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PHYSICO-CHEMICAL ATTRIBUTES AND HEAVY METAL CONTENT OF MANGOES (*MANGIFERA INDICA* L.) CULTIVATED IN DIFFERENT REGIONS OF PAKISTAN

SAEED AKHTAR[1*], SAFINA NAZ[1] , M.TUSEEF SULTAN[1] , SEEMA MAHMOOD[2], MUHAMMAD NASIR[3] AND ANWAAR AHMAD[4]

[1]Department of Food and Horticultural Sciences, Bahauddin Zakariya University Multan, Pakistan
[2]Institute of Pure and Applied Biology, Bahauddin Zakariya University Multan, Pakistan
[3]Department of Animal Products Technology, University of Veterinary & Animal Sciences, Lahore, Pakistan
Department of Food Technology, University of Arid Agriculture, Rawalpindi, Pakistan

Abstract

The present study was carried out to evaluate the physico-chemical attributes and heavy metal content of 4 popular mango (*Mangifera indica* L.) varieties viz., *Dusahri, Chaunsa, Ratol* and *Langra* grown in Multan (MUL), Rahim Yar Khan (RYK) and Mir Pur Khas (MPK), three major districts of Pakistan. Ash content, total soluble solid (TSS), pH and titratable acidity significantly ($p<0.0.5$) varied among these varieties. *Langra,* collected from MUL showed the highest ash % with relatively lower pH and TSS. The results indicated a substantial build-up of macro (Na, K, Ca, P) and micro (Fe, Zn, Ni, Cr, Cd, and Pb) elements in the selected mango varieties. Mango varieties collected from MUL showed a higher concentration of these metals as compared to other regions which may be attributed to irrigation from industrial effluents and sewage water. This study concludes that the levels of heavy metals in tested Pakistani mango varieties are higher than the safe limits laid down by World Health Organization (WHO) and need regular monitoring both at the farm and the table.

Introduction

Fruits are an integral part of human diet as they supply vitamins and minerals, the important constituents essential for human health (Mumzuroglu *et al.,* 2003). Among the most popular fruits, mango (*Mangifera indica* L.) is generally regarded as King of the Fruits. Likewise, mango as an emerging tropical export crop is produced in about 90 countries in the world. Pakistan is the 5th largest mango producer with a production capacity of ~ one million tones per year, contributing a share of 7.6% in the world market. Multan, Rahim Yar Khan and Mir Pur Khas are the main mango producing regions of Pakistan (Alam & Khan, 2001).

A substantial quantity of ripe mangoes are converted into pulp for use in jams, jellies, nectars, squashes, juices, paper/chips, mango toffees, ice creams, milk shake, fruit cocktail and in topping products (Hussain *et al.,* 2003). Therefore, most of the fruit processing industry in Pakistan preserves mango pulp for the manufacture of mango products all around the year.

Macro and trace elements play a significant role for maintaining health in humans (Anon., 1996). However, non essential trace elements like Pb, Cd. Cr and Ni, are non biodegradable thus, persist everywhere in the environment. These metal elements have the ability to deposit in various body organs which poses a great threat to the human health (Singh *et al.,* 2004; Chen *et al.,* 2005). Agricultural soils irrigated with waste water

get severely contaminated with heavy metals. Crops grown on such soils can accumulate a significant amount of heavy metals in different tissues (Khairiah *et al.,* 2004; Chojnacha *et al.,* 2005; Muchuweti *et al.,* 2006).

Rapid industrialization and urbanization in the developing countries in the last decades have resulted in a significant increase in environmental pollution. The soils, the plants and the products made thereof have been shown to be highly contaminated with heavy metals (Mazurek *et al.,* 1995; Motylera & Sosnina,1996; Hussain *et al.,* 2003; Zahoor *et al.,* 2003) and this concern has created a certain apprehension in the public regarding the safety of the food, they consume every day (Radwan & Salama, 2006).

Emission of heavy metals from the industries and vehicles may result in the deposition of such metals on the surface of the fruits and vegetables and contaminate (Geert *et al*., 1989; Ozores-Hampton *et al.,* 1997; Jassir *et al.,* 2005) by entering the food during industrial processing and packaging (Tsoumbaris & Tsoukali-Papadopoulou, 1994).

Since, these heavy metals might seriously damage human health e.g., decrease in immunological defense, neurological disorders, intrauterine growth retardation, impaired psycho-social behavior, disabilities associated with malnutrition and a high prevalence of upper gastrointestinal cancer (Arora *et al.,* 2008) hence, regular survey and monitoring programs of heavy metal contamination in food stuff were mainly centered for decades in developed countries (Jorhem & Sundstroem, 1993; Milacic & Kralj, 2003; Saracoglu *et al.,* 2004) but no substantial research have been conducted to address this issue in the developing countries (Zahoor *et al.,* 2003). Consequently, there are limited data available in Pakistan to reflect the levels of heavy metal contamination in most fruits like mangoes.

The aim of the present study was to evaluate most commonly cultivated mango export varieties (*Dusahri*, *Chaunsa*, *Ratol* and *Langra*) for physico-chemical, nutritional and safety status of the fruit, grown in three major regions of Pakistan. Concentrations of macro (Na, K, Ca, P) and micro elements (Fe, Zn, Ni, Cr, Cd, and Pb) were determined in the mango pulp. The levels of heavy metals content of the pulp samples were compared with the approved safe limits.

Materials and Methods

Procurement of the materials: Four popular varieties of mangoes (*Dusahri*, *Chaunsa*, *Ratol* and *Langra*) were selected and ripened fruits were obtained from three major mango growing areas of Pakistan i.e. MUL, RYK and MPK. The samples were brought to the laboratory of the Department of Food and Horticultural Sciences, Bahauddin Zakariya University, Multan, Pakistan. The fruits were thoroughly washed with double distilled deionized water to remove any pollutant, pesticide residues, dirt and dust on the surface.

Reagents used were of analytical grade unless otherwise stated and the solutions were prepared with distilled water. Glassware were soaked overnight in a 10% nitric acid solution and then rinsed with distilled water before its use. Standard solution for each element was used for calibration, diluting a stock solution of 1,000 mg/l, supplied by Merck (Darmstadt, Germany).

Pulp extraction: Ten fruit from each cultivar and location were sampled. Harvesting was carried out three times for each cultivar. The fruits of each mango variety and location were weighed and passed through a mango pulper (locally fabricated) to separate pulp from the stone and skin. The pulp obtained was weighed and packed in labeled

polyethylene bags. These bags were stored in a refrigerator at 4 ºC for around 3-4 days for further analysis.

Analytical tests

Physico-chemical assay of the mango pulp samples: Total soluble solids were determined directly in each sample by using refractometer (Atago PAL-1, Japan) and expressed as °Brix. The acidity was determined as citric acid by titration against 0.1 N solution of NaOH and pH by using pH meter (Jenway 3510-UK) by taking a sufficient quantity of sample in 50 mL clean beaker as described in AOAC (Anon., 2000).

Determination of macro and micro elements in mango pulp samples: Metals determination was carried out following the method outlined by Arora *et al.,* (2008). A weighed quantity of the pulp was air-dried for a day and oven-dried in hot air oven (Memmert 100-Germany) at 70-80ºC for 24 hr. The dried samples were ground and sieved through a muslin cloth. Ground sample (in triplicate) weighing 0.5 g of each was placed in digestion flask and 15.0 ml concentrated HNO_3 (Merck, 99.9% purity) was added to this dried pulp. The sample was completely digested after heating it at 60-70°C for one hour on a hot plate (ARE, Velp Italy). The digested samples were cooled to room temperature and 5.0 mL concentrated $HClO_4$ (Merck, 99.9 percent purity) was added to the digested sample with heating until white fumes appeared in the flask. The reaction mixture was filtered with Whatman filter paper No. 42 and transferred to a measuring flask after cooling to room temperature and volume made up to 25.0 mL with distilled water. The sample solutions were subsequently analyzed for the concentrations of these macro and micro elements (Na, K, Ca, P, Fe, Zn, Ni, Cr, Cd, and Pb) using Atomic Absorption Spectrophotometer (Perkin Elmer-100) and flame photometer. The experiment was repeated twice for each variety for accuracy and the values reported are the means for each element.

Statistical analysis: The data were statistically analyzed using two-way analysis of variance (ANOVA) to assess the effect of different variables on the concentrations of heavy metals and physico-chemicals attributes of the tested mango varieties (Steel *et al.,* 1997). Duncan's Multiple Range Test was applied to assess the difference between means at significance level of $p<0.05$ (Duncan, 1955).

Results and Discussion

Physico-chemical characteristics of various mango varieties: Data pertaining to physico-chemical composition of various mango cultivars have been presented in Figure 1. The highest ash content (%) was observed in the pulp samples obtained from *Langra* followed by *Dusahri* while *Chaunsa* and *Ratol* did not vary for their ash content (Fig. 1A).

No varietal difference could be observed among *Dusahri*, *Chaunsa* and *Ratol* for TSS however, *Langra* showed a significantly ($p<0.05$) lower concentration of TSS (Fig. 1B). This difference in TSS content of mangoes might be attributed to the storage time and temperature since, reduced rate of development of soluble solids was observed at low temperature (Medicott *et al.,* 1986). Rao & Breummer (1981) ascribed a decrease in TSS of the mangoes to over ripening and microbial spoilage.

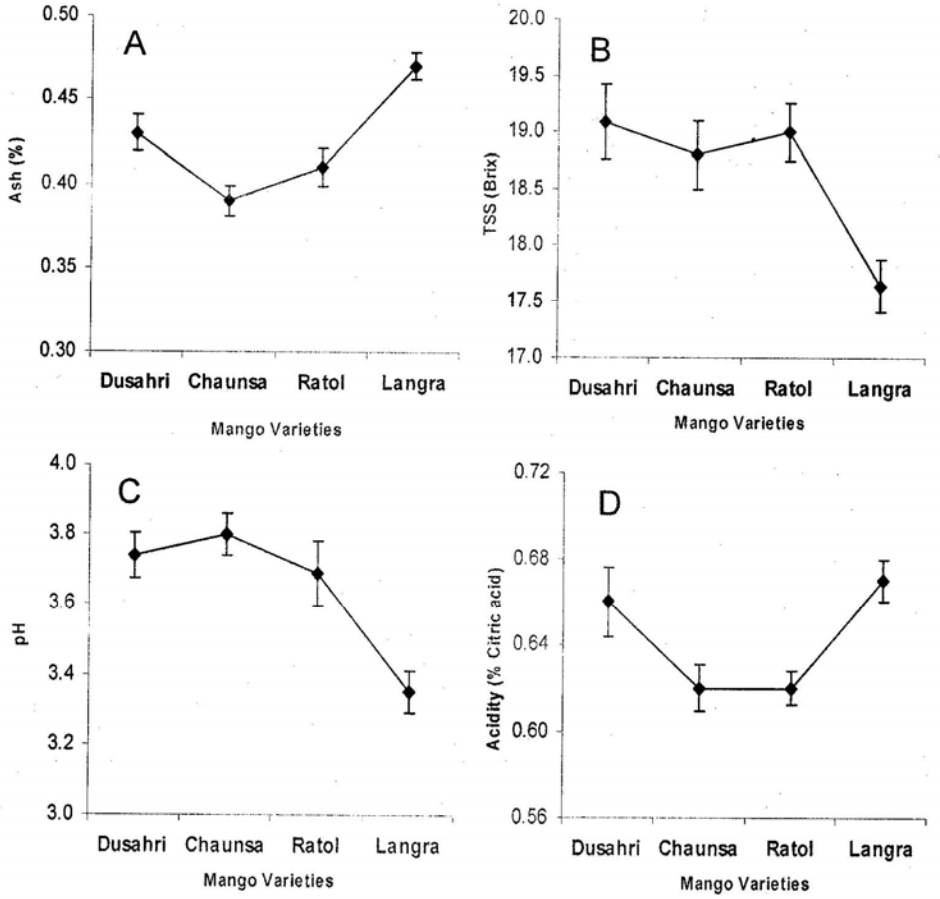

Fig. 1 Physico-chemical differences among various mango varieties (*Dusahri*, *Chaunsa*, *Ratol* and *Langra*). Ash content (%) (A), Total soluble solids (TSS) (B), pH (C) and Acidity (D). The values are reported as means ± SE at 5% level of probability of all three locations (Multan, Rahim Yar Khan and Mir Pur Khas) for a particular variety and each attribute.

Variability in pH and acidity among different mango varieties has been shown in Figures 1C & 1D which clearly indicates that *Langra* variety was found to be relatively more acidic with pH 3.35. Numerous studies have confirmed the variation in pH and acidity of mangoes and mango products due to the ripening of the mango and the storage (Prusky *et al.*, 1993; Bajwa, 1998; Saeed &Atif 2009). The regions under investigation have different ripening time because of location at different sea levels.

Ash (%) was observed to be the highest in *Langra* variety grown in MUL as compared to RYK and MPK (Fig. 2). The difference in ash content of *Langra* variety might be related to the higher content of mineral in this cultivar as reported in the present study.

Distribution of macro and micro elements in different mango cultivars: Concentrations of Na, K, Ca and P in mangoes grown in three major districts of Pakistan have been presented in Table 1. Mango growing locations under experimentation have been pointed out on the map (Fig. 3). Comparison for Na content in mangoes grown in MUL and RYK indicates a non significant ($p>0.05$) difference but mangoes from MPK significantly differed from RYK. Mango varieties from MUL region were containing slightly higher Na level followed by RYK (Table 1). The K, Ca and P exhibited almost a similar pattern for their presence in mangoes grown at all three sites with a highest mean concentration in mangoes from MUL followed by RYK and MPK. However, the mean concentrations of these elements recorded in mangoes grown in RYK and MPK were shown to be identical ($p<0.05$) (Table 1).

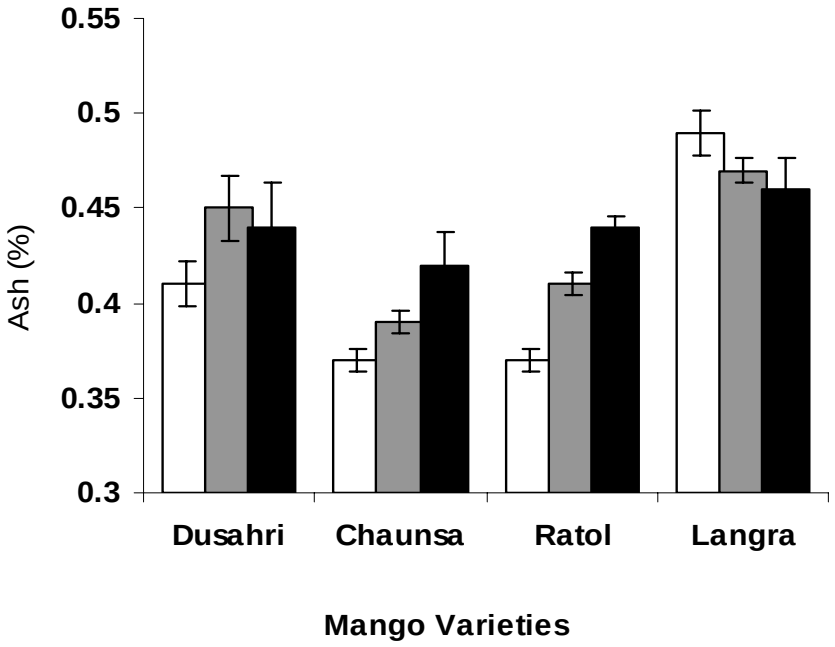

Fig. 2. Ash content (%) of various mango cultivars (*Dusahri*, *Chaunsa*, *Ratol* and *Langra*) grown in Multan (MUL) (White bar) Rahim Yar Khan (RYK) (Grey bar) and Mir Pur Khas (Black bar).The values are reported as the means ± SE at 5% level of probability of all three locations (Multan, Rahim Yar Khan and Mir Pur Khas) for a particular variety.

Fig. 3. Map of Pakistan showing (arrows pointing the sites under investigation) the relative positions of different mangoes production regions.

The concentration of Fe, Ni, Pb and Cd was found to be higher in mangoes from MUL as compared to other areas however, no significant difference for these metals could be observed in mangoes collected from RYK and MPK (Table 2). The maximum concentration of zinc was recorded in mangoes from MUL followed by those in MPK and RYK (Table 2). Similarly, Cr content of the mangoes from MUL were slightly higher as compared to the other two regions (Table 2).

It is evident from the results presented in Table 1 & 2 that the mangoes tested from MUL contained higher concentration of macro elements and were significantly contaminated with all the heavy metals determined in the current study. However, no significant differences were observed in the mangoes from the rest of the two regions. This situation has lead to establish the fact that there are primarily two major zones of comparison for the presence of heavy metals rather three which cover more or less the whole mango cultivation area of the country. Therefore, it is imperative that the future studies be carried out by sampling from more distantly located regions differing in agricultural practices and prevalence of industries.

Mean concentrations of Na and K present in all varieties (Table 3) depicted that *langra* variety had a tendency to build up higher content of these metals. Considerably higher ($p<0.05$) level of Ca was also observed in *Langra* variety as compared to its concentration in *Dusahri*. Contrarily, P has been identified to be the only metal under experimentation that the *langra* variety accumulated least.

Similarly, the concentration of Zn, Ni, Cr and Pb was relatively higher in *Langra* variety (Table 4). Cd was found to be the highest in *Ratol* variety and the lowest in *Chaunsa* variety. Thus, different varieties have shown variability for the accumulation of these metals, but *Langra* variety has shown a considerable potential to take up metals (Table 4).

Ona *et al.,* (2006) confirmed that plants were capable of absorbing heavy metals from soil and that some plants naturally absorb far more lead than others. Further, metals accumulation in plants depends on plant species, growth stages, type of soil and metals, soil condition, weather and environment (Chang *et al.,* 1984; Domergue & Vedy, 1992) .

Table 5 indicates the average concentrations of various macro elements in different varieties in relation to their site of production. The elements K and Ca, were among those tested metals which did not show any difference ($p<0.05$) in their concentration when the regions and/or varieties were compared. Mango variety *Dusahri* grown in MPK was found to be least contaminated with Na. By contrast, *Langra* variety, produced in RYK was found to contain higher concentration of Na. Rest of the varieties and the sites of production of mangoes showed almost similar pattern of Na accumulation. The degree of the presence of these elements in various varieties from different regions greatly varied for each tested metal. It is evident from the results for P (Table 5) that *Chaunsa* variety from MUL exhibited the highest P concentration while *Langra* variety in RYK displayed the lowest level. As reported above, *Langra* variety seemed to possess the least possible potential for the uptake of the P despite this variety was found to be the most susceptible to build up higher levels of all the tested metals.

The varieties showing heavy accumulation of metals (Fe, Zn, Cr, Pb, Ni and Cd) from MUL was presumably because of more contaminated soil of this region. *Langra* variety with a slight difference in Cr and Pb accumulation as compared to other varieties, produced in MUL showed maximum contamination. In the same way, *Langra* variety along with *Ratol* variety grown in MUL still resided at the top for their potential to have a higher build up of Cd in comparison with other points of production where Cd was shown to be the minimum in *Chaunsa* variety in MPK (Table 6).

Table 1. Distribution of selected major elements (ppm) in mangoes grown in three major areas of Pakistan.

Metal	Regions		
	Multan	Rahim Yar Khan	Mir Pur Khas
Na	63.06 ± 0.78[ab]	65.08 ± 1.28 [a]	60.59 ± 1.69 [b]
K	382.77 ± 5.23[a]	347.67 ± 5.41[b]	362.06 ± 3.80[b]
Ca	75.10 ± 1.20 [a]	66.76 ± 1.40 [b]	67.03 ± 1.58 [b]
P	15.69 ± 0.559[a]	13.42 ± 0.433 [b]	12.96 ± 0.260 [b]

Means ± SE sharing similar superscript in the rows are not significant by DMRT at 5% level of probability. The values are reported as the mean of all mango varieties (Dusahri, Chaunsa, Ratol and Langra) in a particular region for each metal element

Table. 2. Distribution of selected heavy metals (ppm) in mangoes grown in three major areas of Pakistan.

Metal	Regions		
	Multan	Rahim Yar Khan	Mir Pur Khas
Fe	3.70 ± 0.073 [a]	2.86 ± 0.082 [b]	2.77 ± 0.090 [b]
Zn	2.76 ± 0.054 [a]	2.10 ± 0.030 [c]	2.45 ± 0.031 [b]
Ni	6.28 ± 0.136 [a]	5.17 ± 0.191 [b]	5.38 ± 0.113 [b]
Cr	4.44 ± 0.111 [a]	4.04 ± 0.058 [b]	4.26 ± 0.113 [ab]
Pb	1.32 ± 0.032 [a]	1.00 ± 0.031 [b]	0.95 ± 0.062 [b]
Cd	0.22 ± 0.008 [a]	0.18 ± 0.007 [b]	0.19 ± 0.008 [b]

Means ± SE sharing similar superscript in the rows not significant by DMRT at 5% level of probability. The values are reported as the mean of all mango varieties (Dusahri, Chaunsa, Ratol and Langra) in a particular region for each metal element

Table 3. Distribution of selected major elements (ppm) in mangoes varieties grown in Pakistan.

Metal	Mango varieties			
	Dusahri	Chaunsa	Ratol	Langra
Na	61.53 ± 1.66	62.81 ± 0.95	63.69 ± 1.65	63.60 ± 2.07
K	361.33 ± 7.97	361.44 ± 6.41	365.51 ± 6.61	368.40 ± 9.17
Ca	66.22 ± 1.86 [c]	67.42 ± 2.47 [bc]	70.67 ±1.51 [ab]	74.20 ± 1.27 [a]
P	14.90 ± 0.46[a]	14.65 ± 0.87 [ab]	13.90 ± 0.492[b]	12.64 ± 0.390[c]

Means ± SE sharing similar superscript in the rows are not significant by DMRT at 5% level of probability. The values are reported as the means of all three locations (Multan, Rahim Yar Khan and Mir Pur Khas) for a particular variety and metal element

A number of serious health problems can develop as a result of excessive uptake of dietary heavy metals (Arora *et al.*, 2008). Some heavy metals such as Cu, Zn, Mn, Co and Mo act as micronutrients for the growth of animals and human beings when present in trace quantities, whereas others such as Cd, As, and Cr act as carcinogens (Feig *et al.*, 1994).

Previous studies (Liu *et al.*, 2005; Muchuweti *et al.*, 2006; Sharma *et al.*, 2007) demonstrated that the plants grown on waste water-irrigated soils are generally contaminated with heavy metals, which pose a major health concern.

Another study (Zahoor *et al.*, 2003) conducted in Pakistan confirmed the higher concentration of tested heavy metals in fruits. The levels reported by these researchers are a little lower than those determined in the current study and the slight variation may be due to the difference in region of cultivation, variety and level of the presence of effluents in the irrigation water. Similarly, higher concentrations of Cd, Cr, Cu, Fe, Mn,

Ni, Pb and Zn (ug g^{-1} Dry Weight) were reported in mangoes collected from Indian Market (2.14, 85.71,14.22, 189.31, 39.31, 14.06, 9.52 and 32.67 respectively) which may be attributed to the level of these metals in the irrigation water, air and environment (Mahdavian & Somashekar, 2008).

Spontaneous urban and industrial developments have significantly contributed to the elevated levels of heavy metals in the urban environment of the developing countries (Tripathi *et al.*, 1997; Wong *et al.*, 2003; Khairiah *et al.*, 2004; Sharma *et al.*, 2008). Growing industrialization and urbanization in Pakistan is mainly associated with Pakistan's growth rate of 8% which results in the generation of massive quantities of industrial and urban wastes, polluting the land, water and atmosphere. MUL, a growing city of Pakistan with a population of 1396100 heads is around six fold populated than RYK and MPK. This expansion process called for more land to dwell converting the mango orchards in the nearby areas to residential sites and rest of orchards got closer to populated areas. This situation clearly portrays the incidence of higher levels of metals accumulation in the mango fruit grown in MUL regions as compared with RYK and MPK which are relatively smaller towns with a moderate expansion and growth.

Table. 4. Distribution of selected heavy metals (ppm) in mangoes varieties grown in Pakistan.

Metal	Mango varieties			
	Dusahri	Chaunsa	Ratol	Langra
Fe	2.81 ± 0.162^{b}	3.23 ± 0.18 ^{a}	3.20 ± 0.143 ^{a}	3.19 ± 0.174 ^{a}
Zn	2.34 ± 0.093^{b}	2.40 ± 0.08 ^{b}	2.45 ± 0.121^{ab}	2.55 ± 0.107 ^{a}
Ni	5.31 ± 0.191^{b}	5.89 ± 0.19 ^{a}	5.17 ± 0.207 ^{b}	6.07 ± 0.228 ^{a}
Cr	4.12 ± 0.088 ^{b}	4.11 ± 0.12 ^{b}	4.30 ± 0.122 ^{ab}	4.46 ± 0.136 ^{a}
Pb	1.18 ± 0.042 ^{a}	1.08 ± 0.09 ^{b}	0.92 ± 0.07^{c}	1.18 ± 0.054 ^{a}
Cd	0.20 ± 0.007 ^{b}	0.17 ± 0.006 ^{c}	0.22 ± 0.011^{a}	0.20 ± 0.008 ^{b}

Means ± SE sharing similar superscript in the rows are not significant by DMRT at 5% level of probability. The values are reported as the means of all three locations (Multan, Rahim Yar Khan and Mir Pur Khas) for a particular variety and metal element

Table.5. Distribution of selected major elements (ppm) in different mango varieties grown in three major areas of Pakistan.

District	Variety	Metal elements			
		Na	K	Ca	P
Multan	Dusahri	63.34 ± 1.96^{abc}	384.83 ± 7.12	71.85 ± 0.85	16.32 ± 0.445^{b}
	Chaunsa	61.48 ± 1.01^{bcd}	374.89 ± 13.5	75.85 ± 4.00	17.85 ± 0.618^{a}
	Ratol	62.37 ± 1.3 $^{a-d}$	379.53 ± 13.6	74.85 ± 1.55	15.54 ± 0.375^{b}
	Langra	65.03 ± 1.86^{ab}	391.83 ± 10.3	77.85 ± 1.81	13.03 ± 0.277^{d}
Rahim Yar Khan	Dusahri	65.45 ± 0.39^{ab}	334.43 ± 5.84	65.44 ± 3.20	14.92 ± 0.508^{bc}
	Chaunsa	64.48 ±1.09^{ab}	354.89 ± 6.81	61.73 ± 1.20	13.73 ± 0.479^{cd}
	Ratol	61.37 ± 3.59^{bcd}	349.53 ± 8.11	67.55 ± 1.05	13.58 ± 0.248^{cd}
	Langra	69.03 ± 2.59^{a}	351.83 ± 19.3	72.31 ± 0.91	11.43 ± 0.647^{e}
Mir Pur Khas	Dusahri	55.80 ± 1.78^{d}	364.72 ± 5.78	61.36 ± 1.65	13.45 ± 0.185^{cd}
	Chaunsa	62.48 ± 2.51^{a-d}	354.53 ± 11.3	64.67 ± 0.65	12.36 ± 0.577^{de}
	Ratol	67.33 ± 2.78^{ab}	367.46 ± 3.87	69.62 ± 3.12	12.58 ± 0.658^{de}
	Langra	56.73 ± 1.43$^{c\ d}$	361.54 ± 9.73	72.45 ± 2.33	13.46 ± 0.433^{cd}

Means ± SE sharing similar superscript in the columns are not significant by DMRT at 5% level of probability.

Table 6. Distribution of selected heavy metals (ppm) in different mango varieties grown in three major areas Pakistan.

District	Variety	Metal Element					
		Fe	Zn	Ni	Cr	Pb	Cd
Multan	Dusahri	3.41 ± 0.104^{bc}	2.63 ± 0.139	5.98 ± 0.058	$4.31 \pm 0.231^{a-d}$	1.28 ± 0.035^{b}	0.22 ± 0.006^{b}
	Chaunsa	3.91 ± 0.127^{a}	2.63 ± 0.029	6.48 ± 0.075	4.11 ± 0.035^{bcd}	1.43 ± 0.035^{a}	0.19 ± 0.006^{c}
	Ratol	3.65 ± 0.104^{ab}	2.83 ± 0.092	5.88 ± 0.098	4.62 ± 0.248^{ab}	1.18 ± 0.023^{cd}	0.26 ± 0.012^{a}
	Langra	3.81 ± 0.098^{a}	2.93 ± 0.046	6.78 ± 0.346	4.71 ± 0.202^{a}	1.38 ± 0.023^{a}	0.21 ± 0.000^{b}
Rahim Yar Khan	Dusahri	2.56 ± 0.139^{f}	2.05 ± 0.017	4.72 ± 0.098	4.11 ± 0.069^{bcd}	1.02 ± 0.006^{f}	0.18 ± 0.006^{cd}
	Chaunsa	3.02 ± 0.029^{de}	2.11 ± 0.087	5.88 ± 0.260	3.79 ± 0.029^{d}	0.98 ± 0.012^{f}	0.16 ± 0.006^{ef}
	Ratol	2.72 ± 0.127^{f}	2.03 ± 0.029	4.54 ± 0.058	$4.22 \pm 0.023^{a-d}$	0.87 ± 0.046^{g}	0.22 ± 0.000^{b}
	Langra	3.12 ± 0.098^{cd}	2.21 ± 0.035	5.55 ± 0.312	4.03 ± 0.133^{cd}	1.12 ± 0.052^{de}	0.17 ± 0.006^{de}
Mir Pur Khas	Dusahri	2.45 ± 0.087^{f}	2.35 ± 0.017	5.23 ± 0.144	3.94 ± 0.029^{cd}	1.23 ± 0.035^{bc}	0.19 ± 0.006^{c}
	Chaunsa	2.75 ± 0.046^{ef}	2.46 ± 0.075	5.31 ± 0.162	4.43 ± 0.254^{abc}	0.83 ± 0.035^{g}	0.15 ± 0.000^{f}
	Ratol	3.22 ± 0.058^{cd}	2.48 ± 0.069	5.09 ± 0.214	4.05 ± 0.179^{cd}	0.71 ± 0.035^{h}	0.19 ± 0.006^{c}
	Langra	2.65 ± 0.075^{f}	2.51 ± 0.058	5.89 ± 0.058	4.63 ± 0.162^{b}	1.04 ± 0.023^{ef}	0.22 ± 0.006^{b}

Means ± SE sharing similar superscript in the columns are not significant by DMRT at 5% level of probability

Furthermore, the physical and chemical nature of the soil of the production sites, the ability to take up heavy metals by the plants, deposition of heavy metals in the environment, use of untreated water, the nature of the fruit, exposed surface area and the anthropogenic activities like use of metal-based pesticides around production sites and urban industrial activities at market sites are some of the factors responsible to boost up the accumulation of heavy metals in the fruits in many parts of the developing countries (Zurera *et al.,* 1989; Sharma *et al.,* 2006; Sharma *et al*., 2009).

Conclusion

The permissible levels of Cr, Ni, Cd and Pb in mangoes were found to be much lower i.e., 1.00mg/kg than the concentrations found in the current study, suggesting a great deal of monitoring and immediate measures to address this issue with respect to economic and health standpoint. Since, sufficient information on the nutritional status of the mango varieties has been obtained along with the data on the variability in the concentration of heavy metals with respect to variety and region hence, the whole set of information may provide a better understanding of the quality and safety of this major fruit crop, mango (*M. indica).* This will also help promoting export of the best quality mangoes and to avoid potential health issues associated with the consumption of toxic metals through mangoes. Since, the importance of the environment on the uptake of heavy metals by the fruit is established therefore, further research is needed on the soil, water and air as significantly contributing factors to the elevated heavy metal content of the fruits.

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