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Assessment of Trace Element Intake through Some Vegetables to the Population of Mumbai

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Abstract

Major and Trace element concentrations were determined in Potato, Cabbage and Bottle gourd purchased from Mumbai using flame atomic absorption spectroscopy. Concentration of some major elements Ca, Na, K and Mg were found to be higher in Cabbage as compared to Potato and Bottle Gourd while the concentration of Fe, Zn and Cu was observed to be higher in Bottle Gourd. Toxic elements Cd and Ni concentrations in all the vegetables were <0.5 ppb. Calculated daily dietary intake values for the elements were found to be lower than the reference dietary intake values, indicating that these vegetables are safe for human consumption.

Keywords: Vegetables; Toxic elements; Atomic absorption spectroscopy; Daily dietary intake

Introduction

Vegetables are an essential dietary component for the human body. They contribute protein, vitamins, iron, calcium and other nutrients to human body, which are usually short in supply [1]. They also act as buffering agents for acidic substances produced during the digestion process. Eating vegetables lowers the risk of many chronic diseases and can also help with weight management [2]. It has been reported that eating seven or more portions of fruit and vegetables in a day reduces risk of death at any point in time by 42% compared to eating less than one portion and also fresh vegetables has more protective effect than fruits, with each daily portion reducing overall risk of death by 16% [3].

Vegetables are a rich source of various essential elements including Ca, K, Na, Mg, Fe, Mn, Zn, Cu which are required for the proper functioning of the human body. The availability of different elements to the human body depends on the dietary preferences/ habits of an individual. There are around thirty chemical elements that are recognized as essential elements however the essential elements can also become toxic at higher concentration [4]. For example Cr and Mn are essential but may become toxic at higher levels. Pb and Cd are toxic at all the concentrations and can be cumulative [5,6]. Hg is one supratoxic element with high neurotoxicity. Many anthropogenic activities such as use of fertilizers, coal combustion, refuse incineration; mining and smelting waste [7-9] release large amounts of heavy metals into the environment that can be transported along hydrologic gradients for hundreds of kilometres in relatively short times. These heavy metals can enter in the food and deliver their toxic effects to humans through different intake pathways [10,11].

Many studies have reported that food crops accumulate trace metals in their tissues when grown on contaminated soil [12-14]. It is recognized that land used for food production has been contaminated with Cd, Pb and Zn from metal smelting activity, irrigation with wastewater, disposal of solid wastes including sewage sludge, vehicular exhaust and adjacent industrial activity [14-16]. Compared to crops from rural sites, horticultural crops in urban or peri-urban areas are generally exposed to higher level of pollutants including trace metals and organic contaminants [17-19]. Trace element concentration at higher or elevated levels can bring undesirable chemical changes. Many other conventional pollutants can also bring biological changes due to its presence in the environment of the public. However living systems has evaluated as a very efficient repair mechanism that usually limits the damage caused to body cells. The carcinogenic effects linked with the toxic element are not different and distinguished from the radiation exposure. Various studies have revealed that consuming crops from polluted sites can lead to serious public health problems in both developing and developed countries [13,20]. For these reasons, it is essential to determine the trace metal content of different vegetables and assure that these vegetables are safe for consumption.

In the present work we have selected three vegetables, Potato (*Solanum tuberosum*), Cabbage (*Brassica oleracea*) and Bottle Gourd (*Lagenaria steraia*) for our study. The selection was based on dietary choices of the local population as well as their production. Potato popularly known as king of vegetables is the fourth most important crop in India and third most important crop in the world only after wheat and rice and consumed by more than 1 billion people worldwide [21]. India is the second largest producer of Potato in world [22] with the total production of 42.34 million ton [23]. The total consumption of potato in India is 32.55 million tonnes with per capita consumption of 36.4 kg/year [24]. India is also the second largest producer of Cabbage with the total production of 7.95 million tones which is equivalent to the 12% production of the total cabbage [25]. While the per capita consumption is 7.34 kg/year [24]. Similarly the total production of bottle gourd is 1.43 million tonnes [26] with per capita consumption of 7.03 kg/year [24]. Being an important dietary component of Indian population it is important to study the elemental concentration in these vegetables.

Experimental

Sample collection and processing

All three vegetables namely Potato (*Solanum tuberosum*), Cabbage (*Brassica oleracea*) and Bottle Gourd (*Lagenaria siceraria*) 1 kg each, multiple samples of each variety were purchased from APMC Market, Vashi, Navi Mumbai, a local market which is one of the largest suppliers of food and vegetable to the city of Mumbai. Collected samples were immediately sealed in polythene bags, labeled and stored. Non-edible portion of vegetables were removed and each sample was washed with

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water to remove the soil particles and air dried. Samples were then finely chopped, labeled and ashed at a temperature of 450°C in muffle furnace. Ashed samples were weighed and stored. 0.1 g of dried sample was digested in 5 mL of conc. HNO_3 and 2 mL of HF using a microwave digestion (Anton paar). Samples were then evaporated to dryness (hot plate, open beaker digestion) and a final solution of 25 mL with 0.25% of HNO_3 was prepared for subsequent analysis.

Analytical technique

Samples were analyzed for major and minor elements 904 BT, Double Beam flame Atomic Absorption Spectrometer (GBC Avanta) which uses Hollow Cathode Lamp as radiation source. The concentration of the analyte was determined by calibration curve method. A typical calibration curve for Pb is shown in Figure 1. The lamp, working range and sensitivity for each metal ion is different and are given in Table 1.

Quality control

For the estimation of elemental concentrations and also for quality assurance purposes, certified reference materials, NIST SRM 1570a (Spinach leaves) and NIST SRMs 1573a (Tomato leaves) were analyzed as control samples. The standards and samples were subjected to same digestion procedure and measurement conditions. All chemicals used for analysis were obtained from Merck or of electronic grade. Deionized water (Barnstead T11, Barnstead Nano pure, and Thermo Scientific) was used throughout the experiment. Constant temperature was maintained during the analysis and efforts were taken to keep dust level very low. All samples were analysed in triplicate. Care was taken to avoid cross contamination of samples.

Element	Wavelength (nm)	Working Range ($\mu g.mL^{-1}$)	Sensitivity ($\mu g.mL^{-1}$)
Ca	422.7	1-4	0.020
Cd	228.8	0.2-1.8	0.009
Co	240.7	2.5-9.0	0.050
Cr	357.9	2.0-15	0.050
Cu	324.7	1-5	0.025
Fe	248.3	2 - 9	0.050
K	766.5	0.4-1.5	0.008
Mg	285.2	0.1-0.4	0.003
Mn	279.5	1-3.6	0.020
Na	589.0	0.18-0.7	0.004
Ni	232.0	1.8-8.0	0.040
Pb	217.0	2.5-20	0.060
Zn	213.9	0.4-1.5	0.008

Table 1: Wavelengths used for the determination of metals, working range and sensitivity.

Results and Discussion

Elemental concentrations

The elemental concentrations determined by AAS in NIST SRM 1570a (Spinach leaves) and NIST SRMs-1573a (Tomato leaves) along with the certified values are listed in Table 2. Standard deviations associated with the values were obtained from replicate analyses. A comparison of determined values with the certified values shows good agreement within ± 10%. Relative standard deviation (RSD) values were <5% in most cases indicating good precision of the measurements. Therefore, our experimental data are expected to be accurate and precise within ± 10%.

Table 3 shows the concentration of both essential and toxic elements in different vegetables. The trace metal content differs widely among vegetables (Table 3). All three vegetables have low concentration of Co, Ni, Cr and Cd and is less than the detection limit of our instrument (0.5 ppb). Significant differences in Zn and Fe concentrations were observed where the concentration of both the elements is more in bottle gourd followed by cabbage and comparatively less in potato. Both of these elements are essential micronutrients for human growth and their deficiency in body leads to poor growth and impaired immune response. Cu concentration is found to be low in potato and cabbage (0.17 ± 0.012 and 0.155 ± 0.014 ppm respectively) while it is higher in bottle gourd (1.575 ± 0.13 ppm) however on the other side the concentration of Mn is higher in Cabbage as compared to Potato and Bottle Gourd (1.98 ± 0.19, 0.40 ± 0.03 and 1.48 ± 0.13 ppm respectively). In case of essential elements the concentration is higher in Cabbage as compared to other two vegetables. Concentration of K and Mg follow the order Cabbage>Bottle Gourd>Potato while the concentration of Na and Ca follow the order as Cabbage>Potato>Bottle Gourd.

Figure 2 shows the concentration of both essential and toxic elements in all three vegetable. It is clear from Figure 2 inset that concentration of K is more in Potato and Bottle Gourd as compared to other essential elements while cabbage has the highest concentration of Ca among all the elements. Figure 2D shows a comparison of concentration of analyzed trace elements with analyzed essential elements in different vegetables used in the study. It is evident from Figure 2D that concentration of trace elements is very less as compared to essential elements. In Potato and Cabbage more that 99% concentration comes from essential elements while in case of Bottle Gourd more than 97% contribution is from essential elements. This indicates that Bottle Gourd has comparatively higher concentration of trace elements as compared to other two vegetables. Earlier [27] had determined the concentration of various elements in Potato and Cabbage and their result also suggests that Potato and Bottle Gourd has

Element	Certified values (SRM 1570a)	Observed Value (N=3)	Certified values (SRM 1537a)	Observed Value (N=3)
Na (mg/kg)	18180 ± 430	22000 ± 1000	136 ± 4	145 ± 5
K%	2.90 ± 0.05	3.02 ± 0.07	2.70 ± 0.05	2.60 ± 0.10
Mg (mg/kg)	-	-	0.05 ± 0.01	0.05 ± 0.01
Ca%	1.53 ± 0.04	1.50 ± 0.06	5.05 ± 0.09	5 ± 0.20
Fe (mg/kg)	-	-	368 ± 7	350 ± 10
Co (mg/kg)	0.39 ± 0.05	0.40 ± 0.01	0.57 ± 0.02	0.60 ± 0.04
Mn (mg/kg)	75.90 ± 1.90	72 ± 2	246 ± 8	250 ± 6
Ni (mg/kg)	2.14 ± 0.10	2.05 ± 0.15	1.59 ± 0.07	1.60 ± 0.10
Zn (mg/kg)	82 ± 3	81.75 ± 0.70	30.90 ± 0.70	30 ± 0.50
Cr (mg/kg)	-	-	1.99 ± 0.06	2 ± 0.10
Cu (mg/kg)	12.20 ± 0.60	12 ± 0.50	4.70 ± 0.14	4.60 ± 0.12
Cd (mg/kg)	2.89 ± 0.70	2.90 ± 0.25	1.52 ± 0.04	1.50 ± 0.06

Table 2: Comparison of certified values with the observed values for different elements analyzed by AAS.

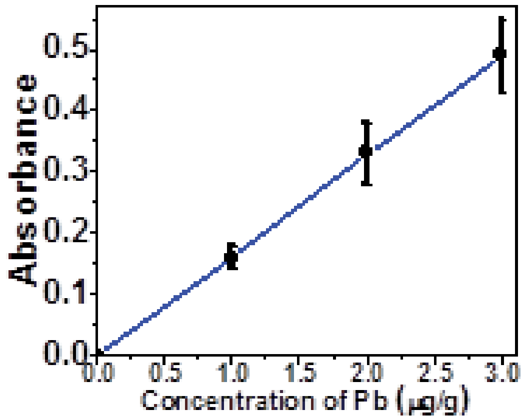

Figure 1: Calibration curve for determination of lead using flame atomic absorbance spectrometry.

higher concentration of K as compared to other elements and cabbage has the highest concentration of Ca followed by K and Na as evident in our results also. Abbasi et al. [28] had determined the concentration of various trace elements in wild leafy vegetables where they have found out that concentration of Fe is higher followed by Zn and Mn. We have made similar observations in this study. This is due to the fact that the uptake characteristics of the vegetables may be similar in different geological regions.

Estimation of daily dietary intake and estimated dietary intake for trace elements

Daily dietary intake (DDI) and estimated dietary intake (EDI) have been calculated in this study to ascertain whether the intake of these vegetables is safe for the population in this region. USEPA has given a reference dose (RfD) value for different trace and toxic elements exceeding which an elemental level will be considered to be detrimental. The DDI of elements for adults was determined using the

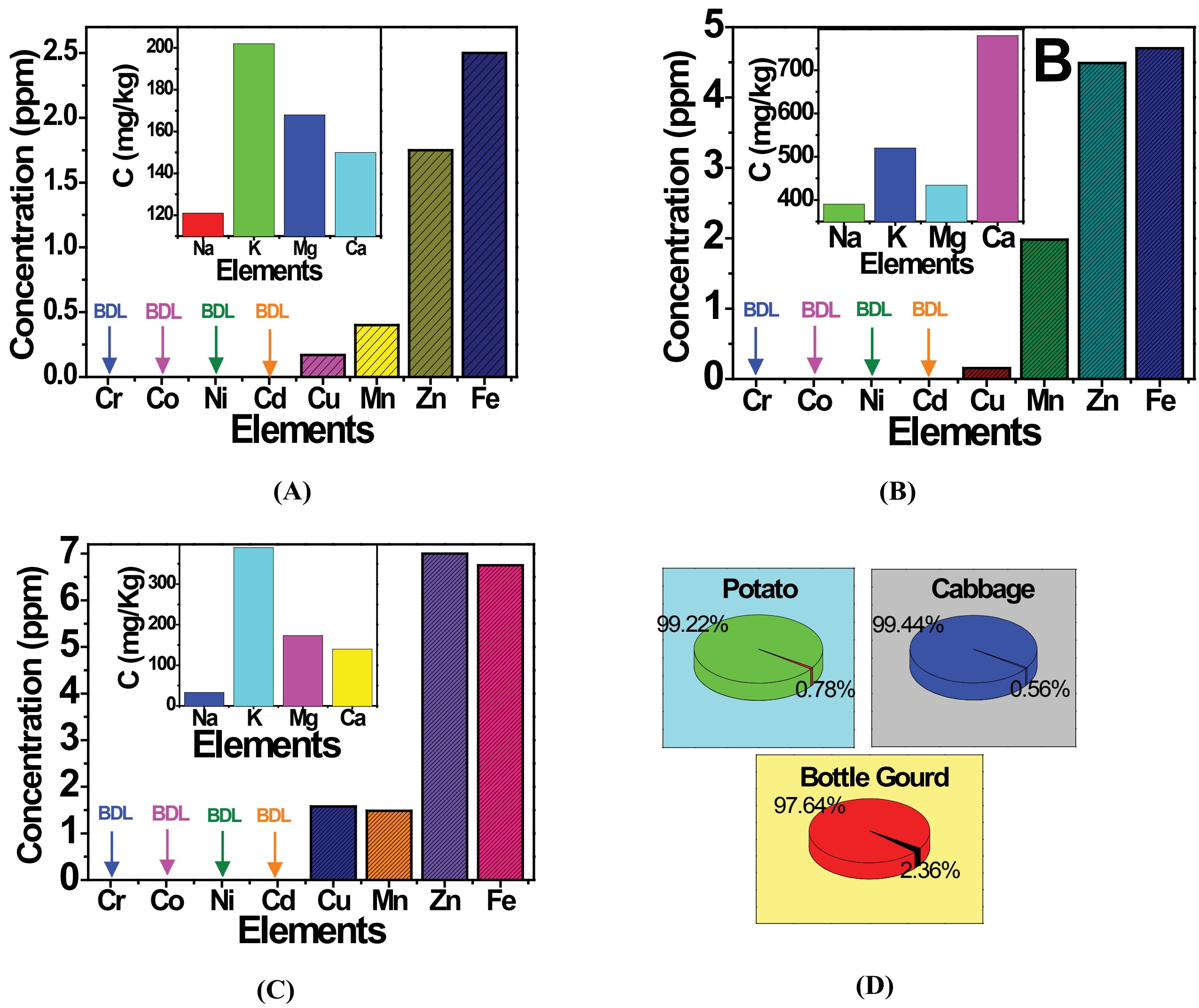

Figure 2: Concentration of trace elements in different vegetables (A) Potato (B) Cabbage (C) Bottle Gourd. Figure A, B, C inset shows the concentration of major elements in respective vegetable. (D) A comparison of concentration of analyzed trace elements with essential elements in potato, cabbage and bottle gourd.

following equation:

$$DDI = C_{vegetable} \times I_{vegetable} \quad (1)$$

Where, $C_{vegetable}$=Trace element concentration in vegetable (µg/kg), $I_{vegetable}$=Daily per capita vegetable consumption (kg/day). The national intake rate of potato considered in this study was 36.4 kg/year [24] while cabbage and Bottle Gourd has an intake rate of 7.34 kg/year and 7.03 kg/year respectively [24]. Based on these values DDI value for all the elements in all three vegetables were calculated and result are shown in Table 4.

EDI (Estimated Dietary Intake) for each element was calculated as

$$EDI = DDI/BW \quad (2)$$

Where, BW=average body weight of 70 kg considered for the target population [29,30]. A comparison between EDI and RfD value will give an idea whether there is any risk by the ingestion of these vegetables or not. Estimated Dietary Intake and Hazard quotient for all different elements in all three vegetables is shown in Table 4.

It is clear from Table 4 that estimated dietary intake values for different elements in different vegetables is less than the reference dose value which shows that these vegetables contribute only a small fraction of the total essential elements requirement in the body. This is expected because the balanced diet of an individual will include cereals, pulses, milk and other food too. Earlier [31] had determined the concentrations of cadmium, lead, mercury and arsenic in Chinese market milled rice and they found that health risk associated with the intake of a single element through consumption of rice was absent. Roychowdhury et al. [32] investigated the concentration of arsenic, copper, nickel, manganese, zinc and selenium in foodstuffs and drinking water. They have found that most of the individual food composites contain a considerable amount of arsenic because the shallow large diameter tubewells, installed for agricultural irrigation contain an appreciable amount of arsenic. However the concentration of other metals was less than the limits given by USEPA. Sivaperumal et al. [33] had determined the heavy metal concentration in fish, shellfish and fish product using an atomic absorption spectrometer where the concentration is less than the maximum residual levels prescribed by the EU and USFDA and is safe for human consumption. Alvarenga et al. [34] determined the concentration of total As, Cu, Pb, and Zn in the soils and in three different vegetables, lettuce (*Lactuca sativa*), coriander (*Coriandrum sativum*), and cabbage (*Brassica oleracea*) collected from the same location. They found that the soils were contaminated with As, Cu, Pb, and Zn however the estimated daily intake (EDI) for Cu and Zn, through the consumption of these vegetables, falls below the recommended upper limit for daily intake of these elements which is due to less transfer of these elements from soil to the plant. Similarly Singh et al. [35] determined the concentration of various elements in cereals, vegetables and spices where they have shown that potato does not have high concentration of any essential elements.

It is to be noted that RfD value for the essential elements like Na, K, Ca, Mg has not been given by USEPA because reference value is defined only for toxic elements. However average daily levels of sodium intake for adult range from 2 to 5 g [36] which is much less than the concentration found in the analyzed vegetables. This is expected since these vegetables comprise only a portion of the total human diet and remaining fraction of essential elements will come from the other part of human diet which includes cereal, pulses etc. [37-43].

Elements	Potato (N=5)	Cabbage (N=5)	Bottle guard (N=5)
Na (mg/kg)	121 ± 10	390 ± 30	33 ± 3
K (mg/kg)	202 ± 15	520 ± 35	390 ± 30
Mg (mg/kg)	168 ± 12	434 ± 35	173 ± 10
Ca (mg/kg)	150 ± 12	780 ± 50	140 ± 11
Fe (mg/kg)	2.50 ± 0.20	4.70 ± 0.39	6.75 ± 0.42
Co (µg/kg)	<0.50	<0.50	<0.50
Mn (mg/kg)	0.40 ± 0.03	1.98 ± 0.19	1.48 ± 0.13
Ni (µg/kg)	<0.50	<0.50	<0.50
Zn (mg/kg)	1.75 ± 0.15	4.49 ± 0.37	7 ± 0.60
Cr (µg/kg)	<0.50	<0.50	<0.50
Cu (mg/kg)	0.17 ± 0.01	0.16 ± 0.015	1.56 ± 0.13
Cd (µg/kg)	<0.50	<0.50	<0.50

Table 3: Concentration of elements in Potato, Cabbage and Bottle Guard.

Elements	DDI_{Potato}	$DDI_{Cabbage}$	$DDI_{Bottle\ Gourd}$	EDI (P)	EDI(C)	EDI(BG)	RfD
Na	12067 ± 997	7842 ± 604	638 ± 57.80	172 ± 14.2	112 ± 8.63	9.11 ± 0.83	
K	20,145 ± 1495	10,457 ± 704	7543 ± 578	287 ± 21.3	149 ± 10.0	107 ± 8.26	
Mg	16,754 ± 1197	8727 ± 704	3346 ± 193	239 ± 17.1	124 ± 10.0	47.8 ± 2.76	
Ca	14,252 ± 1197	15,685 ± 1005	2708 ± 212	203 ± 17.1	224 ± 14.3	38.7 ± 3.03	
Fe	249.2 ± 19.94	94.5 ± 7.80	13 ± 8.10	3.56 ± 0.28	1.35 ± 0.11	1.86 ± 0.12	700
Co	0.06	5×10^{-3}	4.8×10^{-3}	8.57×10^{-4}	7×10^{-5}	6.9×10^{-5}	0.3
Mn	15.95 ± 2.98	39.8 ± 3.80	28.6 ± 2.50	0.23 ± 0.04	0.57 ± 0.05	0.41 ± 0.04	140
Ni	0.06	5×10^{-3}	4.8×10^{-3}	8.57×10^{-4}	7.00×10^{-5}	6.90×10^{-5}	50
Zn	174.64 ± 14.95	90.3 ± 7.40	135 ± 11.56	2.49 ± 0.21	1.29 ± 0.11	1.93 ± 0.17	300
Cr	0.06	5×10^{-3}	4.8×10^{-3}	8.57×10^{-4}	7.00×10^{-5}	6.90×10^{-5}	3
Cu	16.93 ± 1.96	3.11 ± 0.29	30.3 ± 2.31	0.24 ± 0.03	0.04 ± 0.01	0.43 ± 0.03	40
Cd	0.06	5×10^{-3}	4.8×10^{-3}	8.57×10^{-4}	7.00×10^{-5}	6.90×10^{-5}	0.001

Table 4: Daily dietary intake (DDI) (µg/day), Estimated Dietary Intake (EDI) (µgday^{-1}kg^{-1}) for different elements in all three vegetables. Reference dose (µgday^{-1}kg^{-1}) established by USEPA [39,40].

Conclusion

In the present study, three different vegetables from APMC market, Navi Mumbai were analysed for both major and minor elements. The concentration of Na varies from 33 mg/kg to 390 mg/kg while concentration of Ca varies 140 mg/kg to 780 mg/kg. Concentration of Fe is 2.5 ± 0.2 mg/kg to 6.75 ± 0.42 mg/kg in different vegetables. Essential element concentration is found to be least in Potato while it is highest in Cabbage. DDI and EDI are calculated and it is compared with the RfD values. It has been seen that for all the elements the concentration is less than the RfD values which suggests that the food is safe to eat and these vegetables are fit for human consumption.

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