 8% *Peucedanum graveolens* incorporated *thalipeeth* in comparison to the control. A significant increase was seen in the calcium, total and β-carotene content of *thalipeeth* that were incorporated with dehydrated greens in comparison to the control. Similar observations have been reported by Kaveri *et al*. (2004) who incorporated dehydrated *Peucedanum graveolens* in wheat based *papads*. Mineral, vitamin and fiber content of greens incorporated *papads* increased remarkably. Ingestion of meals containing provitamin A rich carotenoids from yellow and green leafy vegetables improves the total-body vitamin A pool size and Hb concentration, and decreases anaemia rates in Filipino schoolchildren as reported by Maramag *et al*. (2010).

From the above observations, it can be concluded that dehydration seems to have little effect on the proximate, mineral and antinutrient content of the GLV. However, statistically significant lowering was seen for vitamin content of the GLV on dehydration. Sensory evaluation of products incorporated with different levels of dehydrated *Amaranthus paniculatus* and *Peucedanum graveolens* greens revealed that they could be incorporated in traditional products at lower levels of 4% with no detrimental effects on sensory quality. Addition of dehydrated greens increased the nutrient density of all products. Value addition of traditional products with dehydrated greens can be advocated as a feasible food based approach to combat micronutrient malnutrition.

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