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Nutritional Assessment and Proximate Analysis of Selected Vegetables Grown in Larkana, Sindh, Pakistan

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Abstract: Food security and protection are the most crucial concerns worldwide. However, vegetables may significantly contribute to the macro and micro-nutrients for good health compared to dietary supplements. Eight vegetables of the Larkanadivision, namely spinach (*Spinacia oleracea*), brinjal (*Solanum melongina* L.), sponge gourd (*Luffa acutangula*), lotus root *(Lelumbo nucifera)*, okra (*Abelmoschus esculentus*), coriander leave *(Coriandrum sativum*), fenugreek leave (*Trigonella foenum graecum*), and cauliflower (*Brassica oleracea*) were studied for their proximate, macro and micro-mineral contents to estimate their importance in human nutrition. The results showed that almost all vegetables contain appreciable amounts of essential nutrients. All the vegetables showed moisture contents of >70.00%. Lotus and sponge gourd have a maximum level of carbohydrates (>10.00%). Fiber was found in the range of 2.70 – 5.10%, with the highest in the okra. Protein and fat were found at < 4.00%, with maximum protein in spinach and fat in fenugreek leaves. The studied vegetables showed maximum levels of K and Ca, followed by Na, Mg, Fe, Zn, and Cu while Cr and Mn were observed to be < 5.00 µg/g. The macro and micro-minerals in the studied vegetables were within the maximum permissible limits recommended by WHO. Moreover, the eight studied vegetables of the Larkana division can also provide up to 1.00% of the required dietary daily intake of macro and micro-nutrients as recommended by the Food and Nutrition Board.

Keywords: Vegetables, Larkana, proximate composition, minerals, daily intake, risk assessment.

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INTRODUCTION

Compared to other food products, vegetables are low-cost sources of energy. Vegetables are rich in essential nutrients comprising carbohydrates, protein, vitamins, calcium (Ca), iron (Fe), ascorbic acid, trace minerals, and phytochemicals (1). These vegetables provide energy and nutrients to human beings (2). Quality control and management are important aspects of food selection. Therefore, the national and international agencies, especially Food and Agricultural Organization (FAO) and the World Health Organization (WHO) have set the recommended levels for this nutrition in the food commodities for human beings (3). There are two types of essential nutrients that are required for a healthy life. The first one is the macronutrients, including water (moisture content), carbohydrates, fibers, fats, and proteins while the second is the micro-nutrients, including minerals (macro and micro minerals), vitamins, and phytochemicals (4). These macronutrients (carbohydrate, lipid, and protein) are instant and general sources of energy for humans and all other living organisms. However, ash and water only play a part in mass (5).

Furthermore, the vegetables contain macro minerals such as Ca, potassium (K), sodium (Na), and magnesium (Mg), as well as micro minerals such as Fe, copper (Cu), manganese (Mn), chromium (Cr), and zinc (Zn). Minerals are important because they significantly contribute to the several metabolic functions in living cells (6, 7).

Minerals can be conjugated proteins or bonded to other micromolecules, such as phosphates and polyphenols (8). These minerals can participate in several metabolic processes in living cells because they are constituents of several enzymes (9). Deficiencies in micro-nutrients have become a major health issue globally. These deficiency disorders lead to poor quality of life. The deficiencies may raise when people lack access to micronutrient-rich foods such as animal products, vegetables, fruits, and fortified foods, typically due to low dietary quality or a lack of dietary variety from several food groups (10, 11). The weakest groups usually suffering from micronutrient deficiencies are pregnant women, young children, and lactating women because of relatively higher micronutrient requirements, which are more susceptible to the harmful consequences of micronutrient deficiencies (12, 13). Macro-minerals (Na, K, Ca, and Mg) and chloride ions must be required to balance extracellular fluid for muscular irritability (4). Ca has a significant effect on growth. However, it has a negative impact on health and increases the risk of osteoporosis (14, 15). Fe and vitamin A deficiencies are the most prevalent forms of micro-nutrient malnutrition apart from Zn deficiency (16, 17). It has been reported that over 25% of the global population suffers from Fe deficiency, particularly in young women and children. Anemia is caused by insufficient consumption of Fe, leading to a decrease in red blood cells (RBCs) or hemoglobin. This may cause tiredness and fatigue, weakness, shortness of breath, and reduced exercise tolerance (18, 19). Similarly, Zn acts as a cofactor of various enzymes involved in gene expression, nucleic acid and amino acid metabolism, and cell replication (20). Moreover, the metabolism and bioavailability of essential vitamins (A and E) may also depend on the status of Zn (21). Cu is another important micro-mineral and assists Fe in being used in an early stage of hemopoiesis as well as essential for the neurologic and haematologic systems. Its deficiency may increase the content of Fe in the liver and vice versa (21, 22). Metabolism and reproductive function are only a few of the metabolic roles of Mn. It plays a role similar to an antioxidant, which protects cells from damage due to free radicals (23). Mn also plays an essential role in the regulation of cellular energy, bone and connective tissue growth, and blood clotting (24). Compared to dietary supplements, vegetables may contain large amounts of these macro and micro nutrients, which are necessary for optimal health (25). Based on the aforementioned facts, it is important to establish food composition data of macro and micro-nutrients in common vegetables in the Larkana region, which is required for nutritional planning and epidemiological studies.

The objective of this study is to establish the levels of macro-nutrients (moisture, ash, carbohydrates, fats, proteins, fiber), macro-minerals (Na, K, Ca, and Mg) and micro-minerals (Cr, Cu, Fe, Mn, and Zn) in local vegetables of Larkana division, Pakistan. The analytical characteristics such as precision and accuracy of methods for each element were studied in detail. Meanwhile, the obtained estimated daily dietary intake of each vegetable was compared with the recommended daily mineral requirements for adults. The contents of macro and micro-nutrients in vegetables were compared to literature reported values.

MATERIAL AND METHOD

Description of the study area

Larkana is located in the northwest part of Sindh (upper Sindh) on the right bank of the River Indus. Larkana district is split into four sub-divisions and 48 union councils for administrative purposes. The climate of Larkana is subtropical, with hot summers and freezing winters. It has an average temperature of 2 to 48 °C. The annual rainfall in the study area is more significant than 127 mm. The total population of this district is about 1.4 million, and 28.7% of the total population lives in urban areas. The coordinates of the research area 27°33′30′′ N and 68°12′40′′E are north of the Indus River and lie between North (6.41 km) and East (3.43 km), covering an area of 18.08 km^2. Larkana is famous due to the thousands of tons of quality production of Guava fruit. The weather permits the growth of various cereals and vegetable crops, including rice, wheat, tomato, cabbages, brinjal, okra, spinach, sponge gourd, coriander, fenugreek, lotus, onion and chilly, etc. grow in different villages of Larkana on the right bank of River Indus such as Gulab Bhutto, Goth Dodo, Shadan JatoiMahotta, Naudero, Chooharpur, Agani, Metla, Izzat Ji Wandh, Phulpota, and other villages.

Sampling of vegetables

During 2020–2021, fifty-seven samples of eight vegetables were collected randomly from Gulab Bhutto, Goth Dodo, Chooharpur, and ShadanJatoi villages of Larkana, Sindh, Pakistan. Vegetable samples include eight spinach (*Spinacia oleracea),* seven brinjals (*Solanum melongina. L*), eight sponge gourd (*Luffa acutangula*), ten lotus root *(Lelumbo nucifera*), eight okra (*Abelmoschus esculentus*), six coriander leaves (*Coriandrum sativum*), six fenugreek leaves (*Trigonella foenum graecum*), and four cauliflower (*Brassica oleracea*) were collected as shown in Table 1.

Table 1: List of studied vegetables with their English & local names family, scientific name, and edible parts.

English Names	Local name	Family	Botanical Names	Part used
Spinach	Palak	Amaranthacea	*Spinacia oleracea*	Leaves
Brinjal	Wagan	Solanaceae	*Solanum melongina* L.	Fruits
Spongiguord	Tore	Cucurbitae	*Luffa acutangula*	Fruits
Lotus root	Bahi	Nelumbonaceae	*Lelumbo nucifera*	Roots
Okra	Bhandi	Malvaceae	*Abelmoschus esculentus*	Fruits (pods)
Coriander leaves	Dhana	Apiaceae	*Coriandrum sativum*	Leaves
Fenugreek leaves	Hurbo	Fabaceae	*Trigonella foenum graecum*	Leaves
Cauliflower	Gobe	Brassicaceae	*Brassica oleracea*	Fruits

As reported by Kazi et al. (27), all-vegetable samples were returned to the lab, they were placed through a three-step washing procedure that included agitating and rinsing with distilled water. A freeze drier was used to dry the vegetables, as Khan et al. (26) briefly reported. The dried vegetable samples were pulverized in an agate mortar and sieved through a nylon sieve with a mesh size of 75 mm. Before standard procedure analysis, the final samples were maintained in a labeled polypropylene container at room temperature.

Reagents and glassware

During the experiment, high-purity water (conductivity 0.05 S/cm) was acquired from a Milli-Q purification system (Bedford, MA, USA). The concentrated reagents of Merck (Darmstadt, Germany) such as sulphuric acid (H_2SO_4), nitric acid (HNO_3), hydrochloric acid (HCl), hydrogen peroxide (H_2O_2), boric acid (H_3BO_3), copper sulphate ($CuSO_4$), and other analytical reagents, while acetone (C_3H_6O) and sodium hydroxide (NaOH) was purchased from Sigma Aldrich (St. Louis, MO, USA). The essential metals' typical working solutions (Ca, Cr, Cu, Fe, Mn, Mg, K, Na, and Zn) were freshly prepared by diluting recognized standard solutions of the respective element in a series of steps (1,000 mg/L) purchased from Fluka Kamica (Buchs, Switzerland) in 0.2 mol.L^{-1} HNO_3. The acid digestion method for metals in vegetables was validated using BCR-189 (wholemeal flour) and BCR-100 (beech leaves). Table 2 indicated that the method is quantitative for metals analysis by the AAS method, as reported earlier (28).

Apparatus

The analysis of Na, K, Ca, Mg, Cu, Fe, and Zn were determined by flame atomic absorption spectrometer (FAAS) of Hitachi (Tokyo, Japan) assembled with a hollow cathode lamp flame atomizer (air-acetylene). In contrast, Cr and Mn were measured using pyrocoated graphite tubes by graphite furnace atomic absorption spectrometer (GF-AAS). The instrumental conditions for measurement by both techniques were set according to the vendor's manual, as reported elsewhere (27). For digestion of vegetable samples, a hotplate (Heidolph MR Hei-Standard, Germany) was used. The hollow cathode lamps of Cr and Mn were used, working at 7.5 mA current, passing through a 1.3 and 0.4 nm spectral bandwidth for 357.9 and 279.5 nm, respectively. The heating program for Cr and Mn by GF was adjusted according to the manual for drying, ashing, atomization, and cleaning steps as temperature range °C/time (s) [(80-120/15), (300-700/15), (2600-2700/5), and (2700-2900/2)] and [(80-120/15), (400-500/15), (2400-2500/5), (2500-2800/5)], respectively. The acid digested and chemical modifier solutions (10 + 10 µL) were introduced directly into the GF. A deuterium lamp was used for background correction. Argon gas was used as a carrier gas with 200 mL.min^{-1} for each analysis.

The wavelengths, lamp currents, and spectral bandwidths for Na, K, Ca, Mg, Cr, Cu, Fe, Mn, and Zn were used as 589 nm, 10 mA, and 0.4 nm; 767 nm,10 mA, and 2.6nm, 423 nm,7.5 mA, and 2.6 nm; 285 nm,7.5 mA, and 2.6 nm; 357.9 nm, 7.5 mA, and 1.3 nm; 325 nm, 8.0 mA, and 1.3 nm; 248 nm,10 mA, and 0.2 nm; 279.5 nm, 7.5 mA, and 0.4 nm; and 214 nm, 7.55 mA, and 1.3 nm, respectively. The flame air pressure were set at 1.60 kg.cm^{-2} for all studied elements whilst the pressures of acetylene and height of burner for analysis of Na, K, Ca, Mg, Cu, Fe, and Zn are set as 0.20 kg.cm^{-2}, and 7.5 mm; 0.30 kg.cm^{-2}, and 7.5 mm; 0.40 kg.cm^{-2}, and 12.5 mm; 0.30 kg.cm^{-2}, and 7.5 mm; 0.20 kg.cm^{-2}, and 7.5 mm; 0.30 kg.cm^{-2}, and 7.5 mm; and 0.25 kg.cm^{-2}, and 7.5 mm, respectively.

Table 2: Analytical characteristics of conventional acid digestion method for essential metals by certified reference materials.

a. Certified reference material Wholemeal Flour BCR-189			
Metals	Certified / Estimated value	Obtained Values	Recovery(%)[a]
Cu	6.40±0.20	6.32±0.08	98.70
Mn	63.30±1.60	62.90±0.07	99.40
b. Certified reference material Beech leaves BCR-100			
Metals	Certified / Estimated value	Obtained Values	Recovery(%)[a]
Na	240.00	247±2.40	103.00
K	9940.00	9935±180.00	100.00
Ca	5300.00	5288±42.00	99.80
Mg	878.00	880±15.00	100.00
Cr	8.00	7.95±0.08	99.40
Fe	550.00	547±5.00	99.50
Zn	69.00	73.0±1.85	99.50

[a]Recovery % = Obtained / Certified/estimated × 100.

Procedures for Proximate Analysis

The term "proximate analysis of vegetables" refers to examining the entire content of a dietary component (29). The dried vegetables were analyzed for proximate composition, including moisture content, ash content, fats, protein, fiber, and carbohydrates. The proximate analysis of vegetables was performed at the laboratories of NCEAC, University of Sindh, Jamshoro. For the moisture, ash, protein, fat, fiber, and carbohydrate content of the vegetables, the Association of Official Analytical Chemists (30) procedures were used. Moisture content was determined using an AOAC method No. 930.15 reported by Iheanacho et al. (28). The standard methods No. 942.05, No. 984.13, No. 920.39, and No. 978-10 were used to estimate ash, protein, fat, and fiber content in vegetable samples, and total carbohydrates were determined by the difference method (100 - (proteins + fats + moisture + ash) as reported by Hussain et al. (31).

Conventional Wet Acid Digestion Methods

For minerals analyses, 0.5 g of vegetable samples in triplicate and 0.2 g of BCR-100 samples in separate conical flasks were treated with the concentrated 5 mL mixture of H_2O_2 and HNO_3 (1:2, v/v), initially for 30 min at ordinary temperature and then at 80 °C on an electric hotplate until the transparent semi-dried materials left. The digested vegetable samples were cooled at ordinary temperature and added 10 mL 0.2 N solution of HNO_3. The mixture solutions were filtered using filter paper (Whatman No. 42). Likewise, the same method was used for the preparation of blank samples.

Analytical Figure of Merit and Method Validation

The equations for the detection limit of the normal calibration curves of essential elements are given in Table 3.

Statistical Analysis

The calibration analyses and compilation of experimental data were performed by "*Excel*" 2010 (Microsoft Office ®). The significance of each statistical test was measured at $p< 0.05$. The assessment of the significant variation of elemental experimental data was tested by the student *t-test*.

Estimation of Daily Intake

The daily intake of macro and micronutrients in vegetables was calculated using adults' average vegetable consumption rate (g/day), followed by the formula given below as reported elsewhere (32).

$$DI = C_{\text{macro and micronutrients in vegetables}} \times AC$$

Where DI stands for daily intake of macronutrients (fiber, fat, protein, and carbohydrate) and micronutrients (Na, K, Ca, Mg, Cr, Cu, Fe, Mn, and Zn) in $g.day^{-1}$ or $mg.day^{-1}$ or $\mu g.day^{-1}$ from vegetables, C is the concentration of macronutrients in g/kg, micronutrients (macro-minerals Na, K, Ca, and Mg) in mg/kg and micro-minerals (Cr, Cu, Fe, Mn, and Zn) in $\mu g.kg^{-1)}$ in each vegetable, and AC is the average consumption of vegetable g/day. The AC of spinach, brinjal, sponge gourd, lotus root, okra, and cauliflower was estimated at 25 g/day based on their consumption of 1.0 kg for a family of four people in a week. In contrast, AC of coriander and fenugreek leaves was 5.00 $g.day^{-1}$ based on their 20.00 g application per day to prepare daily meals for a family of four-people.

Table 3: Slope and intercepts with linear regression lines of concentration versus absorption data of standard solutions of different elements.

Element	Dynamic Range ($\mu g.L^{-1}$)	Regression equation	R^2	LOD/LOQ ($\mu g.L^{-1}$)
Na	100-5000	$y = 0.363x - 2.9\times10^{-3}$	0.991	5.52/18.40
K	100-5000	$y = 0.143x - 5.0\times10^{-4}$	0.996	14.00/46.80
Ca	750-2000	$Y = 1.44\times10^{-2}x + 4.0\times10^{-4}$	0.999	164.00/547.00
Mg	100- 5000	$Y = 9.0\times10^{-4}x + 1.0\times10^{-3}$	0.998	2.46/8.21
Cu	100-1000	$y = 0.128x + 6.0\times10^{-5}$	0.997	17.30/57.70
Cr	50-500	$y = 5.0\times10^{-4}x + 2.3\times10^{-3}$	0.998	4.70/15.80
Fe	500 – 2000	$y = 3.2\times10^{-2}x - 4.0\times10^{-4}$	0.992	69.20/231.00
Mn	100-2000	$y = 0.138x + 2.0\times10^{-3}$	0.995	17.70/59.10
Zn	100-2000	$y = 0.199x + 4.0\times10^{-4}$	0.990	10.00/33.50

RESULTS AND DISCUSSION

The proximate analysis of all the vegetables depends on the source of water and soil used for their growth as reported by Naz et al. (33). The proximate analyses like moisture, ash, protein, fat, fiber, and carbohydrate contents in vegetable samples were measured and found to be significantly different from each other ($p < 0.05$), as listed in Table 4. Moisture content in vegetables is a good source of water and is necessary as it is considered that around 20% of the total water consumption must come from food moisture (34). The average moisture content holding capacities depended on the vegetables' nature and the environment (34). Moisture contents in spinach, brinjal, sponge gourd, lotus root, okra, coriander leaves, fenugreek leaves, and cauliflower were found in the range of 73.30 ± 0.10 – 87.50 ± 0.20% (Table 4). The highest moisture content was observed in brinjal (87.50 ± 0.20%), whereas the lowest was in lotus root (73.30 ± 0.10%). The high moisture content in vegetables (>73.00%) might be due to their water holding capacity, which may vary based on the available pose in leaves/fruit/stem as well as the size and length of xylem in each case. These moisture values in spinach, sponge gourd, coriander leaves, fenugreek leaves, and cauliflower aligned with FAO recommendations (60.00 – 90.00%) for the examined vegetables (29). The comparatively high moisture levels (>73.00%) in the examined vegetables indicated that the vegetables require special attention for proper preservation since they are prone to degradation (35). Similarly, the high moisture content may enhance the activity of water-soluble enzymes and co-enzymes participating in the metabolic processes (29). Similarly, ash content is also an essential biochemical parameter for all the nutritional ingredients, especially minerals, both micro and macronutrients, which are important for the body's normal physiological functions (36). Ash content in spinach, brinjal, sponge gourd, lotus root, okra, coriander leaves, fenugreek leaves, and cauliflower was found to be (3.07 ± 0.40, 4.37 ± 0.20,3.24 ± 0.30,1.66 ± 0.20,3.38 ± 0.10,4.12 ± 0.10,3.60 ± 0.20 and 2.10 ± 0.10%), respectively (Table 4). The lowest amount of ash content was observed in lotus root, whilst higher amount of ash was found in brinjal as compared to all the vegetables. These results suggest that these vegetables may be regarded as a good source of minerals when compared to grains and tubers (2 to 10%) as reported by Baloch et al. (37).

Table 4: Proximate analysis of vegetables collected from Larkana division.

Samples		Moisture (%)	Ash (%)	Fiber (%)	Total Fat (%)	Protein (%)	Carbohydrate (%)
Spinach	Mean ± SD	85.00± 0.34	3.07 ± 0.40	3.50± 0.10	0.85 ± 0.10	3.50± 0.40	8.03± 0.20
Brinjal	Mean ± SD	87.50 ± 0.20	4.37 ± 0.20	2.83 ±0.20	0.55 ± 0.10	1.55 ± 0.10	6.03 ±0.20
Spongi gourd	Mean ± SD	79.40± 0.10	3.24 ± 0.30	2.65±0.90	1.00 ± 0.20	0.82 ± 0.20	15.54 ± 0.40
Lotus root	Mean ± SD	73.30± 0.1	1.66 ± 0.20	5.50± 0.40	0.55 ± 0.40	1.74 ± 0.20	22.75± 0.55
Okra	Mean ± SD	79.40± 0.25	3.38 ± 0.10	5.60 ±0.70	1.50± 0.30	2.54 ± 0.50	13.63 ± 0.23
Coriander leaves	Mean ± SD	85.80± 0.10	4.12 ± 0.10	2.77± 0.20	1.25 ± 0.30	2.80± 0.40	5.98± 0.20
Fenugreek leaves	Mean ± SD	79.70± 0.18	3.60± 0.20	5.50±0.50	2.52 ± 0.40	1.94 ± 0.80	12.21 ± 0.20
Cauliflower	Mean ± SD	87.00± 0.11	2.10± 0.10	2.80± 0.10	0.80 ± 0.20	2.20± 0.10	15.24 ± 0.21

The crude fiber in spinach, brinjal, sponge gourd, lotus root, okra, coriander leaves, fenugreek leaves, and cauliflower were found to be 3.50 ± 0.10, 2.80 ± 0.20, 2.65 ± 0.95, 5.50 ± 0.40,5.60 ± 0.70, 2.77 ± 0.20, 5.50 ± 0.50, and 2.80 ± 0.10 %, respectively (Table 4). The resultant data shows that okra is the richest source of fiber as compared to other vegetables ($p < 0.05$), followed by lotus root (5.10–5.90%), whereas the least was observed in coriander leaves (2.75–2.80%). Furthermore, the high amount of crude fiber (9.00–26.00%) in these vegetables would be favorable for their active participation in controlling intestinal transportation and improving dietary bulk due to their capacity to absorb water (37). Fibers have the capability to lower cholesterol levels as well as smoothen intestinal functions (38). Fat content is very important from the nutritional point of view because 1 g of the lipid gives 9 kcal of energy. The fate contents in spinach, brinjal, sponge gourd, lotus root, okra, and coriander leaves, fenugreek leaves, and cauliflower were found to be 0.85 ± 0.10, 0.55 ± 0.10, 1.00 ± 0.20, 0.55 ± 0.40, 1.50 ± 0.30, 1.25 ± 0.30, 2.52 ± 0.40, and 0.80 ± 0.20 %, respectively. It was observed that fenugreek leaves have high fat contents (Table 4). The values obtained (0.51– 2.56 %) for fat in these vegetables endorsed the results of many authors, which showed that leafy and green vegetables are poor sources of fat, as reported by Nawab et al. (39). Moreover, it is significant to remember that a diet containing 1 – 2% of total caloric energy as fat is believed to be sufficient for humans. In contrast, excess fat consumption leads to cardiovascular diseases such as atherosclerosis, aging, and cancer (39). Thus, these green vegetables with low fat levels may benefit those suffering from obesity and other related disorders. Protein contents in spinach, brinjal, sponge gourd, lotus root, okra, coriander leaves, fenugreek leaves, and cauliflower are listed in Table 4. The current results indicated that spinach has high levels of protein (3.50 ± 0.40%) followed by coriander leaves (2.80 ± 0.40%) and okra (2.54 ± 0.50%). Thus, these three vegetables are a good source of protein to produce. At the same time, the lowest contents of protein were present in sponge gourd (0.82 ± 0.20%) followed by brinjal (1.55 ± 0.10%) and lotus root (1.74 ± 0.20%). These findings were in good agreement with those studies reported in the literature that indicated that leafy and green vegetables are poor protein sources (39). Thus, these vegetables may be helpful for those suffering from weight-related disorders due to the consumption of high energy foodstuffs. Carbohydrates are the primary source of energy in the body. The highest content of carbohydrates was obtained in lotus root (22.75 ± 0.55 %). Lotus root is one of the very famous vegetables in the traditional food of Sindhi culture as fried pakora (fritter) and lotus salad are delicious and yummy local food dishes. Whereas sponge gourd and okra were also rich sources of carbohydrates, containing > 7.00% in Table 4.

Daily Intake of Macronutrients

The daily intake (DI) of fiber, fat, protein, and carbohydrates from the studied vegetables by the local adult population are listed in Table 5. The higher DI of fiber was consumed from spinach (8.31 $g.day^{-1}$). In contrast, lower fiber consumption was observed from the fenugreek leaves (1.37 $g.day^{-1}$). The DI of carbohydrates was found to be higher from sponge gourd (9.38 g/day) whereas lower from cauliflower (1.04 $g.day^{-1}$). The studied vegetables contributed < 1.00% for the dietary DI of carbohydrates compared to the Food Nutritional Board value as reported by Shan et al. (40). Fiber is important because it reduces the risk of chronic disease; it also has gastrointestinal benefits for health. It has been observed that the local population acquires carbohydrates and fiber from each vegetable. The highest DI values of fat were observed from cauliflower (8.80 $g.day^{-1}$) and protein from okra (9.74 $g.day^{-1}$), while lower fat and protein were obtained from spinach (1.44 $g.day^{-1}$), (1.02 $g.day^{-1}$), respectively. Generally, the studied vegetables could contribute to a small portion of the dietary DI of fat and protein.

Table 5: Daily intake of macronutrients ($g.day^{-1}$) in vegetables of Larkana division.

Samples	Consumption	Fiber	Total Fat	Protein	Carbohydrate
Spinach	20	8.31	1.44	1.02	1.11
Brinjal	28	3.13	6.63	7.23	3.14
Spongi gourd	36	3.62	8.20	4.92	9.38
Lotus root	25	6.09	6.65	7.25	2.29
Okra	23	1.59	1.70	9.74	3.61
Coriander leaves	6	2.74	5.94	2.85	2.70
Fenugreek leaves	11	1.37	1.49	3.56	2.79
Cauliflower	18	4.11	8.80	6.60	1.04
RDA* ($g.day^{-1}$)			56	18	38

Mineral Content

Essential minerals like Ca, K, Na, and Mg may serve as structural components of tissues. These may have an active function in many cellular and basal metabolism as well as the control of water levels based on the acid-base balance (41). The concentrations of Na, K, Ca, and Mg in common vegetables are reported in Table 6. The levels of Na in the eight studied vegetables were observed in the range of (3.80 ± 0.40 – 10.90 ± 0.92) $mg.kg^{-1}$. The highest contents of Na were found in cauliflower (10.90 ± 0.92 $mg.kg^{-1}$) followed by sponge gourd (8.75 ± 0.46$mg.kg^{-1}$), lotus root (8.44 ± 0.20 $mg.kg^{-1}$), and brinjal (7.00 ± 0.12 $mg.kg^{-1}$). Thus, these vegetables may play an important role in fulfilling the daily dietary requirements of Na.

The reported content of Na in brinjal and okra was lower than in the reported study (31). However, the contents of Na in sponge guard, coriander (32) and okra (42) were significantly higher than the contents of Na in these vegetables. Potassium (K) is a major intracellular ion that generates electrical potentials in nervous tissues (43). The levels of K were observed in the studied vegetables in the range of (38.40 ± 0.40– 57.30 ± 0.10mg.kg^{-1}**)** Table.6 The highest contents of K were found in coriander leaves (57.30 ± 0.10 mg.kg^{-1}) and cauliflower (57.10 ± 0.10 mg.kg^{-1}), whereas the lowest contents of K were observed in spinach (30.20 ± 0.45 mg.kg^{-1}) and fenugreek leaves (33.60 ± 0.50 mg.kg^{-1}). Generally, the low level of K in humans may cause severe neurological dysfunctions (43). However, all studied vegetables have K levels greater than 30.20 ± 0.45 mg.kg^{-1}, indicating that the studied vegetables are enriched with K, which may lead to providing a sufficient amount of K to humans for their consumption. The levels of K in all studied vegetables were higher than the reported values of K in the literature (37, 44, 45). The Ca levels were observed in the studied vegetables (10.30 ± 0.40, 41.80± 0.50 mg.kg^{-1} (Table 6). The highest contents of Ca were observed in spinach (41.8 ± 0.5 mg.kg^{-1}), whereas the lowest was in okra (10.30 ± 0.40 mg.kg^{-1}).

Table 6: Macro minerals (mg.kg^{-1}) in vegetables of Larkana division.

Samples		**Na**	**K**	**Ca**	**Mg**
Spinach	Mean±SD	4.76±0.39	30.20±0.45	41.80±0.50	5.42±0.20
Brinjal	Mean±SD	7.00 ±0.12	39.00±0.50	29.90±0.40	8.63±0.10
Spongi gourd	Mean±SD	8.75 ±0.460	50.40±0.40	30.40±0.20	10.60±0.10
Lotus root	Mean±SD	8.44 ± 0.20	38.40±0.40	22.90±0.50	7.30±0.20
Okra	Mean±SD	6.60±0.11	42.30±0.10	10.30±0.40	9.89±0.30
Coriander leaves	Mean±SD	4.60 ±0.35	57.30± 0.10	23.50±0.30	16.94±0.80
Fenugreek leaves	Mean±SD	3.80 ±0.40	33.60±0.50	22.50±0.10	12.16±0.70
Cauliflower	Mean±SD	10.90±0.92	57.10±0.10	27.00±0.40	10.44±0.60

The current study revealed that the levels of Ca were higher in brinjal and okra as compared to the reported study (46). Similarly, the current study shows higher Ca in sponge gourd and coriander leaves (47). In contrast, lower Ca was observed in okra compared to the reported study (47), whereas (37) reported lower Ca in cauliflower compared to the current study. Similarly, the Ca levels in okra and coriander leaves were reported lower (35) than in the current study (Table 7).

The concentration of Mg was found in the range of (5.42 ± 0.20 – 16.94 ± 0.80 mg.kg^{-1}) in all the studied vegetables (Table 6). The highest contents of Mg were obtained in the coriander leaves (16.94 ± 0.80mg.kg^{-1}), and the lowest was found in the spinach (5.42 ± 0.20 mg.kg^{-1}). Mg plays a vital role in stabilizing the entire cellular polyphosphate compounds, primarily in the synthesis of DNA and RNA (45). However, the levels of Mg in brinjal, okra, coriander leaves, and cauliflower of the study area were higher than the reported levels of Mg in these vegetables (35, 37, 39) as listed in Table 7.

Daily Intake of Macronutrients

The DI of Na, K, Ca, and Mg from the studied vegetables by the local adult population are listed in Table 8. The higher DI of Na and K was consumed from fenugreek leaves at 6.97 and 6.16 (mg/kg bw/day), respectively. The maximum DI of Ca was estimated in the lotus root (9.54 mg.kg^{-1} bw.day^{-1}), and the highest DI of Mg was found in the sponge gourd (6.36 mg/kg bw/day). The lowest DI of Na, K, Ca, and Mg was observed (1.59, 1.01, 1.39, and 1.81 mg.kg^{-1} bw.day^{-1}), respectively, by consuming fenugreek leaves. The studied vegetables contributed < 1.00% to the daily dietary intake of Ca and Mg as compared to the food nutritional board (39).

Micro Minerals in Vegetables

Micro minerals are essential nutrients for the sustenance of human beings with a range of functions. They are incorporated into the structures of proteins, enzymes, and carbohydrates to participate in biochemical reactions. Cr complexes play a key role in the metabolism of carbohydrates and lipids, so the use of vegetables in our diet is a good source of Cr (43). The concentration of Cr was found in the range of 0.82–6.00 µg.kg^{-1} (Table 9). The highest content of Cr (5.60–6.00 µg.kg^{-1}) was observed in the sponge gourd, whereas the lowest concentration was observed in the cauliflower (0.82 –1.20 µg.kg^{-1}). The content of Cr in vegetables was compared with the reported values in the literature (Table 10a). The contents of Cr in spinach for study areas were higher than reported in the literature (33, 48). The Cr content reported by Islam et al.(36) in brinjal was slightly lower than in the current study. While the current study has lower Cr content in brinjal as compared to those reported by Ashraf et al. (38). Okra and coriander leaves showed higher contents of Cr than the reported studies (33, 38, 39, 43, 44, 48). Cauliflower collected from the study areas has higher contents of Cr, as reported by Hameed et al. (33). In contrast, it was comparable with those reported by Mahmood et al. (48) and lower than those reported by Perveen et al. (44). The contents of Cr in all studied vegetables were found to be within the WHO maximum permissible limit (30 µg.kg^{-1}) in vegetables. Cu is an essential component of many enzymes, therefore, it plays a significant role in different physiological processes like iron utilization, free radicals elimination, bone and connective tissue development, melanin production, and many others (4). The range of Cu in studied vegetables was (1.72-9.30 $\mu g.kg^{-1}$ (Table 9). The highest concentration of Cu was found in the cauliflower samples (7.50 – 9.30 $\mu g.kg^{-1}$), whereas the lowest was found in okra (1.72 – 2.30 $\mu g.kg^{-1}$). The Cu contents in spinach and brinjal were higher reported by ur Rehman et al. (49) than studied spinach and brinjal whereas lower was in cauliflower reported by (48). The current study has a higher concentration of Cu in spinach than in the reported literature (26, 33, 48, 41, 50). In brinjal and okra, Cu content reported in the literature (33, 36, 38, 41, 49) was higher than in the current study. Coriander leaves reported by (38) have a lower concentration than coriander leaves in the current study (Table 10a). It has been observed that the contents of Cu in all studied vegetables were within the WHO maximum permissible limit (50.00 $\mu g.kg^{-1}$). The Fe concentrations in the studied vegetables of Larkana division were between 2.70 and 11.30 $\mu g.kg^{-1}$ **(**Table 9). The highest contents of Fe were found in okra (11.10 $\mu g.kg^{-1}$) followed by spinach (7.45 $\mu g.kg^{-1}$), lotus root (6.99 $\mu g.kg^{-1}$), and sponge gourd (4.17 $\mu g.kg^{-1}$),whereas the lowest was found in coriander leaves (2.76 $\mu g.kg^{-1}$). Thus, these vegetables may be considered a good alternative to the supplementary source of Fe (46). The concentrations of Fe in spinach, brinjal, okra, and cauliflower were reported in the literature (26, 33, 38, 47, 49, 51) to be higher than the Fe contents in these studied vegetables. The contents of Fe were found in all the vegetables within the WHO maximum permissible limit (300.00 $\mu g.kg^{-1}$). However, the deficiency of Fe is very common in all types of physiological disorders (46). The concentration of Mn in studied vegetables was found in the range of 1.21–4.76 $\mu g.kg^{-1}$ (Table 9). The highest content of Mn was found in the fenugreek leaves (4.73 $\mu g.kg^{-1}$) and the lowest was found in the lotus root (1.23 $\mu g.kg^{-1}$). The resulting data showed that Mn contents in the studied vegetables were within the WHO maximum permissible limit (100.00 $\mu g.kg^{-1}$). The contents of Mn in spinach, cauliflower, brinjal, and okra in the literature (38, 47, 49, 50, 51) were higher than the current study in these vegetables of Larkana (Table 10b). Zn is an essential element and plays an important role in hormonal growth. The concentration of Zn in the vegetables of the Larkana was found in the range of (1.95 – 4.83) $\mu g.kg^{-1}$ (Table 9). In the present study, the highest content of Zn were observed in spinach (4.68 $\mu g.kg^{-1}$), whereas the lowest was found in the lotus root (2.07 $\mu g.kg^{-1}$). Studied vegetables have Zn levels within the permissible limit recommended by WHO (100.00 $\mu g.kg^{-1}$). The levels of Zn in spinach and cauliflower reported in the literature (26, 45, 59) were lower as compared to currently studied vegetables reported by Akhtar et al. (45). There were lower Zn values in fenugreek leaves than those from Larkana (Table 10b).

Similarly, the concentrations of Zn in spinach were reported to be higher (39, 41, 50, 51) than in the currently studied spinach. In the studied vegetables, brinjal has a lower concentration of Zn as compared to the reported literature (36, 38). On the other hand, okra (38, 39, 41) and cauliflower (41, 47) were higher in the same studied vegetables of Larkana divisions listed in Table 10b. However, the variations in levels of micro minerals might be due to the uptake of these elements from the soil, irrigation water, geochemical, or geographical/climatic changes in native countries.

Table 8: Daily intake of macro minerals from the studied vegetables by the local adult population.

	Consumption ($g . day^{-1}$)	**$mg.kg^{-1}bw.day^{-1}$**			
Samples		**Na**	**K**	**Ca**	**Mg**
Spinach	20	1.59	1.01	1.39	1.81
Brinjal	28	3.27	1.82	1.40	4.03
Spongi gourd	36	5.25	3.02	1.82	6.36
Lotus root	25	3.52	1.60	9.54	3.04
Okra	23	2.53	1.62	3.95	3.79
Coriander leaves	6	4.60	5.73	2.35	1.69
Fenugreek leaves	11	6.97	6.16	4.13	2.23
Cauliflower	18	3.27	1.71	8.10	3.13
RDA ($mg.day^{-1}$)		1300 – 1500	1000 – 1200	300 – 3500	

Daily Intake of Macro and Micro Minerals

The DI of Cr, Cu, Fe, Mn, and Zn from the studied vegetables of Larkana division by the local adult population are listed in Table 11. The highest DI of Cr and Cu were observed at 9.33 and 8.56 $\mu g.kg^{-1}$ $bw.day^{-1}$, respectively, by the consumption of spinach and fenugreek leaves, while the highest DI of Fe, Mn, and Zn were observed (8.37, 8.67, and 1.69 $\mu g.kg^{-1}$ $bw.day^{-1}$) by the consumption of fenugreek and okra, respectively. Fenugreek leaves showed the lowest DI of Cr, and Cu, while coriander leaves have the lowest DI of Fe, Mn, and Zn, as listed in Table 11. However, these eight vegetables of the Larkana division can also provide up to 1% of the required dietary daily intake of micro minerals recommended by FNB (FNB 2002).

Table 9: Micro minerals (µg.kg^{-1}) in vegetables of Larkana division.

Samples		Cr	Cu	Fe	Mn	Zn
Spinach	Mean±SD	2.80±0.20	4.66±0.40	7.45±0.80	2.49±0.14	4.68±0.20
Brinjal	Mean±SD	1.30±0.40	2.70±0.20	3.43±0.40	3.07±0.11	3.23±0.10
Spongi gourd	Mean±SD	5.80±0.20	3.70±0.30	4.17±0.60	3.36±0.30	2.74±0.20
Lotus root	Mean±SD	1.30±0.30	7.20±0.40	6.99±0.90	1.23±0.20	2.07±0.12
Okra	Mean±SD	3.44±0.20	2.00±0.30	11.1±0.20	1.81±0.80	4.41±0.16
Coriander leaves	Mean±SD	2.67±0.70	5.62±0.60	2.76 ±0.15	3.27±0.21	2.10±0.90
Fenugreek leaves	Mean±SD	1.61±0.21	4.67±0.40	3.77±0.30	4.73±0.30	3.52±0.20
Cauliflower	Mean±SD	1.00±0.20	8.41±0.90	2.79±0.90	1.37±0.40	2.54±0.90
WHO permissible levels		30.00	50.00	300.00	100.00	100 .00

Table 10a: Comparison of Cu (µg.kg^{-1}) in common vegetables with literature.

Vegetables	Current study	26	33	38	41	50	36	49	48
Spinach	4.66	0.02	0.19	0.44	0.03	0.17	-	8.48	-
Brinjal	2.70	-	-	-	10.23	-	17.04	3.18	-
Spongi gourd	3.70	-	-	-	-	-	-	-	-
Lotus root	7.20	-	-	-	-	-	-	-	-
Okra	2.04	-	5.34	3.91	13.65	-	-	-	-
Coriander leaves	5.62	-	-	1.65	-	-	-	-	-
Fenugreek leaves	4.67	-	-	-	-	-	-	-	-
Cauliflower	8.41	-	-	-	-	-	-	4.58	1.19

Table 10b: Comparison of Cr (µg.kg^{-1}) in common vegetables with literature.

Vegetables	Current study	33	48	36	39	44	38	43
Spinach	2.80	0.56	0.91	-	-	-	-	-
Brinjal	1.03	-	-	1.02	-	-	2.36	-
Spongi gourd	5.37	-	-	-	-	-	-	-
Lotus root	1.19	-	-	-	-	-	-	-
Okra	3.44	0.71	-	-	2.37	-	1.56	2.23
Coriander leaves	2.67	-	1.40	-	-	1.52	-	-
Fenugreek leaves	1.61	-	-	-	-	-	-	-
Cauliflower	1.00	0.61	0.99	-	-	1.24	-	-

Table 7: Comparison of macro minerals (mg.kg^{-1}) in common vegetables with literature.

	Na				K				Ca					Mg			
Vegetables	**Curr. study**	**(31)**	**(32)**	**(42)**	**Curr. study**	**(37)**	**(44)**	**(45)**	**Curr. study**	**(46)**	**(47)**	**(35)**	**(37)**	**Curr. study**	**(35)**	**(37)**	**(39)**
Spinach	4.76	-	-	-	30.2	-	-	-	41.8	-	-	-	-	5.42	-	-	-
Brinjal	7.00	0.2	-	-	39.0	-	-	2.4	29.9	0.14	-	-	-	8.63	0.14	-	-
Spongi gourd	8.75	-	55.5	-	50.4	-	-	-	30.4	-	10.5	-	-	10.6	-	-	-
Lotus root	8.44	-	-	-	38.4	-	-	-	22.9	-	-	-	-	7.30	-	-	-
Okra	6.60	0.63	-	42	42.3	-	1.7	2.52	10.3	0.75	11.9	6.4	-	9.89	7.51	3.0	-
Coriander leaves	4.60	-	39.5	-	57.3	-	1.62	-	23.5	-	12.7	6.6	-	16.94	-	5.2	-
Fenugreek leaves	3.80	-	-	-	33.6	-	-	-	22.5	-	-	-	-	12.16	-	-	-
Cauliflower	10.9	-	-	-	57.1	73.9	-	-	27	-	-	-	3.8	10.44	-	-	1.13

Table 10c: Comparison of Fe (μg.kg^{-1}) in common vegetables with literature.

Vegetables	Current study	26	33	38	51	47	49
Spinach	7.45	71	179	58.1	60	-	69.7
Brinjal	3.43	-	-	-	98.3	-	-
Spongi gourd	4.17	-	-	-	-	-	-
Lotus root	6.99	-	-	-	-	-	-
Okra	11.1	-	123	-	94.3	13.4	-
Coriander leaves	2.79	-	-	-	-	-	-
Fenugreek leaves	3.77	-	-	-	-	-	-
Cauliflower	2.79	48	117	-	-	52.4	-

CONCLUSION

This research illustrated the significance of plant species, especially vegetables used in the daily diet. The studies on these vegetables indicated that all of them could provide essential nutrients to human beings. Coriander leaves, lotus roots were envisaged as good sources of fibers and carbohydrates. These vegetable species were also significantly helpful in terms of elemental resources, mainly Na, K, Ca, Mg, Cr, Cu, Fe, Mn, and Zn levels. Hence, elemental toxicity in the vegetables, which is lethal, is well below WHO standards. Moreover, the macro and micro minerals in studied vegetables were comparable with the literature reported on the same vegetables in different areas of Pakistan and other countries. This study indicated that the vegetables of Larkana have an excellent profile of studied macro and micro-nutrients and equally contribute to providing these nutrients to the local population.

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