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Research Article

Determination of Elements in Indigenous Vegetables Using ICP-MS

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ABSTRACT

Determination of elements in indigenous vegetables is important as source of dietary that are essential for human consumption. Heavy metal concentrations were determined in indigenous vegetables collected in Erbil city-Kurdistan region of Iraq. ICP-MS was applied to determine total concentrations of Al, Co, Fe, Mn, Ni, Se and Zn in *Malva parviflora, Gundelia tournefortii*, *Arum* spp, *Spinacia oleracea*, *Mentha longifolia*, *Beta vulgaris* subsp, *Apium graveolens*, *Lepidium sativum L*, *Allium Kurrat. Schweinf* and *Allium fistulosum* after acid digestion of the samples with the aid of microwave using nitric acid/hydrogen peroxide. The contents of heavy metals in vegetable samples varied between 40 and 451 for Al, 0.04 and 0.96 for Co, 53 and 247 for Fe, 3.37 and 11.58 for Mn, 0.26 and 5.53 for Ni, 0.09 and 0.98 for Se and 1.58 and 4.41 for Zn on the basis of dry weight. The methodology was validated by certified reference material GBW10015-spinach and inductively coupled plasma mass spectrometry analysis. The levels of Al, Mn, and Ni in some investigated vegetables are higher than the permissible limits for human consumption.

Keywords: Heavy metals, ICP-MS, indigenous vegetables, microwave acid digestion, validation

INTRODUCTION

Recently, more attention has been paid to cumulating of heavy metals and metalloids in vegetables. Vegetables can be exposed to environmental pollution more than other food systems because of loading vegetables into the air. The accumulation and taken up of heavy metals by vegetables in eatable and non-eatable fractions at a certain quantity may lead to health concerns to both living organisms and humans.[1]

Food safety concerns may occur because of phytotoxicity and absorption of high levels of heavy metal by vegetation resulted from transferring high levels of these heavy metals from agriculture soils.[2,3] Bioaccumulation high quantity of toxic heavy metals in vegetables can cause the deficiency of nutrients of dietary to human beings or may cause health issues for both human beings and ecosystem.[4-7]

Heavy metals can be categorized into vital metals (Fe, Mn, Cu, Se, Zn and etc.), possibly essential (Ni, V, and Co) and conceivably toxic (As, Cd, Pb, Hg, etc.). Essential metals play a major role for living organisms if they exist at low or high quantity, while exposures to toxic metals may harm even at low level for long-term exposure. Exposure to toxic metals can cause various serious health issues with changing degree of harshness and circumstances such as issues of kidney, neurobehavioral and developmental disarrange, hypertension, and probably cancer.[8-13] Furthermore, numerous of nervous, cardiovascular, renal, neurological deterioration in addition bone illness and many other health issues may occur because of high content exposure of metals beyond Maximum Permissible Level (MPL).[1,14]

Humans consume vegetables in both cooked and raw forms because they are considered as an essential part of their diet. Vegetables function as acid generation throughout digestion and some available metals in vegetables are even vital biochemically and psychologically from health prospective.[15]

Although Al is relatively low bioavailable, it has been suggested that there is a connection between aluminum and Alzheimer's disease.[16] Human metabolism can be regulated via metals including, Co, Fe, Mn, Se, and Zn. Mn is one of the important components of many enzymes exist in human and considered an essential element functions as an activator. Although Co and Ni are vital for human beings, higher levels than the recommended values lead to metabolic abnormal.[1]

This study was conducted to evaluate the contents of heavy metals found in various edible indigenous vegetables.

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EXPERIMENTAL

Chemicals and Reagents

All chemical compounds utilized in this work were of high purity reagent and Milli-Q water (18MΩcm) was used to prepare all solutions. A standards stock solution of concentration 100 µg mL^{-1} in 5% Nitric acid (HNO_3) for Al, Co, Fe, Mn, Ni, Se, and Zn was obtained from CPI international, USA. HNO_3 70% reagent was ordered from Merck (Germany) and used to digest vegetable samples to obtain extracts of Al, Co, Fe, Mn, Ni, Se, and Zn. Hydrogen peroxide (H_2O_2) 37% was purchased from Fischer Scientific, United Kingdom. A certified reference material (Spinach GBW10015) was supplied by the Institute of Geophysical and Geochemical Exploration, Langfang, China. All glasswares used in this work then rinsed with Milli-Q water followed by soaking it in HNO_3 acid before use.

Instrumentation

Inductively coupled plasma mass spectrometry (ICP-MS, Perkin-Elmer SCIEX ELAN 6100 DRC II) was applied to identify the total elements (Al, Co, Fe, Mn, Ni, Se, and Zn) in the analyzed vegetable samples.

The instrument was supplied with a Sturman-masters spray chamber and a V-groove quartz concentric nebulizer for sample induction. In concise, the optimum parameters of the instrument were a Radio frequency power of 1250 W with Ar flow rates of 13, 0.8 and 0.95 L min^{-1} for cool, auxiliary, and sample gas, respectively. For the experimental results, the intensity of the following isotopes was measured: ^{55}Mn, ^{59}Co, ^{27}Al, ^{56}Fe, ^{60}Ni, ^{66}Zn, and ^{78}Se. Possible interferences were eliminated using collision cell technology and also 7 % H_2 in He gaseous with average flow rates of 3.4 ml. min^{-1} was used. Internal standards such as Indium (In) and iridium (Ir) were used for all vegetable samples at 10 µg L^{-1} (final concentration).

Sampling and Sample Preparation

A vegetable samples were purchased from the local markets located in Erbil, Kurdistan Region of Iraq in 2021. The common and scientific names of analyzed vegetables are presented in Table 1. All samples were rinsed with Milli-Q water and placed in a sealed plastic box. A freeze drier was used to dry all vegetable samples for 48 h at −40°C. A fine powder of vegetable samples with 180 µm size obtained by sieving of grounded samples using agate pestle and mortar.

Determination of Total Metals in Vegetable Samples

0.2g of freeze-dried vegetable samples was weighted in Teflon vessels with Teflon covers, 5 mL HNO_3 (70%) and 2 mL H_2O_2 (30%) were added. The vegetable samples were acid digested using MARS X-press (CEM, USA) microwave using a previous method by Sadee *et al*.[17] The applied digestion program was as follows: vegetable samples were digested using the microwave for 43 min at 1600 W. Initially, the temperature was raised up to 160°C in 15 min and stayed at this temperature for 5 min. Then, the temperature ramped from 160 to 200°C over 8 min and stayed at this temperature for 15 min. The Teflon vessels were left to cool at room temperature. After digestion, vegetable samples were transferred into a volumetric flask (25 mL capacity), fortified with internal standards of In and Ir with an ultimate contents of 10 µg L^{-1} and made up to final volume (25 mL) with 2% (v/v) HNO_3 using Milli-Q water. Total metals in selected vegetables were determined utilizing ICP-MS. GBW10015-spinach certified reference (CRM) material was applied validation of the method.

RESULTS AND DISCUSSION

Figures of Merit

The slop of the applied calibration curve was used to calculate the detection limit (DL) of the ICP-MS instrument (µg g^{-1}) and 3 times standard deviation of 10 measurements of blank value. The results of DL quantities of the ICP-MS are presented in Table 2.

Validation of Analytical Method

In order to check the quality control of used procedures, total Al, Co, Fe, Mn, Ni, Se, and Zn were quantified in GBW10015-spinach. The results for, total Al, Co, Fe, Mn, Ni, Se, and Zn contents in the CRM are tabulated in Table 3. The elemental contents resulted from the experiment were in well agreement with the certified quantities (the recovery of examined elements ranged from 94% to 105%).

Table 1: Vegetables English common name and scientific name of collected samples

Common English name	Scientific name
Mallow	*Malva parviflora*
Sunflower	*Gundelia tournefortii*
Arum	*Arum* spp
Spinach	*Spinacia oleracea*
Wild mint	*Mentha longifolia*
Chard	*Beta vulgaris* subsp
Celery	*Apium graveolens*
Garden cress	*Lepidium sativum* L
Leek	*Allium Kurrat Schweinf*
Spring onion	*Allium fistulosum*

Table 2: Limit of detection for Al, Co, Fe, Mn, Ni, and Se ($\mu g\ g^{-1}$ dry weight) measured as the mean+3 SD of the signal of method blank

Metals	Concentration $\mu g\ g^{-1}$
Al	0.03
Co	0.03
Fe	0.02
Mn	0.02
Ni	0.03
Se	0.05
Zn	0.02

Total Metal Determinations in Vegetables

The averaged results of heavy metal concentrations in selected varieties of indigenous vegetables based on dry weight are shown in Table 4 and the literature reported values from various origin of the world from corresponding vegetables are listed in Table 5.

Aluminium

The concentration of Al in this study ranged from 40 to 451 μg g^{-1} [Table 4]. The lowest concentration of Al in analyzed vegetables was found in *Malva parviflora* with 40 μg g^{-1}, while the maximum level of Al was detected in *Spinacia oleracea* with value of 451 μg g^{-1}. It was noticed that the Al contents in the vegetable samples collected were in increasing order of *M. parviflora* > *Lepidium sativum* L > *Mentha longifolia* > *Apium graveolens* > *Allium Kurrat Schweinf* > *Beta vulgaris* subsp > *Gundelia tournefortii* > *Arum* spp > *Allium fistulosum* > *S. oleracea*. The observed Al concentration in vegetable samples is compared to the literature reported values ranged 0.160–131.640 μg g^{-1} [Table 5]. The values of Al content of each investigated vegetable of the current study higher than that reported for the corresponding vegetables by other researchers. The concentration of Al in vegetables of this study except *M. parviflora* is higher than the maximum permissible dose limit recommended for Al, 60 mg/day.[18,19]

Cobalt

The concentrations of Co in examined vegetables of this study ranged between 0.040 and 0.143 μg g^{-1} [Table 4]. Although the concentration of Co in vegetables of *M. parviflora*, *G. tournefortii* and *L. sativum* L. were below the limit of detection of the method, the highest Co content was found in *A. fistulosum* which was 0.143 μg g^{-1}. The Co levels in the vegetable samples collected were in increasing order of *M. parviflora* ≈ *G. tournefortii* ≈ *L. sativum* L > *A. Kurrat Schweinf* > *A. graveolens* > *Arum* spp > *B. vulgaris* subsp > *S. oleracea* > *M. longifolia* > *A. fistulosum*. The observed literature values of Co were in the range of 0.01 - 3.00 μg g^{-1} [Table 5]. The values obtained for Co vegetables in the current study are lower than that reported in the literature for the same vegetable species except *M. longifolia*, *A. graveolens* and *A. fistulosum*. The concentration of Co in the vegetables of this study is well within MPL of Co for adults, 50 μg/day.[8,19]

Iron

The quantities of Fe varied according to the types of vegetables concentred with quantities between 53 and 247 μg g^{-1} [Table 4]. The minimum and maximum Fe contents of the samples were found to be 53 μg g^{-1} in *B. vulgaris* subsp and 247 μg g^{-1} in *S. oleracea*, respectively. The Fe concentrations in the vegetable samples collected were in increasing order

Table 3: total metal concentration of CRM GBW10015-spinach; all experimental values are calculated in μg g^{-1}, mean±standard deviation (n=3)

Metals	Certified value	Experimental value obtained	Extraction efficiency %
Al	610±60	602±40	99
Co	0.220±0.03	0.229±0.016	104
Fe	540±20	546±42	101
Mn	41±3	42±0.59	102
Ni	0.920±0.012	0.966±0.020	105
Se	0.092±0.024	0.087±0.004	95
Zn	35.300±1.5	33.450±0.449	95

Table 4: Results of analysis for total metal in the selected vegetables dry weight (mean±standard deviation) (n=3)

Vegetable	Al	Co	Fe	Mn	Ni	Se	Zn
	μg g^{-1} ± SD	μg g^{-1} ± SD	μg g^{-1} ± SD	μg g^{-1} ± SD	μg g^{-1} ± SD	μg g^{-1} ± SD	μg g^{-1} ± SD
Malva parviflora	40±0.352	<0.03	58±0.584	4.930±0.044	0.260±0.002	<0.05	4.412±0.030
Gundelia tournefortii	151±1.985	<0.03	100±0.805	3.370±0.003	0.532±0.004	<0.05	3.483±0.028
Arum spp	298±1.640	0.050±0.006	139±0.791	5.330±0.066	1.142±0.007	<0.05	3.092±0.021
Spinacia oleracea	451±5.361	0.960±0.001	247±2.275	9.382±0.099	1.351±0.015	0.090±0.014	4.080±0.035
Mentha longifolia	103±1.102	0.120±0.013	198±3.823	6.731±0.159	1.533±0.019	<0.05	3.691±0.054
Beta vulgaris subsp	140±0.932	0.070±0.002	53±0.341	11.580±0.076	0.564±0.006	0.980±0.031	4.295±0.039
Apium graveolens	124±1.525	0.040±0.001	81±1.020	9.622±0.115	0.812±0.008	<0.05	3.234±0.035
Lepidium sativum L	65±2.191	<0.03	131±0.415	4.183±0.017	0.722±0.004	0.494±0.004	3.195±0.023
Allium Kurrat Schweinf	132±0.633	0.040±0.001	75±0.820	10.891±0.161	0.473±0.005	<0.05	1.588±0.026
Allium fistulosum	334±3.416	0.140±0.003	138±0.305	5.142±0.035	5.533±0.081	0.242±0.015	2.420±0.024

Table 5: Heavy metal concentration in various vegetables in different countries (literature values)

Vegetable	Concentration $\mu g\ g^{-1}$							Location	Sampling period	Reference
	Al	Co	Fe	Mn	Ni	Se	Zn			
Malva parviflora	NA	NA	296	NA	0.000	NA	59	Ethiopia	2012	[21]
Gundelia tournefortii	NA	NA	1952	NA	8.400	NA	820	Iran	Not mentioned	[22]
	NA	NA	NA	8.400	NA	NA	NA	Turkey	2001	[23]
	NA	1.080	408.370	178.530	NA	NA	20.050	Turkey	Not mentioned	[24]
Arum spp	NA	1.4100	166.400	9.900	17.140	NA	9.60	Saudi Arabia	2003	[25]
	131.640	NA	NA	NA	NA	NA	NA	Iran	Not mentioned	[26]
	NA	NA	NA	NA	NA	762	NA	Turkey	Not mentioned	[27]
Spinacia oleracea	NA	0.01	374.700	131.900	0.000	NA 0.177	202.40	Iran	2007	[28]
	570	NA	NA	NA	NA		NA	India	2004	[29]
Mentha longifolia	NA	3	146.300	30.730	21.100	NA	28.100	Saudi Arabia	2003	[25]
Beta vulgaris subsp	NA	0.010	257.300	91.770	0.000	NA	188.000	Iran	2007	[28]
	70	NA	NA	NA	NA	0.020	NA	Finland	2003	[30]
Apium graveolens	NA	0.330	1678	164.300	3.260	NA	100	Iran	2007	[28]
Lepidium sativum L	NA	1.700	118.2	13.840	0.100	NA	17.400	Saudi Arabia	2003	[25]
	0.160*	NA	NA	NA	NA	NA	NA	Sweden	1992	[31]
	NA	NA	NA	NA	NA	2.550	NA	Turkey	2014	[32]
Allium Kurrat Schweinf	50	0.040	28	14	0.280	0.110	16	Finland	2003	[30]

*Wet weight; NA: Not Analysed

of *B. vulgaris* subsp > *M. parviflora* > *A. Kurrat Schweinf* > *A. graveolens* > *G. tournefortii* > *L. sativum* L > *A. fistulosum* > *Arum* spp > *M. longifolia* > *S. oleracea*. In the literature Fe concentration has been documented in the range of 28-1952 µg g^{-1} [Table 5]. The values of Fe varied according to the vegetable species, the concentrations of Fe in this study are lower than the same vegetables reported in the literature except of *S. oleracea*. The results of the present work with the exception of *S. oleracea* are well within the Provisional Maximum Tolerable Daily Intake (PMTDI) of Fe is 0.8 mg/kg bw.[20]

Manganese

The levels of Mn in investigated vegetables of this study ranged between 3.374 and 11.580 µg g^{-1} [Table 4]. The lowest concentration was seen in *G. tournefortii* (3.374 µg g^{-1}) sample while the highest level was 11.580 µg g^{-1} for *B. vulgaris* subsp. The Fe concentrations in the vegetable samples collected were in increasing order of *G. tournefortii* > *L. sativum* L > *M. parviflora* > *A. fistulosum* > *Arum* spp > *M. longifolia* > *S. oleracea* > *A. graveolens* > *A. Kurrat Schweinf* > *B. vulgaris* subsp. The reported literature concentrations of Mn varied from 8.4 to 178.53 µg g^{-1} [Table 5], which are higher than the values obtained for the same vegetables of this investigation. The concentration of Mn in the investigated samples except *M. parviflora*, *G. tournefortii,* and *L. sativum* L is above the recommended intake range of Mn for an adult, 2-5 mg/day.[8]

Nickel

The calculated concentration of Ni in this study was recognized in the range of 0.264–5.532 µg g^{-1} [Table 4]. The lowest level of Ni in this study was found in *M. parviflora* which was 0.264 µg g^{-1}, whereas the highest content of Ni was 5.532 µg g^{-1} for *A. fistulosum*. The Ni contents in the vegetable samples collected were in increasing order of *M. parviflora* > *A. Kurrat Schweinf* > *G. tournefortii* > *B. vulgaris* subsp > *L. sativum* L > *A. graveolens* > *Arum* spp > *S. oleracea* > *M. longifolia* > *A. fistulosum*. The reported literature values of Ni range from 0.1 to 21.1 µg g^{-1} [Table 5]. The contents of Ni in vegetables under study were higher than those corresponding vegetables documented in the literature except *G. tournefortii*, *S. oleracea*, *B. vulgaris* subsp, and *L. sativum* L. The concentration of Ni in vegetables of present work is well above the permissible limit of daily intake of Ni (0.1 mg/day), which is alarming.[18,19]

Selenium

Se was lower than the DL (0.030 µg g^{-1}) in the examined vegetable samples of the current study with the exception for *S. oleracea*, *A. fistulosum*, *L. sativum L.* and *B. vulgaris* subsp were 0.094, 0.241, 0.490 and 0.980 µg g^{-1}, respectively [Table 4]. The literature values of observed concentrations of Se are varying from 0.020 to 762 µg g^{-1} [Table 5]. Except *A. fistulosum*, the results for this study for Se in vegetables under investigation including *S. oleracea*, *A. graveolens*, and *A. Kurrat Schweinf* were lower than the literature values reported for the same corresponding vegetables. The content of Se in *S. oleracea*, *B. vulgaris* subsp, *L. sativum* L, and *A. fistulosum* is higher than the tolerable daily intake of Se which is 55 μg/day.[8]

Zinc

The concentrations of Zn in vegetables under investigation ranged between 1.588 and 4.295 μg g^{-1} [Table 4]. The minimum level of Zn in the analyzed vegetables of the current study was detected in *A. Kurrat Schweinf* which was 1.588 μg g^{-1}, meanwhile the maximum content of Zn in vegetables understudy was detected in *B. vulgaris* subsp (4.295 μg g^{-1}). The Zn concentrations in the vegetable samples collected were in increasing order of *A. Kurrat Schweinf* > *A. fistulosum* > *Arum* spp > *L. sativum L* > *A. graveolens* > *G. tournefortii* > *M. longifolia* > *S. oleracea* > *M. parviflora* > *B. vulgaris* subsp. The reported literature concentrations for Zn are in the range of 9.600–820 μg g^{-1} [Table 5]. This is comparable to the obtained values of this study. The concentration of Zn in investigated samples is well below the PMTDI of Zn, 0.3–1.0 mg/kg bw.[8]

CONCLUSION

The present study has generated data on some of heavy metal profile in common indigenous vegetables consumed in Erbil city located in the Kurdistan region of Iraq. The contents were observed and compared with the literature values that have been reported around the world for the same vegetables. Al, Co, Fe, Mn, Ni, Se, and Zn were measured in vegetables using HNO_3/H_2O_2 microwave-assisted acid digestion followed by ICP-MS. GBW10015-spinach was used to validate the method. Vegetables of this study showed similar ability to accumulate investigated heavy metals as follows: high quantity for both Al and Fe; medium quantity for Zn and Mn and small quantity for both Co and Se. In addition, Al was found to be at high levels in the majority of vegetables of this study, while Se was below the limit of detection in the majority of investigated vegetables. More studies should be taken in order to investigate the high Al contents in analyzed vegetables such measuring “plant available” for absorption or “bioavailable” of total Al in soils that used to cultivate these vegetables.

REFERENCES

1. Y. N. Jolly, A. Islam and S. Akbar. Transfer of metals from soil to vegetables and possible health risk assessment. *Springerplus*, vol. 2, pp. 385, 2013.
2. A. Kabata-Pendias and A. B. Mukherjee. *Trace Elements from Soil to Human*. Berlin: Springer Science and Business Media, pp. 10-11, 2007.
3. P. C. Nagajyoti, K. D. Lee and T. Sreekanth. Heavy metals, occurrence and toxicity for plants: A review. *Environmental Chemistry Letters*, vol. 8, pp. 199-216, 2010.
4. C. O. Ogunkunle, P. O. Fatoba, O. O. Awotoye and K. S. Olorunmaiye. Root-shoot partitioning of copper, chromium and zinc in *Lycopersicon esculentum* and *Amaranthus hybridus* grown in cement-polluted soil. *Environmental and Experimental Biology*, vol. 11, pp. 131-136, 2013.
5. R. A. Wuana and F. E. Okieimen. Heavy metals in contaminated soils: A review of sources, chemistry, risks and best available strategies for remediation. *International Scholarly Research Notices*, Vol. 2011, pp. 1-20, 2011.
6. J. Hu, F. Wu, S. Wu, Z. Cao, X. Lin and M. H. Wong. Bioaccessibility, dietary exposure and human risk assessment of heavy metals from market vegetables in Hong Kong revealed with an in vitro gastrointestinal model. *Chemosphere*, vol. 91, pp. 455-461, 2013.
7. Y. Yang, F. S. Zhang, H. F. Li and R. F. Jiang. Accumulation of cadmium in the edible parts of six vegetable species grown in Cd-contaminated soils. *Journal of Environmental Management*, vol. 90, pp. 1117-1122, 2009.
8. O. D. Uluozlu, M. Tuzen, D. Mendil and M. Soylak. Assessment of trace element contents of chicken products from Turkey. *Journal of Hazardous Materials*, vol. 163, pp. 982-987, 2009.
9. J. Falandysz, A. Frankowska and A. Mazur. Mercury and its bioconcentration factors in King Bolete (Boletus edulis) Bull. Fr, *Journal of Environmental Science and Health, Part A*, vol. 42, pp. 2089-2095, 2007.
10. M. Tüzen. Determinaton of heavy metals in fish samples of the Middle Black Sea (Turkey) by graphite furnace atomic absorption spectrometry. *Food Chemistry*, vol. 80, pp. 119-123, 2003.
11. G. C. Kisku, P. Pandey, M. P. S. Negi and V. Misra. Uptake and accumulation of potentially toxic metals (Zn, Cu and Pb) in soils and plants of the Durgapur industrial belt. *Journal of Environmental Biology*, vol. 32, pp. 831-838, 2011.
12. I. U. Adams and I. U. Happiness. Quantitative specification of potentially toxic metals in expired canned tomatoes found in village markets. *Natural Sciences*, vol. 8, pp. 54-58, 2010.
13. E. Russom, G. Kfle, G. Asgedom and T. Goje. Heavy metals content of spices available on the market of Asmara, Eritrea. *European Journal of Nutrition and Food Safety*, vol. 11, pp. 156-163, 2019.
14. K. Steenland and P. Boffetta. Lead and cancer in humans: Where are we now? *American Journal of Industrial Medicine*, vol. 38, pp. 295-299, 2000.
15. A. Maleki and M. A. Zarasvand. Heavy metals in selected edible vegetables and estimation of their daily intake in Sanandaj, Iran. *Southeast Asian Journal of Tropical Medicine and Public Health*, vol. 39, p. 335, 2008.
16. G. Kfle, G. Asgedom, T. Goje, F. Abbebe, L. Habtom and H. Hanes. The Level of Heavy Metal Contamination in Selected Vegetables and Animal Feed Grasses Grown in Wastewater Irrigated Area, around Asmara, Eritrea. *Journal of Chemistry*, vol. 2020, pp. 1-15, 2020.
17. B. A. Sadee, M. E. Foulkes and S. J. Hill. Obesity before, during, and after pregnancy: A review and comparison of five national guidelines. *Food Additives and Contaminants: Part A*, vol. 33, pp. 433-441, 2016.
18. O. D. Uluozlu, M. Tuzen, D. Mendil and M. Soylak. Assessment of trace element contents of chicken products from Turkey. *Journal of Hazardous Materials*, vol. 163, pp. 982-987, 2009.
19. G. F. Nordberg, B. A. Fowler and M. Nordberg. *Handbook on the Toxicology of Metals*. Cambridge, Massachusetts: Academic Press, 2014.
20. World Health Organization. *Joint FAO/WHO Food Standards Programme* (*Codex Alimentarius Commission*) *39th Session Rome, Italy, 27 June-1 July 2016 and Report of the 10th Session of the Codex Committee on Contaminants in Foods*. Rotterdam, The Netherlands: World Health Organization, 2016.
21. M. M. Ododo and B. K. Wabalo. Determination of Selected Metals in Leaf and Root Bark of Malva Parviflora. *Journal of Natural Sciences Research*, vol. 9, pp. 1-6, 2019.
22. A. Chehregani and B. E. Malayeri. Removal of heavy metals by

native accumulator plants. *International Journal of Agriculture and Biology* (*Pakistan*), vol. 9, pp. 462-465, 2007.
23. M. Turan, S. Kordali, H. Zengin, A. Dursun and Y. Sezen. Macro and micro mineral content of some wild edible leaves consumed in Eastern Anatolia. *Acta Agriculturae Scandinavica, Section B Plant Soil Science*, vol. 53, pp. 129-137, 2003.
24. M. Tuncturk, T. Eryigit, N. Sekeroglu and F. Ozgokce. Chemical composition of some edible wild plants grown in Eastern Anatolia. *American Journal of Essential Oils and Natural Products*, vol. 2, pp. 31-34, 2015.
25. A. Mohamed, M. Rashed and A. Mofty. Assessment of essential and toxic elements in some kinds of vegetables. *Ecotoxicology and Environmental Safety*, vol. 55, pp. 251-260, 2003.
26. H. Shirkhanloo, M. K. Abbasabadi, F. Hosseini and A. F. Zarandi. Nanographene oxide modified phenyl methanethiol nanomagnetic composite for rapid separation of aluminum in wastewaters, foods, and vegetable samples by microwave dispersive magnetic micro solid-phase extraction. *Food Chemistry*, vol. 347, p. 129042, 2021.
27. G. Somer, Ş. Kalaycı and O. Şendil. A new and direct method for the determination of trace elements in spinach using differential pulse polarography. *Journal of Electroanalytical Chemistry*, vol. 778, pp. 49-52, 2016.
28. M. Bigdeli and M. Seilsepour. Investigation of Metals Accumulation in Some Vegetables Irrigated with Waste Water in Shahre Rey-Iran and Toxicological Implications. *American-Eurasian Journal of Agricultural and Environmental*, vol. 4, pp. 86-92, 2008.
29. R. P. Choudhury, A. Kumar and A. Garg. Analysis of Indian mint (*Mentha spicata*) for essential, trace and toxic elements and its antioxidant behaviour. *Journal of Pharmaceutical and Biomedical Analysis*, vol. 41, pp. 825-832, 2006.
30. P. Ekholm, H. Reinivuo, P. Mattila, H. Pakkala, J. Koponen, A. Happonen, J. Hellström and M. L. Ovaskainen. Changes in the mineral and trace element contents of cereals, fruits and vegetables in Finland. *Journal of Food Composition and Analysis*, vol. 20, pp. 487-495, 2007.
31. L. Jorhem and G. Haegglund. Aluminium in foodstuffs and diets in Sweden. *Zeitschrift für Lebensmittel-Untersuchung und-Forschung*, vol. 194, pp. 38-42, 1992.
32. I. Koca and B. Tasci. Mineral Composition of Leek. In: *VII International Symposium on Edible Alliaceae, No. 1143*, pp. 147-152, 2015.