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Distribution of the element quantities in some commonly used vegetables

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Abstract

P and K amounts of the vegetables were characterized to be between 16.11 (lettuce) and 6918.40 (ocra) to 1913.99 (tomatoes) and 27367.55 mg/kg (garlic), respectively. While P content was very low in some vegetables (pepper, cabbage, green beans, chard, potatoes, green onions, onions and lettuce), it was found to be high in vegetables such as okra, garlic and peas. Among the analyzed vegetables, the vegetables containing the highest amounts of Ca were green onion, pepper, garlic, lettuce and chard. The Mg contents of green beans, potatoes, onions, green peppers, carrots, zucchinis, cucumbers and peas were found to be considerably lower than those of other vegetables. Fe and Zn amounts of the fresh vegetables were defined to be between 5.79 (onion) and 205.63 (okra) to 1.94 (onion) and 44.77 mg/kg (okra), respectively. The highest Cu (16.35 mg/kg) and Mn (56.13 mg/kg) and B (41.19 mg/kg) were found in okra and garlic, respectively. The lowest As contents in vegetables ranged from 0.22 to 4.81 mg/kg, while the highest As contents were detected between 8.70 and 34.83 mg/kg. In general, As contents of chard, green onion garlic and pea samples were detected between 30.08 and 34.83 mg/kg. In addition, As contents of fresh bean, okra and zucchini samples were detected between 22.76 and 27.36 mg/kg. In addition, the highest As contents in vegetables were found in Ba chard (22.81 mg/kg) sample, followed by garlic (8.93 mg/kg), purslane (6.74 mg/kg), cabbage (6.59 mg/kg), pepper (4.48 mg/kg) in decreasing order.

Key words: vegetables, macroelement and micro element, toxic element, ICP-OES.

1. Introduction

Vegetables, which are a part of daily nutrition in many homes and constitute an important source of vitamins and minerals necessary for human health, are very rich sources of essential nutrients such as carotene, protein, vitamins, calcium, iron, ascorbic acid and mineral concentration [1]. In recent years, the importance of leafy vegetables in a balanced diet has increased, as less red meat and more vegetables and fruits are recommended for a balanced diet [2]. Green leafy vegetables, which are rich in elements such as carotene, ascorbic acid, retinol, riboflavin, folic acid and calcium, iron, zinc, magnesium, manganese and selenium, have an important place among food products [3]. Plant foods contain indispensable components of human nutrition, providing the body with vitamins, protein, some hormone precursors and energy as well as necessary elements for well-being and health [4]. However, vegetables contribute significantly to macro and micronutrients for health [5]. Vegetables are widely consumed as food because they provide sufficient amounts of vitamins, minerals and fiber [6]. Vegetables can be a good addition to cereals as they are rich in protein, minerals, vitamins and essential amino acids [7]. Since there has recently been an increasing trend towards greater inclusion of green leafy vegetables in the human diet, some of the various green leafy vegetables available for human consumption are limited to a certain region [8]. Carbohydrates, protein, vitamins, calcium, iron, ascorbic acid, trace minerals and phytochemicals constitute the basic nutritional elements of vegetables [1, 9]. As they make significant

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contributions to various metabolic functions in living cells, vegetables are an important source of macro minerals such as Ca, potassium, sodium and magnesium, as well as micro minerals such as Fe, copper, manganese, chromium and zinc [10,11,12].

Contamination of the food chain with harmful elements exposes humans to potentially harmful elements [13]. Potentially harmful element contents in soil, in addition to originating from the parent rock, can also arise from anthropogenic sources. Also, illegal waste deposits, agricultural inputs can increase the contamination of harmful elements to foods [14,15]. Toxic elements, which can cause toxicity problems, accumulate in different parts of plants and have toxic effects [16, 17]. Vegetables grown in unpolluted soil contain heavy metals and have lower heavy metal accumulation than vegetables grown in soil contaminated with various harmful waste [18, 19, 20]. The main factors that cause toxic element accumulation in agricultural products are metal processing industry wastes, pesticides, phosphate and organic fertilizers [21]. Elements are actively involved in the development of biochemical processes that are catalytic, functional and structural [22]. While microelements are generally needed in very small amounts in the body, macroelements are needed in large amounts [22]. The aim of current work was to establish the macro and micro element contents and toxic element accumulation amounts localized in the shell and edible parts of some tuber and bulbous vegetables.

2. Material and methods

Material

Vegetables used in present study were provided from Konya province in 2024 (Fig. 1). Before the analysis, the samples were washed with distilled water, and then they were sliced thinly (2-3 mm thick) with a knife. HNO_3 and H_2O_2 are analytical grade and Merck company (Darmstadt, Germany).

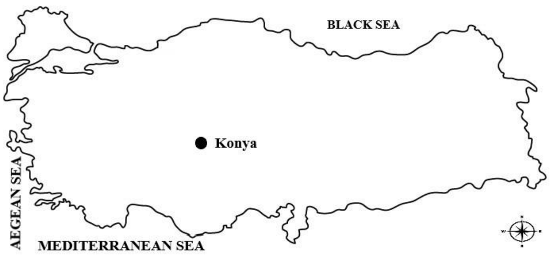

Figure 1. Location where the vegetables used in this study were collected

Element analysis

The samples taken for elemental analyzes in vegetables were washed with tap water, then with pure water, 0.2 N HCl solution, pure water and deionized water, respectively, and were dried with coarse filter papers and then placed in paper bags. Leaf samples were dried in drying cabinet at 70 °C until constant weight. Then, the dried plant samples were ground in a steel blade plant grinding mill. Before the ground plant samples were used in the analysis, samples were taken homogeneously from the plant samples dried in the oven (air circulation drying cabinet) at 70°C until they reached a constant weight, and the weights of these plant samples to be used during burning were determined in grams. Plant samples were dissolved with 5 ml concentrated HNO3 and 2 ml H2O2 (30% w/v) in a microwave device (Cem MARSXpress). After pretreatments, elemental contents of the samples (total P, K, Ca, Mg, Fe, Zn, Mn, Cu, B, Al, As, Ba and Cd elements) was determined by ICP-OES (Agillent-5110a) device [23].

Statistical analysis

The JMP statistical program was used for the statistical analysis of results. Statistically changes were determined using Student's t test by the analysis of variance (ANOVA) procedure in all data $p<0.05$) [24].

3. Results and Discussion

The macroelement contents of edible vegetable species are given in Table 1. As can be understood from Table 1, vegetables were rich in K, followed by P, Ca and Mg in decreasing order. While P content was very low in some vegetables (pepper, cabbage, green beans, chard, potatoes, green onions, onions and lettuce), it was found to be high in vegetables such as okra, garlic and peas. P and K amounts of the vegetables were characterized to be between 16.11 (lettuce) and 6918.40 (ocra) to 1913.99 (tomatoes) and 27367.55 mg/kg (garlic), respectively. In addition, while Ca quantities of vegetables vary between 96.96 (tomatoes) and 8905.50 (garlic), Mg amounts of the vegetables were specified to be between 159.46 (onion) and 8317.76 mg/kg (garlic). P contents of okra, garlic, sorrel, parsley, pepper (Çarliston), carrot, zucchini, cucumber, pea, urslane and tomatoes were found to be considerably higher

Table 1. Macro element contents of some commonly used vegetables

Vegetables	P	K	Ca	Mg
	-------------------- (mg/kg) ---------------			
Pepper	23.19±0.003 K*	8064.33±1.333 C	4798.33±6.984 C	1272.67± 0.882 D
Cabbage	26.15±0.131 J	3318.16±1.88 FG	5842.49±4.526 B	517.94±1.485 H
Fresh bean	25.38±0.009 JK	3493.79±5.232 F	376.58±9.959 K	338.37±2.069 J
Chard	17.18±0.011 MN	6957.06±1.551 D	2602.02±6.634 F	1765.64±0.475 C
Potatoes	20.67±0.198 L	5173.21±3.531 E	197.06±0.866 L	182.89±0.086 L
Green onion	16.40±0.091 MN	3251.86±2.28 FG	4363.11±0.579 D	539.39±0.907 GH
Onion	18.49±0.006 LM	2280.83±0.334 IJ	122.16±0.326 N	159.46±0.611 M
Lettuce	16.11±0.056 N	8000.86±4.287 C	2690.74±0.341 E	548.08±1.494 G
Okra	6918.40±1.455 A	16185.73±8.274 B	1393.67±2.058 G	2060.93±2.325 B
Garlic	3128.32±4.352 B	27367.55±1.520 A	8905.50±0.057 A	8317.76±0.347 A
Sorrel	2050.39±1.811 E	2956.19±491.951 GH	1000.00±3.228 H	777.50±25.867 E
Parsley	2401.02±0.536 D	8355.75±26.258 C	1011.11±0.001 H	749.65±0.329 F
Pepper (Çarliston)	1877.23±0.135 G	2319.61±0.788 IJ	159.11±0.327 M	203.97±0.360 L
Carrot	1965.33±0.337 F	2223.33±2.883 IJ	458.00±0.322 J	239.67±0.299 K
Zucchini	1816.59±0.333 H	1966.84±0.333 J	127.36±0.001 N	205.33±0.333 L
Cucumber	1815.87±0.326 H	2649.34±1.821 HI	365.89±0.032 K	186.67±0.152 L
Pea	2844.54±0.176 C	3028.15±0.471 GH	203.83±0.448 L	370.80±0.364 I
Purslane	1683.54±0.381 I	5000.33±0.333 E	562.89±0.314 I	537.71±0.232 GH
Tomatoes	2052.01±0.266 E	1913.99±0.489 J	96.96±0.446 O	195.16±0.898 L

*P<0.05

than those of other vegetables used in the study. The Mg contents of green beans, potatoes, onions, green peppers, carrots, zucchinis, cucumbers and peas were found to be considerably lower than those of other vegetables. In addition, although vegetables in general were rich in K, the vegetables containing the highest amounts of K were okra (16185.73 mg/kg) and garlic (27367.55 mg/kg). Among the analyzed vegetables, the vegetables containing the highest amounts of Ca were green onion, pepper, garlic, lettuce and chard. Ca contents of onion and zucchini were determined at quite low levels. A wide fluctuation was observed in the Mg content of vegetables depending on the vegetable varieties. The vegetables with the highest and lowest Mg content were garlic (8317.76 mg/kg) and onion (159.46 mg/kg), respectively. It is understood from the table that garlic contained the highest K, Ca and Mg among vegetables.

Microelement contents of fresh vegetables are presented in Table 2. The element found in the highest amounts in the tested vegetables was Fe, followed by Mn, Zn, B and Cu in decreasing order. Fe and Zn amounts of the fresh vegetables were defined to be between 5.79 (onion) and 205.63 (okra) to 1.94 (onion) and 44.77 mg/kg (okra), respectively. The highest Cu (16.35 mg/kg) and Mn (56.13 mg/kg) and B (41.19 mg/kg) were found in okra and garlic, respectively. Cu, Mn and B contents in pepper, carrot, zucchini, cucumber, pea, purslane and tomato were low compared to other vegetables. The highest amounts of microelement contents of vegetables were Fe, Zn and Mn. However, the Zn content of okra was 3-6 times higher than that of other vegetables. In addition, the highest Zn was detected in okra, garlic and pea. This may be due to the fact that okra and pea samples are seeded. B contents of vegetable samples varied between 0.06 (carrot) and 41.19 mg/kg (garlic). In general, B contents of gerlic, chard, okra, pepper, cabbage, parsley samples were found to be considerably higher than those of other vegetables. Copper contents in vegetables were detected mostly in okra (16.35 mg/kg), garlic (8.34 mg/kg), lettuce (6.83 mg/kg) and pepper (4.00 mg/kg). Cu contents of other vegetables varied between 0.96 and 1.96 mg/kg. It was also observed that the Mn contents of the vegetable samples used in the study were quite high. The highest Mn was detected in garlic (56.13 mg/kg), chard (51.37 mg/kg) and okra (29.38 mg/kg). The Mn contents of other vegetables were detected below 16.53 mg/kg.

Table 2. Micro element contents of some commonly used vegetables

Vegetables	Fe	Zn	Cu	Mn	B
	(mg/ kg)				
Pepper	63.00±1.000 C*	7.00±0.001	4.00± 0.001 D	12.00±0.001 F	12.00±0.001D
Cabbage	32.80±0.145 F	2.96±0.017	0.99±0.003 F	16.53±0.269 D	5.97±0.027 F
Fresh bean	15.72±0.048 K	6.85±0.018	1.94±0.022 E	2.93±0.014 K	2.93±0.015 H
Chard	40.73±0.037 E	3.89±0.008	1.95±0.005 E	51.37±0.032 B	18.43±0.004 B
Potatoes	10.70±0.079 L	2.96±0.015	1.97±0.008 E	0.98±0.004 M	1.95±0.009 I
Green onion	39.91±0.009 E	2.00±0.012	1.00±0.012 F	12.93±0.022 E	3.98±0.006 G
Onion	5.79±0.327 M	1.94±0.007	0.97±0.005 F	1.94±0.004 L	1.94±0.003 I
Lettuce	45.20±1.384 D	6.80±0.012	6.83±0.004 C	7.78±0.016 I	1.94±0.027 I
Okra	205.63±0.048 A	44.77±0.325	16.35±0.053 A	29.38±0.331 C	12.51±0.033 C
Garlic	84.38±0.439 B	17.80±0.021	8.34±0.012 B	56.13±0.004 A	41.19±0.536 A
Sorrel	39.55±0.286 E	2.98±0.004	1.00±0.017 F	8.91±0.358 H	0.11± 0.006 J
Parsley	41.17±0.022 E	2.95±0.007	1.96±0.010 E	10.52±0.153 G	7.85±0.003 E
Pepper (Çarliston)	25.38±0.182 I	1.94±0.002	0.96±0.002 F	2.90±0.005 K	0.10±0.012 J
Carrot	24.00±0.001 IJ	2.00±0.001	1.00±0.015 F	2.00±0.001 L	0.06±0.001 J
Zucchini	23.75±0.351 IJ	1.95±0.005	0.97±0.001 F	0.98±0.003 M	0.24±0.020 J
Cucumber	23.59±0.088 J	1.98±0.004	0.98±0.012 F	1.98±0.006 L	0.44±0.001 J
Pea	27.87±0.277 H	11.79±0.006	1.96±0.004 E	2.95±0.003 K	0.21±0.007 J
Purslane	30.70±0.302 G	6.92±0.004	0.98±0.001 F	4.94±0.003 J	0.18±0.001 J
Tomatoes	22.48±0.032 J	6.31±0.001	0.98±0.004 F	1.96±0.003 L	0.40±0.003 J

*P<0.05

Toxic element contents of fresh vegetables differed according to vegetable species are depicted in Table 3. The element detected in the highest amounts in the tested vegetables was As, followed by Ba, Cr, Ni, Pb and Mo in decreasing order. As and Ba quantities of the fresh vegetables were characterized to be between 0.16 (green pepper) and 34.83 (pea) to 0.59 (tomatoes) and 22.81 mg/kg (chard), respectively. In addition, while Cr amounts of the fresh vegetables vary between 2.05 (chard) and 7.59 (parsley), Ni quantities of the vegetables were established to be between 0.37 (cabbage) and 3.87 mg/kg (pea). The highest Mo (7.29 mg/kg) and Pb (1.93 mg/kg) contents were established in tomatoes. In other vegetables, Mo and Pb were found below 1.22 mg/kg. The lowest As contents in vegetables ranged from 0.22 to 4.81 mg/kg, while the highest As contents were detected between 8.70 and 34.83 mg/kg. In general, As contents of chard, green onion garlic and pea samples were established between 30.08 and 34.83 mg/kg. In addition, As contents of fresh bean, okra and zucchini samples were found between 22.76 and 27.36 mg/kg. In addition, the highest Ba contents in vegetables were found in chard (22.81 mg/kg) sample, followed by garlic (8.93 mg/kg), purslane (6.74 mg/kg), cabbage (6.59 mg/kg), pepper (4.48 mg/kg) in decreasing order. Ba contents of other vegetables were detected below 3.48 mg/kg. Cr contents of 11 vegetables ranged from 6.07 to 7.59 mg/kg, while Cr contents of 8 vegetables ranged from 2.04 to 2.76 mg/kg. Mo, Ni and Pb contents of vegetables were found at very low levels. However, N contents were relatively high in a few vegetables, and Ni contents of these vegetables ranged from 1.44 to 3.87 mg/kg. The highest Pb contents among vegetables were found in tomatoes (1.93 mg/kg), chard (1.56 mg/kg), garlic (1.20 mg/kg) and carrot (1.05 mg/kg), while Pb contents of other vegetables were found below 0.98 mg/kg.

All leafy vegetable samples contain varying amounts of elements, which can be attributed to factors such as variation in the genetic structure of plant species and the competitive interaction between metal ions within the lithosphere or variation in mineral amounts in the soil in which the vegetables grow [25]. The levels of some mineral element contents of broccoli, cauliflower, curly kale, red cabbage, and lentils sold in Yankaba Market of Kano State, Nigeria had 43.09 to 76.67 Ca, 0.04 to 2.33 Co, 0.89 to 7.20 Cu, 0.71 to 9.88 Fe, 12.83 to 69.09 K, 15.63 to 86.63 Mg, 0.51 to 1.77 Mn, 8.65 to 37.36 Na, and 0.7-11.88 mg/kg Zn, respectively [26].

Absorption of the surrounding air by the leaf may cause the Fe content of leafy vegetables to increase. Codex Alimentarius Commission stated that the amount of Fe in foods is between 2.5-5.0 mg/kg and the daily amount of Fe that can be taken varies between 10 and 50 mg/day [27]. For this reason, the Fe amounts determined in our study are well above the recommended Fe amounts according to [28] and [27]. The levels of some mineral element contents of broccoli, cauliflower, curly kale, red cabbage, and lentils sold in Yankaba Market of Kano State, Nigeria had 43.09 to 76.67 Ca, 0.04 to 2.33 Co, 0.89 to 7.20 Cu, 0.71 to 9.88 Fe, 12.83 to 69.09 K, 15.63 to 86.63 Mg, 0.51 to 1.77 Mn, 8.65 to 37.36 Na, and 0.7-11.88 mg/kg Zn, respectively [26]. In other study, [29] reported the K, P, Ca, Nai and Mg contents of eight types of onions as 87.85–136.82, 46.17–107.33, 14.22–76.33, 0.11– They found it to be 9.47 and 0.11–3.17 mg/100g, respectively. In other study, white, yellow and red onion varieties contain on average 599.48 Mg, 25.23 Fe, 12.25 Mn, 23.19 Zn and 5.13 mg/kg Cu. g [30].

Results showed some changed compared to results of last studies carried out on leafy and green vegetables. These changes can be likely due to variety, soil and environment factors, plant parts, wild and cultivated plants and some analytical conditions.

Table 3. Toxic element contents of some commonly used vegetables

Vegetables	As	Ba	Cr	Mo	Ni	Pb
	---------------------------------- (mg/kg) --------------------------------------					
Pepper	0.16±0.003 O*	4.48±0.017 E	2.12± 0.002 N	0.24±0.005 K	0.65±0.004 JK	0.12±0.002 L
Cabbage	3.95±0.058 M	6.59±0.015 D	2.18±0.0001 M	0.70±0.032 F	0.37±0.011 L	0.13±0.002 L
Fresh bean	22.76±0.052 E	1.27±0.022 J	2.29±0.0001 L	0.79±0.015 E	1.44±0.012 H	0.57±0.024 I
Chard	30.08±0.013 C	22.81±0.013 A	2.05±0.001 O	0.41±0.005 H	0.18±0.004 M	1.56±0.035 B
Potatoes	3.31±0.006 N	0.77±0.006 M	2.76±0.0001 K	0.29±0.015 J	1.63±0.015 G	0.61±0.006 H
Green onion	32.06±0.502 B	2.51±0.025 H	2.17±0.001 M	0.31±0.008 IJ	0.63±0.013 JK	0.11±0.003 L
Onion	16.89±0.014 G	0.83±0.004 L	2.04±0.0001 O	0.18±0.003 L	0.77±0.008 J	0.90±0.006 F
Lettuce	0.22±0.003 O	3.46±0.008 F	2.10±0.0001 N	0.68±0.005 F	0.54±0.013 K	0.93±0.002 F
Okra	27.36±0.027 D	3.48±0.016 F	6.92±0.0005 E	1.09±0.009 C	1.76±0.003 FG	0.89±0.002 F
Garlic	30.28±0.0001 C	8.93±0.003 B	6.07±0.0001 J	0.93±0.004 D	1.24±0.003 I	1.20±0.002 C
Sorrel	4.81±0.048 L	2.11±0.054 I	6.86±0.003 F	0.41±0.003 H	2.36±0.004 CD	0.59±0.002 HI
Parsley	12.78±0.004 I	1.25±0.018 J	7.59±0.0003 A	1.22±0.009 B	3.29±0.005 B	0.98±0.006 E
Pepper (Çarliston)	15.37±0.013 H	0.54±0.007 O	7.28±0.0003 B	0.50±0.010 G	2.47±0.005 C	0.63±0.019 H
Carrot	8.70±0.058 J	3.40±0.018 G	7.20±0.0001 C	0.42±0.005 H	2.31±0.008 D	1.06±0.002 D
Zucchini	22.82±0.005 E	0.73±0.011 M	6.53±0.002 I	0.34±0.003 I	2.47±0.002 C	0.71±0.009 G
Cucumber	18.08±0.339 F	1.15±0.003 K	6.67±0.010 H	0.43±0.004 H	2.40±0.010 CD	0.13±0.003 L
Pea	34.83±0.014 A	0.83±0.020 L	7.15±0.00001 D	0.51±0.007 G	3.87±0.002 A	0.19±0.003 K
Purslane	17.79±0.338 F	6.74±0.012 C	6.71±0.00001 G	0.39±0.006 H	1.98±0.015 E	0.44±0.005 J
Tomatoes	6.69±0.005 K	0.59±0.024 N	7.20±0.0001 C	7.29±0.046 A	1.77±0.005 F	1.93±0.048 A

*P<0.05

This may be due to factors such as the plant-based element concentration of the soil where the vegetables were grown, the fertility status of the soil, the pH of the soil and the health status of the plant. Plants can only absorb the minerals offered to them in certain chemical forms [31]. Also, fluctuations in element contents of analyzed plants can be attributed to differences in element uptake and translocation abilities of the plant, plant species and growth stages, soil properties and geo-environmental conditions [32].

The main factors affecting the availability of mineral elements in the soil are soil pH, cation exchange capacity, activity of microbes, organic matter and water content [33, 34]. Also, these differences are likely due to the fact that fertilizers and fungicides may increase the concentration of these elements in plants. In addition, the possible reason for the localization of heavy metal concentrations in vegetables is probably due to air and irrigation water contaminated with heavy metals, vehicle emissions and other air pollutants, thus increasing the plants' uptake of harmful elements from the soil [35]. The capacity of plants to take up potentially harmful elements may accumulate at different rates in various plant species depending on the characteristics of the soil [36]. This situation, which poses a risk to humans when roots, tubers and leaves with excessive content of potentially harmful elements are consumed by humans, has become an important subject of scientific research worldwide [37, 36, 38].

4. Conclusions

P contents of okra, garlic, sorrel, parsley, pepper (Çarliston), carrot, zucchini, cucumber, pea, urslane and tomatoes were found to be considerably higher than those of other vegetables used in the study. The Mg contents of green beans, potatoes, onions, green peppers, carrots, zucchinis, cucumbers and peas were found to be considerably lower than those of other vegetables. Among the analyzed vegetables, the vegetables containing the highest amounts of Ca were green onion, pepper, garlic, lettuce and chard. Ca contents of onion and zucchini were determined at quite low levels. A wide fluctuation was observed in the Mg content of vegetables depending on the vegetable varieties. Cu, Mn and B contents in pepper, carrot, zucchini, cucumber, pea, purslane and tomato were low compared to other vegetables. The highest amounts of microelement contents of vegetables were Fe, Zn and Mn. However, the Zn content of okra was 3-6 times higher than that of other vegetables. In addition, the highest Zn was detected in okra, garlic and pea. The element detected in the highest amounts in the tested vegetables was As, followed by Ba, Cr, Ni, Pb and Mo in decreasing order. From the present research, it can be inferred that vegetables are thought to be a good source of minerals because they are rich in macro and microelements and have very low levels of other toxic elements except As, Ba and Cr.

Conflict of interest

No conflict of interest.

References

1. Jimoh, F., Oladiji, A. (2005). Preliminary Studies on Piliostigma thonningii seeds: Proximate analysis, mineral composition and phytochemical screening. African J. Biotechnol. 4(12): 1439–42.
2. Lucarini, S., Canali, R. (1996). National Research Council. Carcinogens and anticarcinogens in the human diet. National Academy Press, Washington, pp 221–232.
3. Fasuyi AO (2006. Nutritional potentials of some tropical vegetables meals. Chemical characterization and functional properties. African J Biotechnol 5(1): 49 53.
4. Renthlei L, Birla SK, Sudarshan M, Ram SS, Mohondas SN (2016) Elemental Profile of the Leafy Vegetables Commonly Consumed by Natives of North Eastern Region of India analysed using Energy Dispersive X-Ray Fluorescence. Indian J Nutr 3(1): 126.
5. Malghani NA, Mahesar SA, Baig JA, Talpur FN, Sherazi STH, Junaid M (2022) Nutritional Assessment and Proximate Analysis of Selected Vegetables Grown in Larkana, Sindh, Pakistan. JOTCSA 9(4): 985–98.
6. Akan JC, Abdulrahman FI, Ogugbuaja VO, Ayodele J (2009) Heavy Metals and Anion Levels in Some Samples of Vegetable Grown Within the Vicinity of Challawa Industrial Area, Kano State, Nigeria. Am J Appl Sci 6(3): 534–542.
7. Laţo A, Radulov I, Berbecea A, Laţo K, Crista F (2012) The transfer factor of metals in soil-plant system. Res J Agric Sci *44*(3): 67–72.
8. Satheesh N, Workneh Fanta S (2020) Kale: Review on nutritional composition, bio-active compounds, anti-nutritional factors, health beneficial properties and value-added products. Cogent Food Agric, *6*(1): 1048-1081.
9. Bhatti S, Baig JA, Kazi TG, Afridi HI, Pathan AA (2019) Macro and micro mineral composition of Pakistani common spices: a case study. Food Measur 13(4): 2529–41.
10. Akhter P, Akram M, Orfi S, Ahmad N (2002) Assessment of dietary zinc ingestion in Pakistan. Nutr 18(3): 274–8.
11. Özcan M (2004) Mineral contents of some plants used as condiments in Turkey. Food Chem 84 (3): 437-440.
12. Özcan MM, Akbulut M (2008) Estimation of minerals, nitrate and nitrite contents of medicinal and aromatic plants used as spices, condiments and herbal tea. Food Chem 106(2): 852–8.

13. Rehman, Z.U.; Khan, S.; Shah, M.T.; Brusseau, M.L.; Khan, S.A.; & Mainhagu, J. (2018). Transfer of heavy metals from soils to vegetables and associated human health risks at selected sites in Pakistan. *Pedosphere* 28, 666–679.
14. Guerra, F., Trevizam, A.R., Muraoka, T., Marcante, N.C., Canniti-Brazaca, S.G. (2010). Hevy metals in vegetables and potential risk for human health. *Scientia Agricola.* 69, 54–60.
15. Rahman, M.; & Islam, M.A. (2019). Concentrations and health risk assessment of trace elements in cereals, fruits, and vegetables of Bangladesh. *Biological Trace Element Research* 191, 243–253.
16. Khanna, P. (2011). Assessment of heavy metal contamination in different vegetables grown in and around urban areas. *Research Journal of Environmental Toxicology 5*(3), 162.
17. Alloway, B. J. (2013). Heavy metals in soil: Trace metals and metalloids in soil and their bioavailability. *Environmental Pollution* 22, Springer Science.
18. Marshall, F. M., Holden, J., Ghose, C., Chisala, B., Kapungwe, E., Volk, J., Agrawal, M., Agrawal, R., Sharma, R. K., & Singh, R. P. (2007). *Contaminated irrigation water and food safety for the urban and periurban poor: Appropriate measures for monitoring and control from field research in India and Zambia", Incpetion Report DFID Enkar R8160*. University of Sussex.
19. Sharma, R.K., Agrawal, M., & Marshall, F. (2007). Heavy metal contamination of soil and vegetables in suburban areas of Varanasi India. *Ecotoxicology and Environment Safety,* 66(2), 258–266.
20. Özcan, M.M., Akçay Kulluk, D., Gökmen Yılmaz, F., Dursun, N. (2023). Macro-, micro-, and heavy metal element levels in different parts of celery (*Apium graveolens* L.) plant. *Environmental Monioring Assessment* 195:550.
21. Kaledin, A. P., Stepanova, M. V. (2023). Bioaccumulation of trace elements in vegetables grown in various anthropogenic conditions. *Foods and Raw Materials 11*(1), 10–16.
22. Cîrtîna, P.D., Capatîna, C. (2018). Considerations on the Role of Mineral Substances in the Organism. Synthesis 4, 322–326.
23. Tošic, S.B., Mitic, S.S., Velimirovic, D.S., Stojanovic, G.S., Pavlovic, A.N., & Pecev-Marinkovic, E.T. (2015). Elemental composition of edible nuts: fast optimization and validation procedure of an ICP- OES method. *Journal of the Science and Food Agriculture* 95, 2271–2278.
24. Savaşlı, E., Önder, O., Karaduman, Y., Dayıoğlu, R., Özen, D., Özdemir, S., Akın, A., Tunca, Z.S., Demir, B., &Aydın, N. (2019). The effect of soil and foliar ürea application at heading stage on grain yield and quality traits of bread wheat (*Triticium aestivum* L.). *Turkish Journal of Agriculture Science and Technology* 7, 1928-1936.
25. Anyawu, E.C., Ijeoma, E.J.E., Saleh, M.A. (2004). Bioavailable of lead concentration in vegetable plants grown in soil from a reclaimed industrial site: Health implications. *Int J Food Safety* 6: 31-34.
26. Umar HM, Mohammed MI (2023) Determination of some mineral elements level in vegetables sold in yankaba market Kano state, Nigeria. *FUDMA J Sci (FJS)* 7: 206-212.
27. CAC (**2003**) Evaluation of certain food additives and contaminants.FAO/WHO, Codex standard. Rome: 230-2001.
28. FAO/WHO (2002) Report of Joint FAO/WHO Expert consultation Bangkok,Thailand. Expert consultation on human vitamin and mineral requirements: 223-229.
29. Abou Azoom, A.A., Hamdi, W., Zhani, K., Hannachi, C. (2015). Evaluation of mineral element, sugars and proteins compositions in bulbs of eight onion (*Allium cepa* L.) varieties cultivated in Tunisia. *International Research Journal of Engineering and Technology,* (IRJET) *2*, 35–39.
30. Jurgiel-Malecka, G., Gibczynska, M., Nawrocka-Pezik, M. (2015). Comparison of chemical composition of selected cultivars of white, yellow and red onions. *Bulgarian Journal of Agriculture Science, 21*, 736–741.
31. White P.J. (2003). Ion transport. In: Thomas B, Murphy DJ, Murray BG, eds. *Encyclopaedia of Applied plant sciences*. London, UK: Academic Press, 625–634.
32. Dghaim R, Al Khatib S, Rasool H, Ali Khan M (**2015**) Determination of heavy metals concentration in traditional herbs commonly consumed in the United Arab Emirates. *J Environ Public Health,* Article ID 973878 Nutrient Requirements. National Academies Press.
33. Frossard E., Bucher M., Mächler F., Mozafar A., & Hurrell R. (2000). Potential for increasing the content and bioavailability of Fe, Zn and Ca in plants for human nutrition. *Journal of the Science of Food and Agriculture* 80, 861–879.
34. Gall, J.E., Boyd, R.S., Rajakaruna, N. (2015). Transfer of heavy metals through terrestrial food webs: A review. *Environmental Monitoring and Assess*ment 187, 201.
35. Chaves, L.H.G., Estrela, M.A., Sena de Souza, R. (2011). Effect on plant growth and heavy metal accumulation by sunflower. *Journal of Phytology* 3, 4–9.
36. Gupta, N., Yadav, K.K., Kumar, V., Kumar, S., Chadd, R.P., Kumar, A. (2019). Trace elements

in soil-vegetables interface: Translocation, bioaccumulation, toxicity and amelioration - A review. *Sci. Total Environment* 651,2927–2942.

37. Alam, M., Khan, M., Khan, A., Zeb, S., Khan, M.A., ul Amin, N., Sajid, M., Khattak, A.M. (2018). Concentrations, dietary exposure, and human health risk assessment of heavy metals in market vegetables of Peshawar, Pakistan. *Environmental Monitoring and Assess*ment 190, 505.
38. Mihaileanu, R.G.; Neamtiu, I.A.; Fleming, M.; Pop, C.; Bloom, M.S.; Roba, C.; Surcel, M.; Stamatian, F.; & Gurzau, E. (2019). Assessment of heavy metals (total chromium, lead, and manganese) contamination of residential soil and homegrown vegetables near a former chemical manufacturing facility in Tarnaveni, Romania. *Environmental Monitoring and Assess*ment 191, 8.