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RESEARCH ARTICLE

Nutritional and mineral composition analysis of desert plants: A case study

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ABSTRACT

The wild arid and semi-arid plants of desert are used as food and medicine by the people of Desert. In this case study, selected plants were characterized physico-chemically for their nutritional and mineral importance by different analytical methods. Analysis showed that crude fibers and protein dominated in plant samples among all nutrients with an average concentration of 38% and 21% respectively. The edible parts of plants generally showed higher concentration of Ca and Mg as compared to Na and K. *Calligonum polygonoides* found comparatively rich in total sugars and ash contents. Similarly, crude fibers (45%), crude lipids (16%) and phosphorous (32 ppm) were observed higher in *Leptadenia pyrotechnica*. However, *Prosopis cineraria* contained higher contents of moisture and protein (24%) among other plants. The statistical presentation by discrimination analysis showed that arid plant found rich in most of the nutrients and minerals except phosphorous and proteins as compared to semi-arid plants with relatively higher moisture contents.

Keywords: Desert; Minerals; Nutritional analysis; Sugars; Proteins; Vegetables.

INTRODUCTION

Most of population in the deserts of south Asia is still living under hard environmental and economic condition. Due to the deficiency of fast transportation, allopathic medicine, infrastructure and qualified personnel, the populations of desert areas in South Asia rely almost solely to wildly grown traditional herbs which are also used as vegetables in these regions. The Great Indian Desert is one of the largest deserts (200,000 km^2) of the word, located between India and Pakistan. A large population of these deserts are subsistence farmers and nomadic tribes which are dependent on the wild grown raw plants for nutrition and treatment of common diseases (Akbar et al., 1996). These plants provide food, fiber, medicines and shelter material to the inhabitants (Arshad et al., 2002). Among these plants, *Calligonum polygonoides*, *Leptadenia pyrotechanica*, *Capparis decidua*,and *Prosopis cineraria* are of fundamental importance due to their abundance and versatile use.

Calligonum polygonoides and *Leptadenia pyrotechanica* are dominantly found in arid areas of desert ecosystem (Vyas et al., 2012). The flower buds of *Calligonum polygonoides* are effectively used for sunstroke treatment and the aqueous paste of stem acts as an antidote against the heavy doses of opium and also against the poisonous effects of certain harmful plants (Singh et al., 1996). *Leptadenia pyrotechanica* is used for relieving pain and inflammation, as well as in a number of metabolic disorders such as diabetes and obesity (Rekha et al., 2013). On the other hand, *Capparis decidua* and *Prosopis cineraria* are semi-arid plants of desert. *Capparis decidua* is a multipurpose woody shrub whose bark and roots has been used in the treatment of cough, fever, asthma and inflammation(Joseph and Jini, 2011).Similarly,

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Prosopis cineraria is used as a safeguard against miscarriage during pregnancy (Velmurugan et al., 2010).

Nutrients, such as proteins, sugars and lipid are the essential components of these medicinal plants which are used as vegetables in this region. Nutrients deficiencies is regarded as a major public health problem in many developing countries especially in desert areas, with infants and pregnant women are more prone to risk (Batra and Seth, 2002). Similarly, the significance of the mineral elements in animals and plants cannot be overemphasized due to their medicinal importance, and their presence in animal feed is vital for normal metabolic processes (Soetan et al., 2010). However, the excessive dietary up take of metals can be carcinogenic and cause serious health problems (Luo et al., 2011). Thus, there is a narrow range between toxic and required concentration of metals (Ražić et al., 2006). WHO & FAO recommended calcium is 1000mg/day, but its high intake can cause calcium salt precipitation in renal tissues (calcification). Also high sodium intake (<2g/day) leads to higher risk of cardiovascular disorders, fatal stoke & coronary heart diseases and high blood pressure (FAO, 1962; WHO, 2012). So far, no systematic study is made for the determination of nutrients and mineral contents of these plants according to our knowledge. Thus, keeping in view the public health concern and nutritional role of these wildly grown plants of arid and semi-arid regions of the Great Indian Desert, the present study was carried out with objectives of determining nutrients (such as proteins, crude lipids, crude fibers, total sugars, reducing sugars and moisture contents) and mineral contents (such as Na, K, Ca, Mg and PO_4) of these plants used as vegetables. The work will provide baseline information for future research on these plants. The official and literature methods will be utilized for the characterization of these plants.

MATERIAL AND METHODS

Sample collection

Four wild plants (Table 1) were collected from the arid and semi-arid areas of Cholistan, an extension of the Great Indian Desert located in Pakistan. Non-edible parts such as small leaves, branches, thorns or any visible dirt were removed, and rest of the plant was washed with distilled water. Plant parts were dried under shade, then ground to a fine powder which was directly used for further analyses.

Reagents and standards

All the reagents used in this study like: ethanol, hydrochloric acid and nitric acid, were of analytical grade and procured from Merck, Schuchardt, Germany. Standard solutions of metals (Na, K, Mg, and Ca) were obtained from commercially available mono element solutions (Merck, Schuchardt, Germany). All solutions were prepared in ultra-pure water.

Determination of mineral contents

With little modifications, pre described methods were followed for the determination of mineral contents. i.e. moisture and ash contents were recorded by the procedures of AOAC and Morrison respectively (Morrison et al., 1959; AOAC, 2000).While quantification of Na, K, Mg and Ca was done according to previous methods (Kment et al., 2005; Haider et al., 2014b). Also spectrophotometric determination of phosphorus was carried by following Bhargava and Raghupathi (Bhargava and Raghupathi, 1995).

Determination of nutrients

The estimation of crude fibers were also carried out by the AOAC procedure (AOAC., 2000), while Kjeldahl method was designed for the analysis of N-terminal i.e., nitrogen contents of the plant samples (Kjeldahl, 1883). Followed by the determination of protein (Sila et al., 2012). Lipids, reducing and total sugars were estimated by adopting standard procedures (Lindsay, 1973; Sawhney and Singh, 2000; Chow and Landhäusser, 2004; Haider et al., 2014b). An "ultrospec 1100 pro" spectrophotometer from Amersham Biosciences was used in all experiments for the measurement of absorbance in UV/visible region. To ensure the reproducibility of obtaining data, all the experiments were performed in triplicate.

Statistical analyses

The quantitative data of mineral contents and nutrients was presented statistically by different techniques. The XLSTAT Version 2013.5.08 (AddinsoftTM) was used for the comparative distribution of the nutrients in all plant samples by a box whisker plot(Abbasi et al., 2013). The samples from arid and semi-arid region were discriminated by PLS-DA according to their nutrients and mineral contents. The model was developed to separate the samples (classes) on the basis of X variables (minerals and nutrient contents) by SIMCA-P software (UMETRICS). The weigh

Table 1: Description of plants and their utilized parts

Source	Scientific name	Family	Common name	Edible part used
Arid	*Calligonum polygonoides*	*Polygonaceae*	Phog	Floral buds
Arid	*Leptadenia pyrotechanica*	*Asclepiadaceae*	Khip	Immature green pods
Semi-arid	*Capparis decidua*	*Capparidaceae*	Karir	Floral buds and flowers
Semi-arid	*Prosopis cineraria*	*Mimosaceae*	Syngrian	Immature green pods

plot of PLS-DA shows the contribution of each variable towards discrimination (Eriksson et al., 2001;Haider et al., 2014a). Cluster analysis is a multivariate method that was utilized to study the differences or similarities among the samples and it was presented by a dendrogram (Patras et al., 2011).

RESULTS AND DISCUSSION

Mineral contents

Ash contents of the plants were obtained in order to estimate the mineral contents (Table 2). Highest value (10%) of ash contents was observed in the floral buds of *C. polygonoides,* while immature green pods of *P. cineraria* showed the lowest one (5%). Highest and lowest ash contents were attributed to arid and semi-arid plants respectively. The richest source of sodium was immature green pods of *L. pyrotechnica*, followed by in immature pods of *P. cineraria* (Table 3 and Fig. 1). The lowest concentration (370ppm) was found in *C. decidua*. Minerals are of critical importance in the diet, even though they comprise of 4-6% of the human body. The minerals served as structural components of tissues and function in cellular and basal metabolism, water and acid-base balance (Humphry et al., 1993). Sodium is the major component of the cations of extra cellular fluid. As indicated in Table 3, *L. pyrotechnica* is rich in sodium contents which establish its use to control the acid-base balance in the body. The lower amount of sodium in other plants may be attributed to the plant nutrition, soil conditions and climate (Hamurcu et al., 2010). Potassium forms an average of 0.095% of plant material from desert. The highest value of potassium i.e. 1150 ppm was recorded in *C. decidua*; while, lowest one i.e. 580 ppm was found in *P. cineraria*. Potassium is present in blood plasma of human beings and controls the osmotic pressure including water retention (Hamurcu et al., 2010). Therefore, floral buds and flowers of *C. decidua* can be more effective to normalize the blood pressure due to higher level of potassium in these parts. The low amount of potassium in other studied plants can be associated with the nature of plant and storage deficiency of this mineral in them.

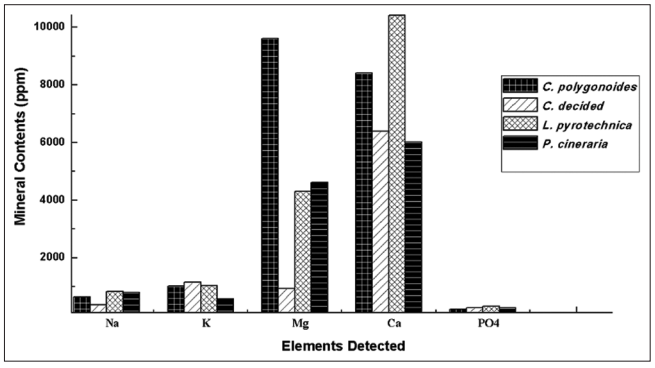

Fig 1. Metals concentration in different plant samples (ppm).

The calcium profile of plant samples of desert revealed that immature green pods of *L. pyrotechnica* contained comparatively high levels (10420 ppm) of calcium followed by *C. polygonoidesi.e.*8410 ppm (Table 3 and Fig. 1). The lowest concentration of calcium was estimated in immature green pods of *P. cineraria* (6010 ppm) which is a semi-arid plant. The concentration of magnesium in the wild plant parts oscillated between 930-9610 ppm. However intermediate concentrations were observed for *P. cineraria* and *L. pyrotecnica* (4620 & 4310 ppm respectively). Calcium plays an important role as factor IV in the blood clotting mechanism, also its deficiency causes osteoporosis and magnesium is an essential activator for all enzymes, which transfer phosphate from adenosine triphosphate to adenosine diphosphate (Harvey and Ferrier, 2010). Normally, there is no magnesium deficiency in the body. However, renal failure and alcoholism may lead to magnesium deficiency, which may cause gross muscular tremor, hallucination, depression and spasmophilia (Harvey and Ferrier, 2010). The results of this study indicate that the studied plant samples of desert are rich in both magnesium and calcium, which further enhances their medicinal use. The arid desert plants such as, *C. polygonoides* and *L. pyrotechnica* can be used to control the deficiency of magnesium and calcium respectively due to the higher available amount of these minerals. Similarly, the highest concentration (320 ppm) of phosphate (PO_4) was determined in immature green pods of *L. pyrotechnica,* however *C. polygonoides* was observed with lowest concentration (210 ppm). Phosphate is significant because the metabolic energy is stored and transferred through high energy bonds of phosphate esters such as adenosine triphosphate and adenosine diphosphate (Tarmizi et al., 2005).

Table 2: Nutritional contents (g/100g) in studied plant samples

Scientific name	Ash contents	Moisture contents	Crude lipids	Crude fibers	Nitrogen	Protein	Total sugars	Reducing sugars	Non-reducing sugars
	(N1)	(N2)	(N3)	(N4)	(N5)	(N6)	(N7)	(N8)	(N9)
Calligonumpolygonoides	10.00	7.61	12.6	39.9	2.69	16.86	3.47	1.92	1.55
Leptadeniapyrotechanica	7.62	3.62	16.20	45.12	3.01	18.78	2.40	1.45	0.95
Capparis decidua	7.52	8.83	9.00	30.92	3.60	22.51	2.08	1.47	0.61
Prosopis cineraria	5.12	11.00	5.20	37.52	3.82	23.91	2.23	1.74	0.49

Table 3: Mineral contents (ppm) in studied plant samples

Species	Na	K	Mg	Ca	PO_4
Calligonum polygonoides	650	1010	9610	8410	210
Leptadenia pyrotechanica	830	1040	4310	10420	320
Capparis decidua	370	1150	930	6400	270
Prosopis cineraria	790	580	4620	6010	260

Major source of minerals is food taken by the individuals and their daily intake level mainly depends on age, gender and body weight. Literature from WHO & FAO has confirmed a wide variation in mineral intakes among different nations of the world, e.g. the lowest mineral intakes were recorded in developing countries; while, higher intakes were observed in developed countries like Europe, USA, and Canada etc. i.e. calcium, magnesium & sodium intake recommendations for adults is 1000 mg/day & 150-500 mg/day, 300-500 mg/day respectively (FAO, 1962; Organization, 1988; Altura and Altura, 1996; WHO, 2012). The present findings (Ca-601-1042 mg, Mg-93-961 mg, Na-37-83 mg) found in accordance with recommended mineral allowances per day. While all estimated plant samples were little less in potassium and phosphate level. This deficiency can be overcome through various food items and supplementation (Organization, 1988).

Nutritional contents

The determination of nutrients such as proteins, crude lipids, crude fibers, total sugars, reducing sugars, and moisture contents has shown that these plants are rich in crude fibers followed by protein and crude lipids with an average concentration of 38%, 20% and11% respectively (Table 3 and Fig. 2). The moisture contents turned out to be higher (11%) in immature green pods of *P. cineraria*; while, the lowest value (3.62%) was recorded in an arid plant (*L. pyrotechnica*) living under limited water conditions. The floral buds of *C. polygonoides* showed 7.61%moisture content; while C. *decidua* showed at 9%. Lipids are a diverse group of water-insoluble organic compounds, which is extracted from tissues by non-polar solvents. *L. pyrotechnica* was found relatively abundant (16%) in crude lipids followed by *C. polygonoides* (13%). The two semi-arid plants had lower quantities of crude lipids. Lipids are the chief source of energy as hydrophobic barrier that permit partitioning of the aqueous contents of cells and sub-cellular structures. Atherosclerosis and obesity may occur due to the shortage or imbalances of lipids (Harvey and Ferrier, 2010).

Like lipids, the highest percentage of crude fibers was noted in *C. polygonoides and L. pyrotechnica*, whereas; two semi-arid plants have lower values (31% and 38% for *C. decidua* and *P. cineraria* respectively). Dietary fibers provide little energy but have several beneficial effects. Fibers can absorb water, ten to fifteen times their own weight. Thus, it draws fluid into the lumen of the intestine and increasing bowl motility.

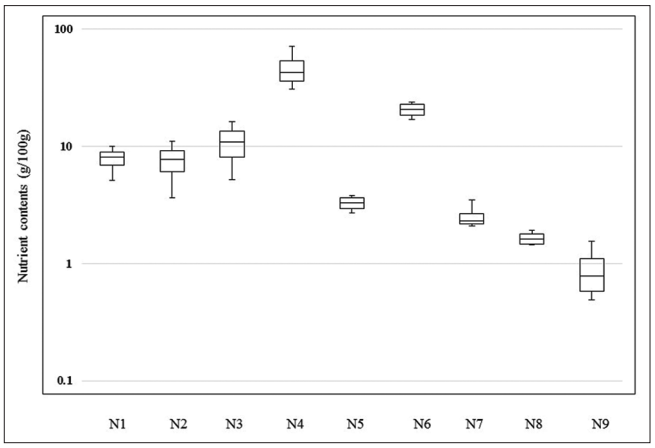

Fig 2. Comparative distribution of nutrients (listed in table 2) in plant samples.

Diets rich in fibers can reduce the risk of cardiovascular disease by lowering cholesterol levels. Also it reduces the risk for constipation, hemorrhoids, diverticulosis and colon cancer (Harvey and Ferrier, 2010). The use of immature green pods of *L. pyrotechnica* (45%) can be beneficial to control the lipids and fibers imbalances.

The highest nitrogen contents were recorded in semi-arid plants (Table 2 and Fig. 2), whereas; two arid plants were found with bit lower concentration. Thus, *P. cineraria and C. polygonoides* had maximum (4%) and minimum concentrations (3%) respectively. The presence of the nitrogen led to the determination of protein in plant samples. The highest percentage (24%) of protein was estimated in a plant sample with highest nitrogen content (*P. cineraria)* followed by *C. decidua* and *L. pyrotechnica.* Floral buds of *C. polygonoides* contained the lowest percentage of protein (17%) because of minimum nitrogen content in this plant. Practically almost every life process depends on this class of molecules. For example, in bone, the protein collagen forms a framework for the deposition of calcium phosphate crystals. In addition, the blood plasma, hemoglobin, a form of protein and plasma albumin are crucial to life (Harvey and Ferrier, 2010).

The contribution of reducing sugars towards total sugar contents was found higher as compared to non-reducing sugars (Table 2 and Fig. 2). The highest value of reducing sugar was observed in *C. polygonoides* followed by *P. cineraria* (1.92 and 1.74% respectively). The immature green pods of *L. pyrotechnica* showed the lowest percentage (1.45%) of reducing sugars. Thus, due to greater contribution of reducing sugars towards total sugars, *C. polygonoides* was found rich (3.47%) in total sugar contents. It was also the only plant which contained the non-reducing sugars above 1%. Immature green pods of *L. pyrotechnica* were observed with 2.40% of total sugars while 2.23% and 2.08% was

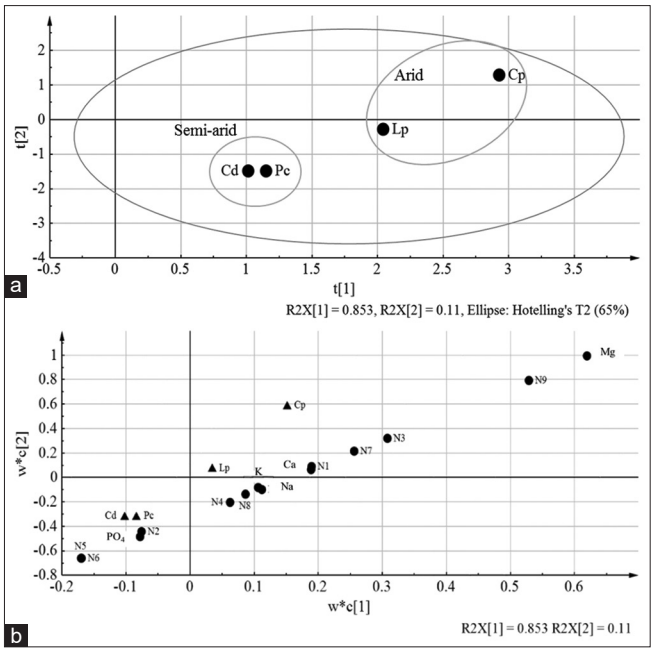

Fig 3. (a) PLS-DA of nutrients and mineral contents of plants from arid and semi-arid region is presented in two-dimensional scores (t[1] and t[2]). The first component (R2X [1]) explains 85% and the second component (R2X [2]) 11% of the variation of the X data. (b) PLS-DA Weight plot of variables, w*c[1] and w*c[2], For studied plant on the first [1] and second [2] components respectively. Variables (listed in Table 2 &3) are represented by a circle along with a symbol for visualization purposes. Cp, Lp, Cd and Pc stand for *Calligonum polygonoides, Leptadenia pyrotechanica, Capparis decidua* and *Prosopis cineraria* respectively.

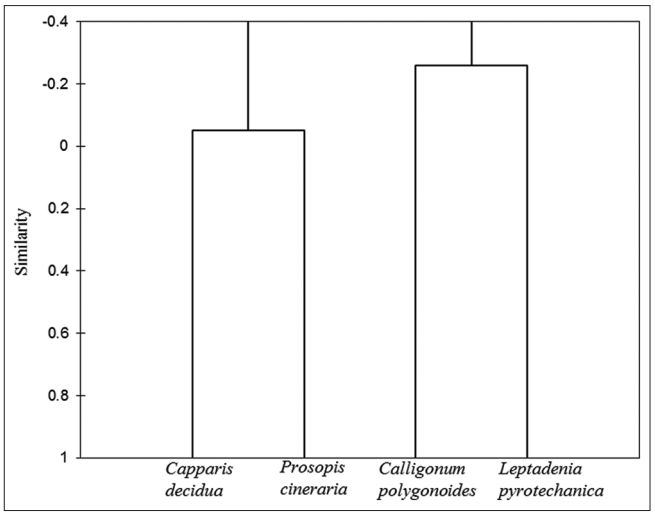

Fig 4. Cluster analysis (ca) of the plants on the basis of mineral contents and nutrients.

recorded in *P. cineraria* and *C. decidua* respectively. They have an extensive series of functions i.e. provide the significant amount of energy, also act as a storage house of energy in the body (Harvey and Ferrier, 2010). Thus *C. polygonoides* is rich in available energy among all studied desert plants as it contains the highest amount of total sugar contents.

The variations in nutritional and mineral contents among four studied plant parts can be associated with the difference in mineral composition of soil used to cultivate the plant and variations in the botanical structure in term of mineral absorbability and their storage. In addition the availability of fertilizer and water can also be the significant contributors (Masson et al., 2010). The four samples from arid and semi-arid regions were compared by PLS-DA and CA on the basis of nutrients and mineral contents (Figs. 3 and 4). The distributions of samples on two dimensional components of statistical model have shown that the samples of each region were close to each other with respect to minerals and others nutrients (Fig. 3a). The role of each mineral and nutrient for discrimination among samples was presented by a two dimensional weight scatter plot of PLS-DA. The variables closer to a particular sample has greater role towards discrimination among samples (Fig. 3b). Generally, the plants from arid region were found rich in minerals and nutrient contents except nitrogen (N5), proteins (N6) and phosphate which were found bit higher in plants samples from semi-arid region. As expected, plants samples from semi-arid region had higher moisture contents than arid plants. The results of PLS-DA were also confirmed by CA (Fig. 4) which showed the similarities between the samples of each region on the basis of minerals and nutrient contents.

CONCLUSIONS

Desert plants are the main source of nutrients and minerals for the people of desert. It is plausible from the results of present study that arid and semi-arid plants are rich in mineral and major nutrients required to sustain life in this region. *C. polygonoides* was found comparatively rich in sugars and minerals contents, whereas, crude fibers and crude lipids are obtained in high concentrations from *L. pyrotechnica*. In short, the arid plants were found more important for nutritional and mineral contents however two semi-arid plants were recorded as a rich source of moisture, protein and nitrogen contents. Such high-yielding and early-maturing wildly grown varieties in combination with other desert plants may not only be a good source of food for the nomads of Great Indian Desert but they can be supplied to other nearby regions by using techniques like controlled atmosphere packaging and chemical preservatives.

Authors contributions

Javed Iqbal and Aqeela Shaheen conducted the experiments and drafted manuscript.Taxonomical identification and plant collection was done by Rashid Iqbal and Muhammad Aslam. Muhammad Awais Ghani and Basharat Ali interpret the results and improved the first draft. Qumer Iqbal carried out multi-body refinement and provided instrumental

analysis. Muhammad Azam, Anam Noor and Adeel Anwar have done statistical analysis. Muhammadi Bibi, Imran Mahmood and Iqra Anwar helped in final drafting of manuscript.

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