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NUTRITIONAL COMPOSITION OF WILD-NON-TRADITIONAL VEGETABLES OF SINDH, UNDER DIFFERENT POSTHARVEST PROCESSING METHODS

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Abstract

The purpose of this study was to determine the nutritional quality of nontraditional (i.e. amaranthus, horse radish tree flowers, lambs quarter and gram leaves) and traditional (Spinach) vegetables in district Mirpurkhas, Sindh-Pakistan. The moisture content (92.66%) was highest in boiled spinach, followed by fresh samples (88.76%) of the same vegetable. The fat and ash content was highest (2.85 and 16.14 %) in thermally dehydrated amaranthus and similarly the carbohydrate content (69.06%) was higher in lambs quarter. The fiber content was higher (13.35%) in shade dried samples of horse radish tree flowers. The interactive effect of processing methods and vegetables revealed the highest mineral content in almost all the vegetables under thermal dehydration treatment over other treatments. There were also significant amounts of vitamins present in selected nontraditional vegetables. The fresh samples of spinach had the highest amount of β-carotene. Among water soluble vitamins, gram leaves had the highest amount of vitamin C and B1 and lambs quarter contained greater amount of Vitamin B2 and B3 in fresh samples. The present study, thus revealed that the nontraditional vegetables are rich source of nutrients and have great potential in providing balanced diet for rural dwellers as well as urban communities in Sindh, Pakistan.

Key words: Wild vegetables, Processing, Proximate, Vitamin, Minerals, Nutritional quality.

Introduction

Vegetables form a major portion of daily diet. The consumption of these vegetables help, not only to meet the dietary requirements but prevent nutrient deficiency at minimal cost (Ebert, 2014). Lack of fertile land, high cost of commercial vegetables and an ever-increasing population has led the rural dwellers to harvest nontraditional vegetables to meet the daily nutritional demand. This is also a source of income security, as poor people cannot afford the staple crops. About 350,000 different species of plants have been identified worldwide from which 80,000 are considered safe for consumption (Fuleky, 2016).

Micronutrient deficiencies are most common in developing countries of the world with monotonous, low quality diet vegetables round the year (FAO, 2013). Furthermore, the use of different chemicals in the form of pesticides, fertilizers and plant growth promoting regulators, has lost their original appearance, taste and quality (Sekeroglu *et al*., 2016).

In Pakistan, there are around 6000 known wild species having great dietary values and medicinal properties. These plants are extensively used in rural areas to treat diarrhea, skin, kidney, gastrointestinal and urinary problems (Hayat *et al*., 2008) and are associated to minimize the danger of many chronic diseases i.e. cancer, neurodegenerative, heart and respiratory ailments (Yahia, 2010), therefore, improve the mental and physical health status of consumers. These plants are wildly grown in forest without any chemical input. It is estimated that about 80% of the population depends upon these locally available wild vegetables as food (Khan, 2012) due to their low cost, availability in local areas (Sher *et al*., 2014, 2015) and yet the unique taste and color (Satter *et al*., 2016).

Despite of rich nutritive value (i.e. carbohydrate, protein, fat, minerals, vitamins and antioxidants) and high consumption, these vegetables are still not grown at commercial level. There is dire need to discover, revitalize and increase the awareness of different nontraditional vegetables to overcome the food insecurity issues, else the knowledge of these vegetables will soon vanish. Systematic studies are required to determine the nutritive and medicinal properties of these vegetables. This study was therefore planned to assess the nutritional value of nontraditional vegetables for human consumption and subsistence by local communities.

Materials and Methods

Sample collection: The nomenclature of nontraditional wild plants commonly utilized by rural dwellers was authenticated by plant botanists and reference books (Table 1). The voucher specimens of the plants were preserved at the Institute of Food Sciences and Technology, Sindh Agriculture University Tandojam. Identified vegetables i.e. amaranthus, horse radish tree flowers, lambs quarter, chickpea leaves and spinach were randomly hand-picked during January, and amaranthus during August from the cultivated and fellow lands of district Badin and Mirpurkhas. About 10 kg of each vegetable was packed in black plastic bag and transported on the same day to Institute of Food Sciences and Technology, Sindh Agriculture University Tandojam using ice chest boxes.

Table 1. Enumeration of selected vegetables.

Plant name	English name	Local name	Family	Position	Parts used	Status
Amaranthus viridis L.	Amaranthus	Mariro	*Amaranthaceae*	Leafy vegetable	Leaves	Wild
Cicer arietinum L.	Gram	Channa	*Fabaceae*	Leafy vegetable	Leaves	Cultivated as pulse crop, leaves under-utilized as vegetable
Chenopodium album L.	Lambs quarter	Jhil	*Chenopodiaceae*	Leafy vegetable	Leaves	Wild
Moringa oleifera L	Horse radish tree flowers	Suhanjhro	*Moringaceae*	Flower vegetable	Flowers	Wild
Spinasia oleraceae L.	Spinach	Palak	*Chenopodiaceae*	Leafy vegetable	Leaves	Cultivated

Table 2. Percentage non-edible and edible parts of the selected vegetables.

Vegetable names	Total weight	Weight of edible part	Weight of non-edible part	Percentage edible portion	Percentage non-edible portion
	------------------- kg	-------------------		----------------- %	-----------------
Spinach (*Spinacia oleracea*)	10	6.9	3.1	69	31
Amaranthus (*Amaranth Virdis*)	10	6.7	3.3	67	33
Horse radish tree flowers (*Moringa oleifera*)	10	6.3	3.7	63	37
Lambs quarter (*Chenopodium album*)	10	6.8	3.2	68	32
Gram leaves (*Cicer arietinum*)	10	6.1	3.9	61	39

Processing: The edible and nonedible parts were separated from each vegetable (Table 2). The separated parts were weighed and percent of each edible and inedible part was calculated by dividing the weight of respective part with whole weight, multiplied with 100. The inedible portions were discarded and edible portions were washed with tap water and repeatedly rinsed with distilled water. The remaining moisture content was evaporated by spreading the samples at room temperature (±25°C) in dark. The samples were then divided into four portions, one portion was packed as fresh (stored in deep freezer at -20°C). The remaining three portions were subjected to boiling, thermal dehydration and shade drying. Leaves were the only edible part of all the vegetables used for analysis, except in case of horse radish tree, where, the flowers formed the part of the edible portion. For boiling process, a 250 g quantity of each vegetable leaves/flowers was washed, chopped, placed in a 24×11.5 cm stainless steel pan and boiled (lid-on) in 500 ml water (700 ml for horse radish tree flowers), till tender (around 20 min). Further, the samples were cooled in air, sieved to discard the excess water, packed into sterilized glass jars and stored in deep freezer at -20°C. The thermal dehydration of samples was performed by separately placing the flowers and leaves in dehydration chamber at 60°C for 5 hours. For shade drying, the samples were spread on table top and left at ± 25°C until a constant weight was achieved. The dried leaves from each treatment were separately pulverized in a cyclone mill at 0.5 mm mesh size (UDY Corporation, USA) and stored in sterilized-airtight glass jars at ± 25°C in the dark.

Analytical Methods

Proximate analysis: Proximate analysis i.e. moisture, ash and fat contents were determined by AOAC (2000) and fiber content as given by Khalil and Durrani (1990). The moisture and ash contents were determined on the day of harvest. The crude fat was determined by using Soxhlet apparatus, followed by extraction of samples in petroleum-ether at 40-60°C boiling point. Nitrogen (N) content determined by Kjeldahl's method was used to calculate protein content with a conversion factor of 6.25 (AOAC, 1990). While, the carbohydrate content was determined by subtracting the sum of moisture, fat, protein, ash and fiber form 100. All the samples were run in triplicate.

Minerals: Minerals i.e. calcium (Ca), magnesium (Mg) potassium (K), sodium (Na), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) contents in leaf and flower samples were acid digested using nitric acid (HNO_3), sulphuric acid (H_2SO_4) and perchloric acid ($HClO_4$) mixture (5:1:0.1) (Allen, 1974). A 0.5 g sample quantity, along with 6.5 ml acid mixture was digested on hotplate, initially at 80°C and gradually increased to 250 °C till it turned into thick viscous material. After cooling, volume was raised to 20 ml using 0.2N nitric acid and the contents were filtered (Whatman No. 42) and run on atomic absorption spectrometer (Shimadzu AA-670, Japan). The instrument was calibrated by a series of standard solutions including a blank, prepared for each nutrient.

Vitamins: Vitamin A (β- Carotene) was determined as given by Horwitz (2000) and Thaifoods (2002). One gram of sample, 40 ml ethanol (C_2H_6O), 10 ml potassium hydroxide (KOH) and 10 ml of $C_6H_8O_6$ were taken into 250 ml brown bottle with round bottom and the contents were mixed after addition of each solution. After shaking on water bath at 80ºC for 30 minutes, the contents were cooled, 50 ml of hexane (C_6H_{14}) were added and shaken on orbital shaken for 5 minutes at 120 rpm. The flasks remained untouched until two layers appeared. The upper layer was carefully transferred into brown colored separating funnel of 250 ml. The sample was extracted 2 times with 40 ml of each C_2H_6O, KOH and $C_6H_8O_6$. The contents were shaken again and kept untouched till layers appeared. The lower layer was discarded and the remaining one was dried with N gas in rotatory evaporator and dissolved with 10 ml of methanol (CH_3OH). The sample was filtered through 0.45 μm membrane filter and collected into brown vials for HPLC analysis. Standard solution of β-carotene was prepared by taking 0.1 mg of β-carotene into 25 ml volumetric flask and volume was raised with hexane.

Vitamin B1 and B2 determinations were carried out as given by Fernando & Murphy (1990). A 5 g sample along with 65 ml of 0.1N hydrochloric acid (HCl) were placed in a conical flask, covered with aluminum foil and placed into autoclave for 30 minutes at 121°C. The sample was allowed to cool, autoclaved and pH was adjusted to 4. The contents in the flask (caped) were mixed and placed into water bath at 45°C for 4 hours. After cooling and transferring to volumetric flask, the volume was raised to 100 ml using deionized water. The samples were filtered by passing through filtration assembly with 0.45 µm pore size and packed into amber glass bottles for analysis on HPLC. Standard solution of B1 was prepared by dissolving 26.7 mg of thiamine hydrochloride ($C_{12}H_{18}C_{l2}N_4OS$) in 25 ml, while, B2 was prepared by dissolving 6.9 mg of riboflavin in 100 ml using distilled water.

Vitamin B3 was determined as given by Ward & Trenerry (1997). For this, 1g sample, 20 ml of deionized water and 0.75 g of calcium hydroxide [$Ca(OH)_2$] were placed in conical flask, covered with aluminum foil. The sample was autoclaved at 121°C for 2 hours, cooled, transferred to volumetric flask and the volume was raised to 50 ml using deionized water. The samples were centrifuged (2500 rpm) at 5°C for 15 minutes. A 15 ml of the supernatant was transferred to another centrifuge, pH was adjusted to 7 and volume was raised to 25 ml. The tubes were again centrifuged as described above. The cartridge series was made by connecting C18 Sep-Pak cartridge (500 mg) on top with 500 mg SCX cartridge with the help of column adaptor. The cartridges were conditioned by passing 10 ml of methanol followed by 10 ml of deionized water. The supernatant of about 10 ml was pipetted and passed through column, eluent was collected into test tube, evaporated with N gas and then 2 ml of deionized water added as final volume (Ward & Trenerry, 1997). Standard solution of B3 was prepared by dissolving 41.5 mg of nicotinamide ($C_6H_6N_2O$) in 25 ml of distilled water.

Vitamin C was determined by placing 2.5 g sample, along with 3% meta-phosphoric acid (HPO_3) solution to 100 ml volume. The sample was shaken on orbital shaker for 5 minutes at 150 rpm and placed into ultrasonic bath containing distilled water for 10 minutes. The solution was filtered through membrane filter with 0.45 µm pores (Lakshanasomya, 1998). For standard solution of vitamin C, 1 mg of ascorbic acid ($C_6H_8O_6$) was taken into 100 ml volumetric flask and final volume was raised with acid mixture (50:50) i.e. 0.3M HPO_3 and 1.4M acetic acid (CH_3COOH).

In all the cases, caution was taken as to prepare and store the stocks of vitamins into the dark at 20°C. The standards were run onto HPLC to note the retention time of each vitamin by injecting 20 µl of each standard (Aslam *et al*., 2008). Chromatographic analysis was carried out by using Supelco LC-18 column (250 mm x 4.6 mm ID), Supelco Park Bellefonte-USA. The mobile phases used were: CH_3OH with deionized water, acetonitrile (C_2H_3N) with CH_3OH and chloroform ($CHCl_3$) and potassium dihydrogen phosphate (KH_2PO_4) in orthophosphoric acid (H_3PO_4).

Statistical analysis

The data was subjected to a two-way analysis of variance (ANOVA) using two factors i.e. vegetables and processing methods (Steel & Torrie, 1980). In case of significant ANOVA, the comparison of means was calculated using least significant difference (LSD) at 5% probability level. Correlation analysis was performed to determine the relationship between each quality parameter of vegetables. Principal component analysis was performed to transform the measured variables into new uncorrelated variables using SPSS-16 (Berrueta *et al*., 2007).

Results and Discussion

Proximate analysis: The results of proximate analysis are presented in Table 3. Highest moisture content was observed in boiled samples of spinach (92.66%), horse radish tree flowers (86.26%), gram leaves (86.13%), lambs quarter (85.46%) and amaranthus (83.05%), while the lowest in thermally dried vegetables (8.62, 5.406, 4.93, 6.00 and 6.41 %), respectively. Moisture content of vegetables signifies the high value of food (AOAC, 1990), however, vegetables with high moisture content cannot be stored for longer duration due to bacterial attack during storage (Emebu & Anyika, 2011), deteriorating the quality. The results of present study are in agreement with the results given by Satter *et al*., (2016), who observed the moisture content in *Dhekishak* (90.37%), *Helencha* (87.60%), *Kalmishak* (90.12%), *Patshak* (86.81%) and *Shapla* stem (94.36%). Hanif *et al*., (2006) and Das *et al*., (2009) reported that green leafy vegetables had high moisture percentage. Similarly, Adnan *et al*., (2010) reported maximum moisture content in *Bupleurum falcatum, Forsskalea tenacissima, Lavendula angustifolia, Valeriana officinalis* and *Otostegia limbata*, which was similar to the values observed in this study. The ash content is actually the total mineral content present in the sample (Shukla *et al*., 2001). The data under Table 3 shows that the nontraditional vegetables are rich source of minerals. The average ash content of amaranthus, horse radish tree flowers, lambs quarter, spinach and gram leaves was in the range of 1.21-16.15, 0.51-8.68, 1.19-10.56, 2.01-10.42 and 1.23-9.51 %, respectively. Ash content of nontraditional edible vegetables is generally between 0.65 and 26.70 % (Demir, 2006; Tuncturk & Ozgokce, 2015), which is high when compared with ash content of commercial vegetables (Roe *et al*., 2013). This is in line with the ash content of traditional vegetables i.e. lettuce (0.40%) and spinach (0.70%) (Salazar *et al*., 2006) and nontraditional ones i.e. *Chancapiedra* (5.55%) Gafar *et al.*, (2011) testified *Telfairia occidentalis* (10.4%) and *Talinum triangulare* (8.85%) (Orhuamen *et al*., 2012).

The highest carbohydrate content (69.07%) was recorded in thermally dehydrated lambs quarter (Table 3). Whereas, the lowest values were found in spinach. The presence of high carbohydrate contents in nontraditional vegetables show their contribution as an energy source (Yirankinyuki *et al*., 2015) to fulfil the dietary requirements. Similar carbohydrate contents were reported (Imran *et al*., 2007) for triden (82.80%), sweet potato (75.00%) and spinach (54.20%).

Table 3. Proximate composition of different vegetables under postharvest processing methods.

Species	PM*	Moisture	Ash	Fat	Protein	Fiber	Carbohydrate
		%					
A	F	81.96 ± 0.30[g]	4.87 ± 0.17[g]	2.15 ± 0.18[def]	3.273 ± 0.06[i]	2.50 ± 0.22[c]	5.23 ± 0.66[def]
	B	83.05 ± 0.31[f]	1.21 ± 0.05[ij]	1.10 ± 0.22[ij]	2.293 ± 0.05[k]	1.70 ± 0.36[c]	10.64 ± 0.74[c]
	TD	6.41 ± 0.11[l]	16.14 ± 0.25[a]	2.85 ± 0.27[a]	5.180 ± 0.06[d]	9.86 ± 9.95[ab]	59.54 ± 9.62[b]
	SD	7.18 ± 0.15[k]	14.82 ± 0.94[b]	2.50 ± 0.30[abcd]	4.830 ± 0.03[ef]	10.48 ± 2.52[ab]	60.18 ± 2.07[b]
LQ	F	84.08 ± 0.72[e]	2.23 ± 0.06[h]	1.25 ± 0.27[hi]	4.760 ± 0.05[ef]	2.17 ± 0.10[c]	5.51 ± 0.61[def]
	B	85.46 ± 0.64[d]	1.18 ± 0.03[ij]	0.75 ± 0.18[j]	3.17 ± 0.05[i]	2.45 ± 0.99[c]	6.98 ± 0.50[cde]
	TD	6.00 ± 0.10[lm]	9.49 ± 0.05[d]	2.75 ± 0.18[ab]	4.306 ± 0.03[gh]	8.38 ± 0.10[b]	69.07 ± 0.19[a]
	SD	6.15 ± 0.12[lm]	10.56 ± 0.07[c]	2.40 ± 0.25[bcde]	4.043 ± 0.03[h]	10.50 ± 0.45[ab]	66.347 ± 0.63[a]
GL	F	82.28 ± 0.10[g]	2.35 ± 0.12[h]	2.35 ± 0.15[cde]	5.916 ± 0.05[de]	2.00 ± 0.18[c]	5.10 ± 0.35[ef]
	B	86.13 ± 0.13[c]	1.22 ± 0.06[ij]	1.85 ± 0.25[fg]	4.57 ± 0.08[fg]	1.03 ± 0.104[c]	5.19 ± 0.30[ef]
	TD	4.93 ± 0.36[o]	8.28 ± 0.27[e]	2.55 ± 0.18[abc]	7.560 ± 0.07[a]	9.00 ± 0.18[b]	67.67 ± 0.42[a]
	SD	5.88 ± 0.13[lmn]	9.50 ± 0.06[d]	2.40 ± 0.20[bcde]	4.917 ± 0.03[de]	10.15 ± 0.57[ab]	67.137 ± 0.42[a]
HRTF	F	80.98 ± 0.24[h]	0.50 ± 0.11[k]	2.40 ± 0.13[bcde]	4.746 ± 0.005[ef]	2.50 ± 0.21[c]	8.86 ± 0.17[cd]
	B	86.26 ± 0.54[c]	0.88 ± 0.08[jk]	1.90 ± 0.26[fg]	3.342 ± 0.105[i]	2.35 ± 0.95[c]	4.59 ± 0.56[ef]
	TD	5.407 ± 0.272[no]	7.75 ± 0.07[f]	2.70 ± 0.22[abc]	5.530 ± 0.05[c]	10.48 ± 0.32[ab]	68.127 ± 0.19[a]
	SD	5.840 ± 0.22[mn]	8.68 ± 0.08[e]	2.10 ± 0.22[ef]	4.283 ± 0.005[h]	13.35 ± 0.60[a]	65.747 ± 0.34[a]
S	F	88.76 ± 0.41[b]	2.01 ± 0.05[h]	1.60 ± 0.13[gh]	2.170 ± 0.51[k]	2.50 ± 0.27[c]	2.95 ± 0.49[f]
	B	92.66 ± 0.08[a]	1.46 ± 0.09[i]	0.85 ± 0.22[j]	1.041 ± 0.019[l]	1.55 ± 0.13[c]	2.44 ± 0.27[f]
	TD	8.62 ± 0.18[j]	9.22 ± 0.08[d]	2.70 ± 0.18[abc]	3.080 ± 0.31[ij]	8.68 ± 0.22[b]	67.69 ± 0.33[a]
	SD	9.83 ± 0.12[i]	10.42 ± 0.06[c]	2.65 ± 0.27[abc]	2.89 ± 0.31[j]	8.75 ± 0.25[b]	65.45 ± 0.51[a]

Species: A= Amaranthus, LQ= Lambs quarter, GL= Gram leaves, HRTF= Horse radish tree flowers, S= Spinach
PM*= Processing Methods: F= Fresh, B= Boiled, TD= Thermally dehydrated, SD= Shade dried
Means within columns and rows followed by same letters are not significantly different at 5% probability level

Fiber content in diet plays a vital role in preventing the risks of heart attack, overweight, colon cancer, serum cholesterol constipation and hypertension (Koca *et al.*, 2015). The shade dried horse radish tree flowers were found to have highest fiber content (13.35%) (Table 3). Similar fiber content (9.50- 12.12%) has been reported by Hussain *et al.,* (2010) in some nontraditional vegetables. Aberoumand (2012) reported fiber content of 8.00% in *Solanum indicum* plant species.

The highest protein content (7.56%) was observed in thermally dehydrated gram leaves and lowest (1.04%) in boiled spinach. These results show that vegetables, and nontraditional ones in particular can be consumed as source of protein, in order to prevent malnutrition (Satter *et al*., 2016). Barua *et al.,* (2015) reported similar protein content in *Zanthoxylum alatum (*10.94%), *Clerodendrum indicum* (7.88%) and *Gnetum gnemon (*6.70%). Fat content in the food is considered as main source of energy, however, vegetable diet with low fat is preferred and recommended for obese people (Barua *et al*., 2015). The fat content varied within small range, the highest values were observed in thermally dehydrated amaranthus (2.85%) and the lowest in majority of fresh vegetables i.e., horse radish tree flowers (2.40%), gram leaves (2.35%), amaranthus (2.15%) and lambs quarter (1.25%). Some wild vegetables of Nigeria (2.00%) and Pakistan (3.01%) had similar fat content (Nkafamiya *et al*., 2010; Khan *et al*., 2013). Yirankinyuki *et al.*, (2015) however, observed higher fat content (5.00%) in *Leptadenia hastata* leaves.

Minerals: Nontraditional leafy vegetables are delicious, refreshing and rich in minerals as they accumulate high amount of minerals from soil (Cobb *et al.*, 2000). The outcome of present study revealed that (Table 4) the thermally dried samples retained maximum mineral content over other treatments. Copper (21.66 mg $100g^{-1}$), Ca (1315 mg $100g^{-1}$), Na (1215 mg $100g^{-1}$) and K (1081 mg $100g^{-1}$) were highest in thermally dried lambs quarter and Fe (162.00 mg $100g^{-1}$), Zn (10.24 mg $100g^{-1}$), Mn (27.52 mg $100g^{-1}$) and Mg (1259 mg $100g^{-1}$) in thermally dried amaranthus. Human body cannot synthesize Cu. The main function of Cu is that it is important component of an enzyme which helps in the incorporation of Fe in red blood cells thereby prevent anaemia (Ihedioha & Okoye, 2011). Copper content was greater in thermally dehydrated sample of lambs quarter (21.66 mg 100 g^{-1}). Similar Cu content was reported by Gupta *et al.,* (2005) in some wild vegetables i.e. *Cocculus hirsutus, Boerhaavia diffusa*, *Centella asiatica* and *Delonix elata* and lowest in *Amaranthus tricolor* and *Commelina benghalensis*.

Iron content of fresh nontraditional vegetables presented in this study is similar to some wild green leafy vegetables of North-East India (6.97-22.73 mg $100g^{-1}$) and in Kano, Nigeria (21.30-33.40 mg $100g^{-1}$) (Saikia & Deka, 2013). Consumption of these vegetables will help to overcome Fe deficiency.

Zinc is an integral part of many enzymes in human body and plays catalytic, structural and regulatory roles. It is essential for normal growth, mental ability, immune system, reproduction and healthy function of the heart (Afolayan & Jimoh, 2009). Zinc content of fresh amaranthus (4.66 mg 100 g^{-1}) in present study compares favorably to Dhekishak (2.29 mg 100 g^{-1}) as reported by Satter *et al.,* (2016).

Table 4. Mineral content of different types of vegetables under the effect of postharvest processing methods.

Species	PM*	Cu	Fe	Zn	Mn	Ca	Mg	Na	K
		mg $100g^{-1}$							
A	F	8.14 ± 0.002^{l}	74.94 ± 0.04^{i}	4.66 ± 0.02^{j}	12.65 ± 0.02^{j}	488 ± 0.002^{o}	585 ± 0.004^{c}	492 ± 0.43^{m}	780 ± 0.04^{o}
	B	7.49 ± 0.003^{n}	74.44 ± 0.04^{j}	3.16 ± 0.02^{n}	11.15 ± 0.04^{k}	477 ± 0.02^{p}	485 ± 0.02^{f}	480 ± 0.06^{o}	768 ± 0.03^{p}
	TD	17.94 ± 0.03^{c}	161.7 ± 0.02^{a}	10.24 ± 0.02^{a}	27.52 ± 0.02^{a}	1048 ± 0.03^{d}	1259 ± 0.02^{a}	1105 ± 0.03^{e}	1067 ± 0.02^{c}
	SD	16.44 ± 0.04^{e}	153.7 ± 0.02^{b}	9.24 ± 0.02^{b}	25.02 ± 0.02^{b}	999 ± 0.02^{f}	1200 ± 0.02^{b}	1024 ± 0.05^{h}	989 ± 0.03^{f}
LQ	F	9.86 ± 0.02^{g}	62.74 ± 0.02^{l}	3.46 ± 0.03^{m}	10.83 ± 0.02^{l}	612 ± 0.43^{j}	126 ± 0.02^{s}	512 ± 0.43^{j}	829 ± 0.02^{k}
	B	11.61 ± 0.02^{f}	72.74 ± 0.02^{k}	3.66 ± 0.02^{l}	12.93 ± 0.02^{i}	611 ± 0.06^{k}	124 ± 0.02^{t}	510 ± 0.06^{k}	817 ± 0.01^{l}
	TD	21.66 ± 0.02^{a}	134.6 ± 0.02^{c}	7.86 ± 0.02^{c}	23.07 ± 0.004^{c}	1315 ± 0.03^{a}	270 ± 2.00^{l}	1215 ± 0.03^{a}	1081 ± 0.02^{a}
	SD	20.86 ± 0.02^{b}	128.1 ± 0.04^{d}	7.41 ± 0.04^{d}	22.07 ± 0.002^{c}	1254 ± 0.05^{b}	258 ± 1.00^{n}	1154 ± 0.05^{c}	998 ± 0.03^{f}
GL	F	4.35 ± 0.02^{p}	28.52 ± 0.05^{r}	2.86 ± 0.04^{o}	4.35 ± 0.03^{r}	294 ± 0.26^{s}	164 ± 0.43^{o}	500 ± 0.43^{m}	765 ± 0.02^{q}
	B	3.35 ± 0.04^{s}	27.52 ± 0.02^{s}	2.36 ± 0.02^{q}	3.05 ± 0.02^{s}	293 ± 0.02^{t}	163 ± 2.00^{p}	490 ± 0.006^{o}	754 ± 0.03^{s}
	TD	9.21 ± 0.03^{h}	61.79 ± 0.02^{m}	6.88 ± 0.02^{e}	9.82 ± 0.04^{m}	633 ± 0.02^{i}	367 ± 2.00^{g}	1115 ± 0.03^{d}	1040 ± 0.02^{d}
	SD	8.21 ± 0.04^{k}	58.79 ± 0.05^{o}	5.38 ± 0.06^{i}	8.32 ± 0.04^{o}	604 ± 0.02^{l}	336 ± 1.00^{h}	1054 ± 0.05^{g}	967 ± 0.04^{i}
HRTF	F	4.15 ± 0.03^{q}	39.38 ± 0.02^{p}	2.35 ± 0.03^{q}	6.55 ± 0.02^{p}	500 ± 0.03^{m}	272 ± 1.00^{j}	402 ± 0.43^{q}	762 ± 0.02^{r}
	B	3.45 ± 0.01^{r}	38.98 ± 2.00^{q}	1.85 ± 0.02^{r}	5.55 ± 0.04^{q}	499 ± 0.02^{n}	271 ± 0.07^{k}	400 ± 0.06^{r}	751 ± 0.02^{t}
	TD	8.25 ± 0.002^{j}	84.63 ± 0.03^{g}	5.52 ± 0.02^{g}	14.85 ± 0.04^{g}	1074 ± 0.04^{c}	584 ± 0.36^{d}	1095 ± 0.04^{f}	1035 ± 0.02^{e}
	SD	8.75 ± 0.004^{i}	80.13 ± 0.04^{h}	4.37 ± 0.02^{k}	13.34 ± 0.04^{h}	1024 ± 0.02^{e}	557 ± 1.00^{e}	1004 ± 0.05^{i}	942 ± 0.04^{j}
S	F	7.96 ± 0.002^{m}	59.3 ± 0.002^{n}	2.55 ± 0.03^{p}	8.84 ± 0.02^{n}	412 ± 0.26^{q}	131 ± 0.06^{q}	502 ± 0.43^{l}	796 ± 0.05^{m}
	B	7.11 ± 0.01^{o}	58.8 ± 0.005^{o}	1.55 ± 0.04^{s}	8.34 ± 0.04^{o}	411 ± 0.26^{r}	130 ± 0.04^{r}	500 ± 0.06^{m}	785 ± 0.04^{n}
	TD	17.8 ± 0.002^{d}	127.2 ± 0.04^{e}	5.45 ± 0.004^{h}	19.45 ± 0.004^{e}	886 ± 0.04^{g}	283 ± 1.00^{i}	1195 ± 0.04^{b}	1075 ± 0.03^{b}
	SD	16.42 ± 0.01^{e}	121.7 ± 0.04^{f}	5.95 ± 0.005^{f}	18.95 ± 0.004^{f}	845 ± 0.06^{h}	269 ± 0.28^{m}	1054 ± 0.05^{g}	993 ± 0.26^{g}

Species: A= Amaranthus, LQ= Lambs quarter, GL= Gram leaves, HRTF= Horse radish tree flowers, S= Spinach
PM*= Processing Methods: F= Fresh, B= Boiled, TD= Thermally dehydrated, SD= Shade dried
Means within columns and rows followed by same letters are not significantly different at 5% probability level

Table 5. Vitamin content of different types of vegetables under the effect of postharvest processing methods.

Species	Processing methods	Parameters				
		β-carotene	Vitamin C	Vitamin B1	Vitamin B2	Vitamin B3
		mg $100g^{-1}$				
A	F	3.28 ± 0.004^{e}	56.34 ± 0.04^{b}	0.027 ± 0.005^{gh}	0.017 ± 0.003^{jk}	0.738 ± 0.003^{cde}
	B	0.97 ± 0.004^{m}	25.98 ± 0.005^{k}	0.017 ± 0.0005^{h}	0.011 ± 0.0005^{k}	0.397 ± 0.005^{i}
	TD	1.01 ± 0.005^{l}	34.67 ± 0.004^{h}	0.018 ± 0.0003^{h}	0.013 ± 0.004^{jk}	0.416 ± 0.003^{i}
	SD	1.09 ± 0.004^{k}	37.57 ± 0.05^{f}	0.024 ± 0.0004^{h}	0.016 ± 0.0006^{ijk}	0.698 ± 0.002^{de}
LQ	F	3.46 ± 0.04^{c}	43.79 ± 0.007^{c}	0.170 ± 0.04^{b}	0.460 ± 0.04^{a}	1.500 ± 0.45^{a}
	B	3.07 ± 0.004^{f}	18.11 ± 0.004^{o}	0.120 ± 0.005^{d}	0.277 ± 0.004^{c}	0.696 ± 0.005^{de}
	TD	3.28 ± 0.005^{e}	22.13 ± 0.005^{l}	0.118 ± 0.002^{d}	0.290 ± 0.04^{bc}	0.850 ± 0.03^{cd}
	SD	3.33 ± 0.02^{d}	27.41 ± 0.005^{i}	0.133 ± 0.006^{cd}	0.309 ± 0.005^{b}	1.114 ± 0.003^{b}
GL	F	0.04 ± 0.005^{p}	60.74 ± 0.004^{a}	0.216 ± 0.004^{a}	0.074 ± 0.004^{fg}	0.665 ± 0.004^{e}
	B	0.01 ± 0.002^{q}	26.33 ± 0.004^{j}	0.120 ± 0.004^{d}	0.038 ± 0.0004^{ij}	0.425 ± 0.004^{i}
	TD	0.023 ± 0.005^{pq}	35.50 ± 0.004^{g}	0.144 ± 0.004^{bcd}	0.045 ± 0.005^{hi}	0.450 ± 0.04^{hi}
	SD	0.026 ± 0.003^{pq}	39.99 ± 0.004^{d}	0.206 ± 0.003^{a}	0.068 ± 0.0007^{gh}	0.629 ± 0.003^{efg}
HRTF	F	2.26 ± 0.04^{i}	6.73 ± 0.004^{q}	0.06 ± 0.04^{ef}	0.180 ± 0.03^{d}	0.880 ± 0.03^{c}
	B	0.55 ± 0.003^{o}	1.98 ± 0.005^{t}	0.038 ± 0.0005^{fgh}	0.101 ± 0.005^{ef}	0.619 ± 0.005^{efgh}
	TD	0.73 ± 0.04^{n}	3.34 ± 0.002^{s}	0.039 ± 0.004^{fgh}	0.115 ± 0.003^{e}	0.640 ± 0.04^{ef}
	SD	1.45 ± 0.005^{j}	3.79 ± 0.005^{r}	0.050 ± 0.0005^{efg}	0.174 ± 0.004^{d}	0.768 ± 0.002^{cde}
S	F	4.93 ± 0.006^{a}	37.95 ± 0.006^{e}	0.154 ± 0.004^{bc}	0.187 ± 0.004^{d}	0.724 ± 0.005^{cde}
	B	2.40 ± 0.003^{h}	12.14 ± 0.004^{p}	0.038 ± 0.0005^{fgh}	0.102 ± 0.003^{ef}	0.467 ± 0.005^{ghi}
	TD	2.81 ± 0.004^{g}	19.90 ± 0.004^{n}	0.054 ± 0.004^{efg}	0.124 ± 0.004^{e}	0.483 ± 0.005^{fghi}
	SD	3.46 ± 0.005^{b}	21.04 ± 0.026^{m}	0.071 ± 0.0005^{e}	0.171 ± 0.004^{d}	0.669 ± 0.006^{e}

Species: A= Amaranthus, LQ= Lambs quarter, GL= Gram leaves, HRTF= Horse radish tree flowers, S= Spinach
PM*= Processing Methods: F= Fresh, B= Boiled, TD= Thermally dehydrated, SD= Shade dried
Means within columns and rows followed by same letters are not significantly different at 5% probability level

The highest Mn value was found in the dried leaves of amaranthus (27.52 mg $100g^{-1}$). This element plays a significant role in the metabolism of fat, carbohydrate and protein and boosts the production of steroid sexual hormones (Saikia & Deka, 2013). Mineral analysis reveals that the leaves of thermally dried lambs quarter contained high amount of Ca content (1315 mg $100g^{-1}$). Comparatively, Gupta *et al.*, (2005) reported lower Ca contents in e *Amaranthus tricolor*-239, *Cucurbita maxima*-302, *Boerhaavia diffusa*-330 and *Digera arvensis*-506 mg $100g^{-1}$. This may be due to high calcareous nature of soils in the study area. Calcium has various functions in the body as it is present in extracellular fluid, blood and bone in large proportions and regulates normal functioning of cell permeability, milk clotting, blood coagulation and cardiac muscles (Indrayan *et al*., 2005).

Magnesium is a mineral element important for circulatory diseases like metabolism of Ca in bones and ischemic heart disease (Hassan & Umar, 2006). It maintains the normal functioning of muscles and nerves, supports a healthy immune system and also control blood glucose levels (Saikia & Deka, 2013). Magnesium content was highest in amaranthus (1259 mg $100g^{-1}$), followed by horse radish tree flowers (584 mg $100g^{-1}$), gram leaves (365 mg $100g^{-1}$), spinach (283 mg $100g^{-1}$) and lambs quarter (270 mg $100g^{-1}$) treated with thermal dehydration. *Echinops giganteus, Capsicum frutescens, Piper guineense* and *Piper umbellatum* of Cameroon had respective Mg content of 89, 254, 296 and 490 mg $100g^{-1}$ (Bouba *et al*., 2012).

Sodium content was 492, 512, 500, 402 and 502 mg $100g^{-1}$, respectively in fresh leaves of amaranthus, lambs quarter, gram leaves, horse radish tree flowers and spinach. Odhav *et al.*, (2007) reported highest Na content in *Oxygonum sinuatum* (1460 mg $100g^{-1}$) and lowest in *C. asiatica* (16 mg $100g^{-1}$). Potassium content of fresh vegetables (829 mg 100 g^{-1}) was much higher than that found in *Indigofera astragelina* leaves (14.55 mg 100 g^{-1}) (Gafar *et al*., 2011). Similarly, Seal *et al.*, (2017) also reported highest K content in *P. acinosa* leaves (73.72 mg g^{-1}) and lowest in *M. khasianus* fruit (13.74 mg g^{-1}). Potassium has diuretic nature and Na helps in transport of metabolites. Suitable Na/K ratio helps in preventing high blood pressure in human body (Saupi *et al*., 2009).

Vitamins: The vitamin analysis (Table 5) illustrated that fresh spinach had the highest β-carotene content. Among water soluble vitamins, gram leaves had highest amount of vitamin C and B1 and lambs quarter contained highest greater amount of Vitamin B2 and B3 in fresh samples. This is comparable with the results given by Bangash *et al.*, (2011). Highest thiamine (0.28 mg 100 g^{-1}), riboflavin (0.19 mg $100g^{-1}$), niacin (0.69 mg $100g^{-1}$) and ascorbic acid (65 mg 100 g^{-1}) content was found in garlic, pot purslane, spinach and bitter gourd, respectively. Gayathri *et al.*, (2004) reported that boiling of amaranthus (misbredie) species resulted in the greatest loss of beta-carotene. This could be due to oxidative destruction of beta-carotene as the leaves were chopped before cooking. Vitamin B2 are most stable but light sensitive and decreased in cooked vegetables as compared to the fresh ones. This was further confirmed by Schonfeldt & Pretorius (2011).

Table 6. Correlation matrix (r) of proximate composition of different vegetables under the influence of processing treatments.

	Moisture	Ash	Fiber	Fat	Carbohydrate
Moisture					
Ash	-0.90**				
Fiber	-0.87**	0.79**			
Fat	-0.11	0.01	0.03		
Carbohydrate	-0.99**	0.87**	0.83**	0.06	
Protein	-0.31**	0.21	0.24*	0.47**	0.26*

** = p<0.01; * = p<0.05, levels of significance

Vitamin C helps in the formation of folic acid derivatives, which are essential for synthesis of DNA and also prevent scurvy (Chatterjea & Shinde, 1998). Vitamin B Complex performs the major role in binding with enzymes, as prosthetic group like enzyme cofactors which in turn help enzymes to carry out their catalytic function. Vitamins are therefore, tightly bound to enzymes as part of prosthetic groups (Bolander, 2006). Water-soluble vitamins are more sensitive to light and heat; therefore, their reduced amount is obtained in boiled and dried samples.

Correlation matrix: The correlation matrix of proximate, mineral and vitamin content is presented under Tables 6-8. Table 6 showed that the moisture content was negatively associated with ash (r=-0.9), fiber (r=-0.87), carbohydrate (r=-0.99) and protein (r=-0.31) content. While, ash had positive and highly significant relationship with fiber (r=0.79) and carbohydrate (r=0.87) content. Similarly, fiber was positively correlated with carbohydrate (r=0.83) and protein (r=0.24); and so were the fat (r=0.47) and carbohydrate (r=0.26) with protein content. The relationship related to mineral analysis showed that all the minerals were significantly and positively associated with each other as indicated by "r" values (0.31-0.99) presented under Table 7. The vitamin analysis (Table 8) showed a significant and positive association of vitamin B3 with vitamin A (r=0.37), B1 (r=0.34) and B2 (r=0.76). Similarly, B2 was correlated with vitamin A (0.46) and B1 (0.40) and B1 with vitamin C.

Principal component analysis: A principal component analysis (PCA) was performed reducing the multidimensional structure of the data, which provided a three-dimensional map for explaining the observed variance (Fig. 1). The scree plot of the extracted components is depicted in (Fig. 2) in which the horizontal axis showed total number of components, where, values are plotted on vertical axis. Based on these values it can be concluded that the first four components are well enough to account for the variability in data. It is clear that first four components have eighteen values more than other components. The four components of the PCA explained 86.96% of the total variance (53.42% first, 14.38% second, 11.52% third and 7.64% fourth). Three-dimensional (3D) plot based on loadings revealed that the moisture and vitamin B1 belonged to the first principal component whereas ash, carbohydrate, fiber, fat, Ca, Na, Mg, K, Zn, Mn, Fe, Cu, vitamins i.e B2, B3, C and β-carotene belonged to second principal component.

Table 7. Correlation matrix (r) of mineral content of different vegetables under the influence of processing treatments.

	Cu	Fe	Zn	Mn	Ca	Mg	Na
Cu							
Fe	0.92**						
Zn	0.80**	0.86**					
Mn	0.92**	0.99**	0.87**				
Ca	0.83**	0.82**	0.77**	0.85**			
Mg	0.31*	0.61**	0.68**	0.61**	0.41**		
Na	0.75**	0.73**	0.81**	0.72**	0.82**	0.36**	
K	0.77**	0.75**	0.81**	0.75**	0.83**	0.37**	0.97**

** = p<0.01; * = p<0.05, levels of significance

Table 8. Correlation matrix (r) of vitamin content of different vegetables under the influence of processing treatments.

	Vitamin A	Vitamin C	Vitamin B1	Vitamin B2
Vitamin A				
Vitamin C	0.12			
Vitamin B_1	0.13	0.50**		
Vitamin B_2	0.46**	-0.08	0.40**	
Vitamin B_3	0.37**	0.21	0.34**	0.76**

** = p<0.01; * = p<0.05, levels of significance

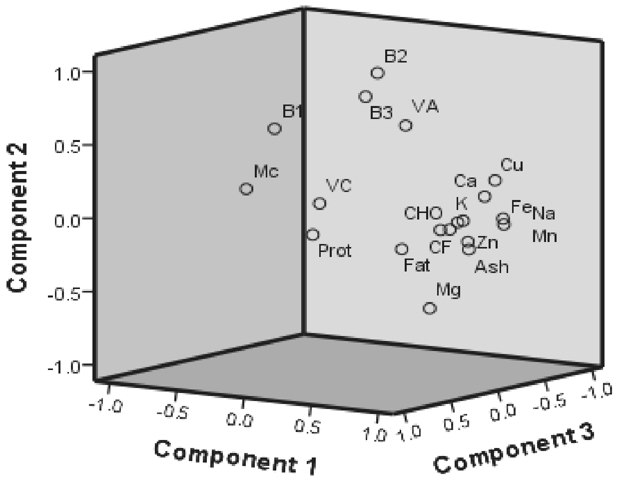

Fig. 1. 3D component plot of nutritional data of selected vegetables in rotated space.

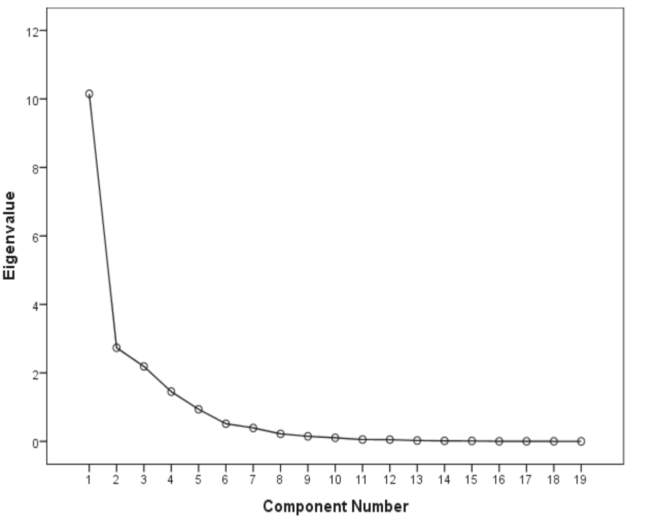

Fig. 2. Scree plot.

Conclusions

This study concludes that, the wildly grown nontraditional vegetables of district Mirpurkhas, Sindh-Pakistan were rich source of minerals with significant quantities of fat, vitamins, fiber, protein and carbohydrate content. In general, thermally dehydrated vegetables had the highest contents. Nutritional quality of nontraditional vegetables ranked lambs quarter > amaranthus > horse radish tree flowers > gram leaves > spinach. Hence, the utilization of these vegetables may be promoted in rural and urban communities to increase their consumption. Further, utilization of these vegetables in developing countries can reduce the common nutrient deficiencies and therefore bring positive health effects.

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