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ORIGINAL ARTICLE

Trace elements in market vegetables of Kuantan, Pahang: A preliminary estimate of dietary exposure

N.W. Sulong [1], , N. Zaharudin[1], and J.H. Tay[1,*]
[1]Faculty of Industrial Sciences & Technology, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia

ABSTRACT – A pilot study was conducted to investigate the concentrations of ten trace elements: Copper (Cu), iodine (I), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), zinc (Zn), arsenic (As), cadmium (Cd) and lead (Pb) in nine ready-to-eat market vegetables collected from Kuantan, Pahang. Samples of vegetables were obtained from a local market, acid-digested using open digestion method and then analysed for elements using Inductively Coupled Plasma - Mass Spectrometry (ICP-MS). The mean concentration of essential elements decreased in the following order: Mn>Zn>Mo>Cu>I>Ni>Se, with individual concentrations ranging from below detection limit (bdl) to 207 mg/kg dw. Cadmium, a non-essential element, was detected in 8 samples at a mean concentration of 0.06 mg/kg dw, while Pb and As were not detected (bdl) in all samples. The estimated daily dietary intake (EDI) as well as the potential health risk associated with vegetable consumption were calculated. Hazard quotient (HQ) values less than one were obtained for both children and adults, indicating that consumption of these vegetables poses low risk to health..

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INTRODUCTION

Food safety is a major public health issue as food is one of the most important sources of sustenance for humans. Fresh vegetables, as important sources of nutrients, minerals and fibre, may constitute a significant portion of a healthy human diet [1]. Vegetables are recognised as important sources of nutrients for human dietary intakes because they contain a variety of nutrients such as potassium, vitamins, fibre and minerals. Consuming vegetables, whether raw or cooked, benefits human development and aids in the prevention of many diseases [2]. Zn, Cu, Mn, Mo, Se and I are examples of essential elements required in a trace amount for normal human body metabolism. They are the primary components of enzymes, proteins as oxygen transporters, transcription factors and also act as detoxifying enzymes in the human body [3]. A high concentration of non-essential elements such as Cd, As and Pb, on the other hand, can be harmful to living organisms, humans and animals [4]. These metals may be deposited on the surface of vegetables and be absorbed into their various tissues, or they may be absorbed from soil and water and accumulate in vegetables. Toxic element accumulation may be greater in vegetables grown in contaminated fields [5].

Because of the potential toxicity and persistence of trace elements, as well as the frequency with which vegetables are consumed, it is necessary to analyse these food items to ensure the levels of contamination. Therefore, the objective of this study is to determine the concentration of selected trace elements in market vegetables collected from Kuantan, Pahang, using the ICP-MS technique, as well as to evaluate potential health risk to consumers by estimating the dietary intake through vegetable consumption.

MATERIALS AND METHODS

Sample collection and preparation

Nine different types of vegetables that are commonly consumed by the local community (Table 1) were obtained from a local market located in Kuantan, Pahang (3.8168°N, 103.3317°E). Most of the vegetables were cultivated locally, except for cabbage. About 1 kg of the fresh samples were thoroughly washed with tap water and rinsed with deionized water, before being cut into small pieces and dried in an oven at 55°C for 24 hours. Dried samples were ground into powder using a mortar and pestle and stored in clean plastic bags until analysis.

*CORRESPONDING AUTHOR | J.H. Tay | ✉ tayjoohui@ump.edu.my

Table 1. Description of the vegetable samples.

Common name	Local name	Scientific name
Green amaranth	Bayam hijau	*Amaranthus viridis*
Choysum	Choysum	*Brassica chinensis var. parachinensis* or *Brassica rapa var. parachinensis*
Chinese Kale	Kailan	*Brassica oleracea var. alboglabra*
Water Spinach	Kangkung	*Ipomea aquatica*
Lettuce	Salad	*Lactuca sativa*
Cabbage	Kobis	*Brassica oleracea var. capitata*
Chives	Kucai	*Allium schoenoprasum*
Pakchoi	Pakchoi	*Brassica rapa subsp. Chinensis*
Indian Mustard	Sawi	*Brassica junsea*

Elemental analysis

About 1g of powdered sample was acid digested with 6 mL of nitric acid and 2 mL of hydrogen peroxide (H_2O_2) using an open digestion method. The solution was heated to 95°C for 45 minutes. After cooling, the solution was filtered through a 5C Whatman filter paper, diluted to 50 mL in a volumetric flask with deionized water, and stored in the refrigerator at 4°C until instrumental analysis. For each batch of digestion, one reagent blank was included. Concentrations of Cu, Cd, Zn, Ni, Mn, Se, I, Mo, Pb, and As were determined using an ICP-MS (Perkin-Elmer NexIon 300X). A five-point external calibration standards ranging between 10 to 160 µg/L was prepared from ICP multi-element standard solution obtained from Merck. The concentrations of elements in vegetable samples were expressed in mg/kg dry weight (dw). The instrumental detection limits were determined as 36.3 µg/L for Zn, 0.73 µg/L for Se, 1.98 µg/L for Ni, 0.02 µg/L for Mo, 2.15 µg/L for Mn, 0.51 µg/L for I, 0.44 µg/L for Cu, 7.26 µg/L for Pb, 0.03 µg/L for Cd and 0.05 µg/L for As.

Health risk assessment

The estimated daily dietary intake (EDI) (ng/kg bw/day) of trace elements was calculated using the following equation:

$$\mathrm{EDI} = \frac{C_{metal} \times C_{factor} \times D_{intake}}{B_{weight}} \tag{1}$$

where C_{metal} is the elemental concentration in vegetables (ng/kg dw), C_{factor} is the conversion factor of 0.208 for dry weights to fresh weight [6], D_{intake} is the daily intake of vegetables in g/day (17 g/day for children and 34 g/day for adults) [7] and B_{weight} is the average body weight in kg (69.2 kg for adults and 15.6 kg for children) [7].

Hazard Quotient (HQ) was calculated by dividing the EDI with the oral reference dosage (RfD, mg/kg bw/day), based on the following equation:

$$HQ = \frac{EDI}{RfD} \tag{2}$$

RESULTS & DISCUSSION

Figure 1 showed the concentrations of trace elements in vegetable samples. The concentrations of trace elements in vegetables varied by species. Mn, Zn and Mo are the most abundant elements in all samples studied. Water spinach had the highest Mn content (207 mg/kg), followed by green amaranth (113 mg/kg). The high ability of leafy vegetables to absorb metals is possibly due to the leaves being the primary component of photosynthesis, where metals are carried to the leaves by mass flow during strong transpiration [8]. Besides that, water spinach and green amaranth are both dwarfish plants with leaves that are closer to the ground, easily exposing the foliage to contaminated soil.

Zn concentrations ranged from 7.92 mg/kg (chinese kale) to 63.6 mg/kg (green amaranth), with a mean concentration of 32.72 mg/kg. Zn is an essential element for plant growth and is frequently found in the vegetables because it easily moves from soils to vegetable edible sections via root absorption [9]. Mo was found in high concentration in Indian mustard (102 mg/kg) but in low concentration in lettuce (4.17 mg/kg). The levels of Zn found in this study were within the range reported in Kuching, Sarawak (28 – 92.33 mg/kg) [10], Kundasang, Sabah (21.5 – 100.5 mg/kg) [11], India

(23.6 – 137.6 mg/kg) [3] and Southern Italy (1.60 – 7.60 mg/kg) [12]; whereas Mn and Mo levels were higher in this study compared to those reported in Italy [12] and India [3].

Iodine were only detected in chives, water spinach and green amaranth with concentrations ranging from 1.63 to 20.0 mg/kg. Copper level in water spinach was high (7.37 mg/kg) but low in chinese kale (0.53 mg/kg). Selenium concentration, on the other hand, were consistent across all samples (ranging from 0.29 to 0.41 mg/kg).

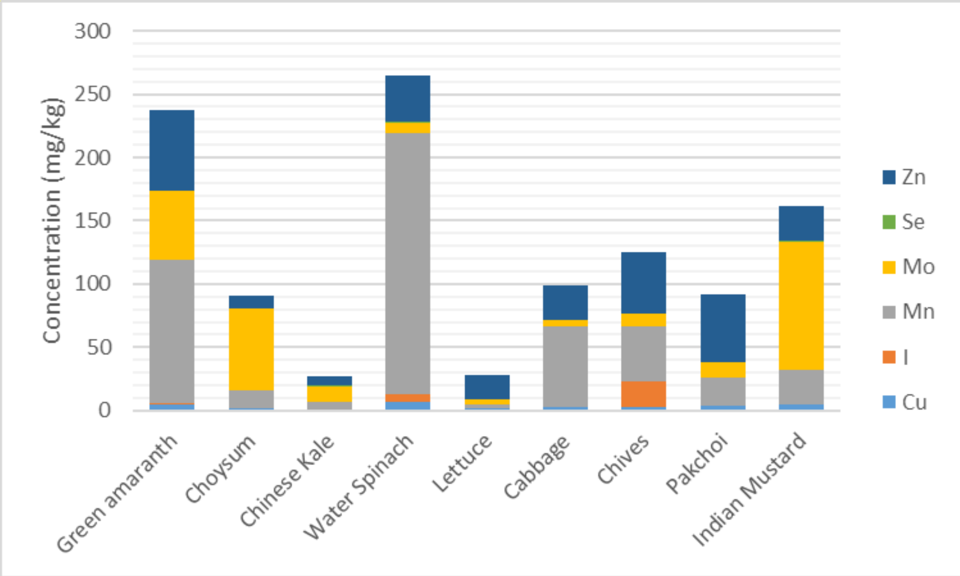

Figure 1. Concentration of trace elements (mg/kg dw) in vegetables.

Non-essential elements Pb and As were not detected in all samples. Chives and Indian mustard had higher Ni content (4.56 and 4.73 mg/kg, respectively) than other vegetables (concentration ranged from 0.08 to 1.69 mg/kg). The levels of Ni found in vegetable samples of this study were within the range of those reported in the literature [3, 8, 12]. Except for chinese kale and lettuce, Cd were detected in the majority of samples, with concentrations ranging from 0.01 mg/kg (cabbage) to 0.16 mg/kg (choysum) (Figure 2). The presence of Cd in vegetable samples is probably due to root absorption [13]. Cd concentrations measured in this study were slightly higher than those reported for Indian mustard and water spinach in Bangi [13] but lower than those reported for pakchoy and choysum in Jengka, Pahang [14]; as well as choysum collected from Kg. Sitiawan, Manjung, Perak [15]. The levels of Cd measured in this study were much below the threshold set in the Malaysian Food Act (1983) and Regulations (1985) of 1.00 mg/kg [16].

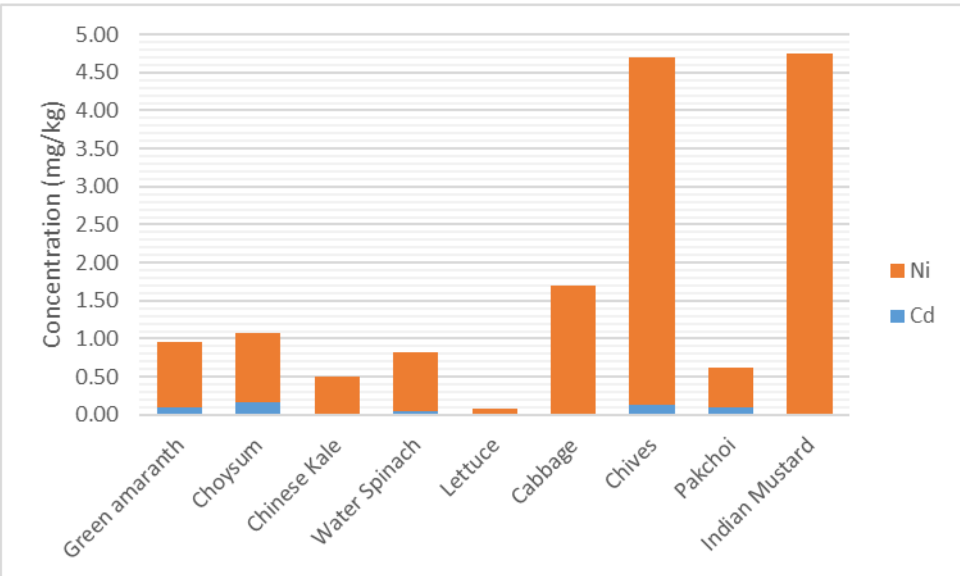

Figure 2. Concentration of Ni and Cd (mg/kg dw) in vegetables.

The EDI of eight elements (expressed as ng/kg bw/day) was calculated based on the concentration of each element in each vegetable (Table 2). Results revealed that water spinach had the highest total EDI of the elements studied, particularly Mn and Cu, followed by green amaranth and Indian mustard. Individual elements EDIs in vegetable samples ranged from 0.35 to 21200 ng/kg bw/day and 0.78 to 46900 ng/kg bw/day for adults and children, respectively. The adult EDI values obtained for Zn in pakchoi, green amaranth and water spinach samples analysed in this study (Table 2) are lower than that reported in a previous study conducted at Ara Kuda, Penang and Seremban, Negeri Sembilan (36.0, 27.1 and 7.34 µg/kg bw/day, respectively) [7].

Table 2. Estimated daily intake (EDI) (ng/kg bw/day) of trace elements in the analysed samples.

Vegetables	Cu		I		Mn		Mo		Ni		Se		Zn		Cd	
	AD	CH	AD	CH	AD	CH	AD	CH	AD	CH	AD	CH	AD	CH	AD	CH
Green amaranth	471	1040	167	370	11600	25700	5540	12300	87.9	195	34.6	76.8	6500	14400	9.18	20.4
Choysum	194	430	-	-	1450	3210	6570	14600	93.6	208	32.9	73.0	1000	2220	16.4	36.5
Chinese Kale	54.6	121	-	-	605	1340	1310	2910	51.6	114	29.5	65.4	810	1800	-	-
Water Spinach	752	1670	536	1190	21200	46900	820	1820	80.4	178	39.3	87.2	3780	8380	4.23	9.37
Lettuce	219	486	-	-	260	576	428	946	7.96	17.7	31.2	69.3	1920	4260	0.35	0.78
Cabbage	268	593	-	-	6500	14400	536	1190	173	383	33.6	74.6	2810	6240	1.14	2.53
Chives	309	685	2030	4500	4510	10000	979	2170	466	1030	41.8	92.7	4940	11000	13.7	30.3
Pakchoi	395	876	-	-	2270	5030	1200	2670	51.9	115	33.8	74.9	5500	12300	10.7	23.6
Indian Mustard	471	1040	-	-	2790	6190	10400	23100	484	1070	31.3	69.4	2830	6280	1.59	3.52

AD: Adults, CH: Children, -: not detected therefore no EDI was calculated

The mean EDI of each element through the consumption of vegetable and the corresponding RfD (mg/kg bw/day) were used to quantify the HQ (Table 3). Results showed that Mo had the highest HQ value, followed by I, Mn, Zn, Ni, Cd, and Se. In general, children had higher HQ values than adults. Except for Mo (children), HQ values were less than one for all measured elements, indicated that exposure to most elements through vegetable consumption poses a low health risk. Despite the fact that HQ>1 was obtained for Mo, the value is not concerning because our dietary intake estimation was based on average Mo concentrations in 9 different vegetable samples. The actual daily intake varies according to the type of vegetable consumed. On the other hand, the reference value represents a tolerable life-long daily intake, and if the relatively high intake calculated here occurs only for a short period of time, no adverse health effects are expected. Our HQ values for Cu, Ni, Mn, Cd and Zn are significantly lower than those reported in the western region of Saudi Arabia where the vegetables were irrigated with sewage water [5], as well as that for Cd, Zn and Cu in leafy vegetables cultivated near industrial areas of Shanghai, China [9].

Table 3. Hazard Quotient (HQ) for each studied element.

Elements	US EPA RfD (mg/kg bw/day) [17]	HQ		Risk
		Adults	Children	
Cu	Not evaluated	-	-	No
Cd	0.001	6.36E-03	1.41E-02	No
Zn	0.3	1.11E-02	2.47E-02	No
Ni	0.02	8.31E-03	1.84E-02	No
Mn	0.14	4.06E-02	9.00E-02	No
Se	0.005	6.85E-03	1.52E-02	No
I	0.017*	1.79E-02	3.97E-02	No
Mo	0.005	6.20E-01	1.37	Children at risk

*: maximum tolerable daily intake from WHO [18].

CONCLUSION

The present study used open acid digestion and ICP-MS to determine the concentration of selected elements in vegetables purchased from local market of Kuantan, Pahang. Results showed that the vegetables contained Cu (0.53 – 7.37 mg/kg), Cd (0.01 – 0.16 mg/kg), Zn (7.92 – 63.6 mg/kg), Ni (0.08 – 4.73 mg/kg), Mn (2.54 – 207 mg/kg), Se (0.29 – 0.41 mg/kg), I (1.63 – 20.0 mg/kg) and Mo (4.17 – 102 mg/kg). Pb and As were not detected in all samples. Dietary intake estimation and health risk assessment based on raw vegetables revealed low health risk of exposure to the consumers. In reality, majority of these vegetables are consumed in cooked form, which may further reduce their trace element content and lower their risk of consumption. This study, however, has several limitations. Firstly, only a small sample size was used (n = 9), and all of them were purchased from the same local market. This could lead to a bias in the results. The digestion efficiency using an open digestion method was not evaluated using standard reference materials. As a result, we may have underestimated actual dietary exposure to these elements through vegetable consumption. In addition, a single conversion value of vegetable's dry weight to fresh weight was applied in the calculation of daily intake. Experimentally determined moisture content values would be more accurate since they vary by vegetable. As a result, a more comprehensive future study is recommended to evaluate the dietary intake of trace elements from different types of fruits and vegetables grown in Pahang farmlands.

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