

DETERMINATION OF MICRO-MACRO ELEMENTS AND HEAVY METALS IN CARROTS GROWN IN TURKEY WITH FAAS

Gulbin Erdogan^{1,*}, Zeynep Demirhan²

¹Marmara University, Faculty of Pharmacy, Analytical Chemistry Department, 34854-Maltepe, Istanbul, Turkey

²Marmara University, Institute of Health Sciences, 34854-Maltepe, Istanbul, Turkey

ABSTRACT

In recent years, with the increase in environmental pollution, contamination in fruit, and vegetable production areas has become for human health. Our research has shown that the metal content of carrots produced in 3 different regions in Turkey and consumed by humans has never been compared between regions. Therefore, we aimed to compare Fe, Mn, Zn, Cu, Ca, K, Mg, Cr, Cd, Al, and Pb in carrots grown in these regions. Carrots were digested using the microwave-digestion method and the amount of these elements was measured by FAAS. According to the results, it was determined that there wasn't Al, Cd, Mn, and Pb in carrot samples, but the presence of Cr, Fe, Zn, Cu, Ca, K, and Mg varied according to the regions. These values have been observed with the limit values determined by the WHO, Turkish Food Codex, and the Ministry of Agriculture and Forestry, that they are acceptable values. Considering the data on beneficial and harmful effects of the metals in the carrots grown in Turkey, it can be said that the heavy metal intake through carrots, does not pose an important risk to human health and they can be safely consumed.

KEYWORDS:

Micro and macro elements, heavy metals, carrot, microwave digestion, FAAS

INTRODUCTION

Vegetables, which are vital for human nutrition, contribute to the health of metabolism with their micro, macro, and trace elements content. These elements, which play a role in the growth of the plant, pass from the soil to the plant and play a role in the nutrient cycle. They are very important for health when it comes from an organic or herbal source, but it is toxic if they come from an inorganic or metallic source, for example, if their heavy metal contents are high. The carrot is a vegetable and two-year herbaceous plant produced directly from seed, with a conical root belonging to the Umbelliferae

family used as a vegetable [1]. The homeland of the carrot is Asia, Europe, and North Africa. Most especially Beypazarı (Ankara), Konya, and Hatay are cultivated in Turkey. Carrot is a source of beta carotene, the precursor of provitamin A and when consumed regularly, it helps digestion in the human body. It is one of the important vegetables for human health thanks to its antioxidant compounds, vitamins (B1, B2, B3, D, E, and C), and minerals (such as Ca, Fe, Na, K, Mg, Cu, and Zn). It is beneficial in vision functions, heart diseases, and arteriosclerosis and helps to clean the blood through the removal of harmful substances from the body. Strengthens the immune system and it has many benefits such as reducing the risk of cancer by maintaining the free radical balance in the body [1-4].

Vegetables and fruits contain carbohydrates, proteins, vitamins, minerals, various antioxidant compounds, and macro and micronutrients, making them an important component of the human diet and metabolism. Therefore, it is extremely important to determine the levels of elements that pollute food in various ways and also cause environmental pollution [5,6]. The metal accumulation which may have toxic effects on human health and plants in the natural environment is caused by the factory and industrial organizations established close to agricultural lands, the use unconscious of the pesticides, chemical fertilizers, and using wastewaters in agricultural fields. Additionally, metal deposition is also caused by factors such as fragmentation of mineral rocks and volcanic activities, random destruction of domestic wastes, livestock fertilizer, and unutilized metallic pieces are the major causes of the water, soil, and air pollution [7-9]. Among these metals that have accumulated in certain layers of the ecosystem through these means are located microelements necessary for maintaining vital activities of humans and plants and macro elements necessary for the growth and development of plants. There are also heavy metals that cannot be biodegradable and accumulate in different body organs and causing ecological toxicity [10,11].

Heavy metals in the soil are the most important toxic pollutants, and they are extremely dangerous to human health. In particular, it is very significant to investigate the concentrations of metals in root

vegetables, which have the potential to accumulate these toxic substances such as carrots, and to determine the positive or negative effects on human health that may occur on plants and humans beings. When these metals exceed acceptable levels, they disrupt events such as germination, sweating, membrane stability, and hormonal balance in plant physiology. They are excreted very slowly from the metabolism of humans, they accumulate in various organs of the body in time and cause DNA damage, chronic diseases such as ulcerative colitis, neurological diseases such as Crohn's disease, depression, Parkinson's, Alzheimer's, Wilson's disease, various cardiovascular diseases, and cancer [5,12].

Fe, Cu, Mn, and Zn are microelements and they are important nutrients for plants and humans. In general, these elements are involved in many biochemical events such as the synthesis of chlorophyll in the plant. The deficiency of these elements necessary for the development of the plant causes a slowdown in growth and chlorophyll synthesis (chlorosis). When taken too much, they affect root and stem growth by causing the cells to thicken. In humans, it causes hypochromic anemia when Fe is deficient, slowing growth; when Zn is deficient, delay in wound healing and weakening of the immune system, normocytic anemia when Cu is deficient excessive intake in the body of these elements causes cirrhosis of the liver, heart diseases, chronic diseases such as pulmonary fibrosis and neurological diseases such as Wilson's disease, Parkinson's disease, and Manganism [13-17].

Ca, K, and Mg, which are macro elements, are necessary elements for plants to grow and develop. These elements protect the plant against freezing and thawing in cold weather conditions. They are effective in increasing the resistance of the plant against drought by regulating the water balance. They also play an active role in photosynthesis. Incomplete intake of these elements causes softening and protein deficiency in fruits, decline in plant height premature defoliation, slowing down photosynthesis, slowing down in seed and fruit formation, and fruit loss. Ca deficiency rickets, osteoporosis, and osteomalacia in humans; K deficiency hypokalemia; Mg deficiency causes muscle cramps and severe spasms. When taken too much, they cause kidney stone formation, hyperkalemia diseases, and cardiovascular diseases [6,18].

Pb, Cr, Al, and Cd are known as heavy metals and they aren't necessary for plants and humans. They have a toxic effect when they accumulate in the environment. When people are exposed to these metals for a long time, the first system affected is the central nervous system. While this causes neurological diseases such as Parkinson-Dementia in humans, it has also been reported to cause diseases such as temporary arterial fibrillation, osteomalacia,

ALS, DNA damage, perforation in the upper respiratory tract, liver and kidney damage [19-23].

The impact of heavy metals on the environment is one of the most important risk factors for the emergence of cancer types. Upper gastrointestinal (GI) cancers are endemic in Van (Turkey), therefore some heavy metal levels in vegetable and fruit samples were investigated with AAS. While high concentrations of Cd, Pb, Cu, and Co were present in the soil by standards, they found Zn levels at lower concentrations. Co, Cd, Pb, Mn, Ni and Cu in fruit and vegetable were higher than the standards. They suggested that the potentially carcinogenic heavy metal content in the vegetable and fruit grown here is high due to the volcanic soil in this region, and they may be associated with the high prevalence of GI cancers in the Van region [24]. Arora et al. [25] determined Fe, Mn, Cu, and Zn levels in vegetables irrigated with different water sources using AAS. As a result, they found that the Fe and Mn elements in spinach and mint, Cu, and Zn elements in carrots are high in the vegetables, irrigated with wastewater. Therefore, they emphasized that it is important to regularly monitor these metals in the food chain to prevent the passage of metals to vegetables and from there to people.

Radwan et al. [26] noted that they examined the levels of Pb, Cd, Cu, and Zn in fruits and vegetables, sold in markets in Egypt, using AAS. They found that the highest Pb, Cd, Cu, and Zn levels in the fruits and vegetables were in strawberry, cucumber, date, and spinach respectively, and that the investigated heavy metals did not exceed the detection limit in carrots were below the limits set by FAO/WHO. Ilic et al. [27] noted that on seeds, which is the first step in vegetable cultivation, the influence of treatment in the seed with different Pb concentrations of Pb-acetate on the seed germination (onion, beans, radish, lettuce, carrot, brussels sprout) was investigated. They found that the maximum concentration of Pb-acetate on seed causes significantly higher loss of germination in nearly all vegetable species studied.

Heavy metals such as Cd, Cr, Cu, Pb, and Zn were investigated using ICP-OES [28] and GFAAS devices in cauliflower, carrot, tomato, onion, and cabbage plants grown in the Lushoto state of Tanzania. At the end of the study, the levels of these accumulated heavy metals were compared value with the permissible limits of FAO/WHO and the Tanzanian government. As a result, they reported that Cu levels in all vegetables were below, and Cr and Zn levels exceeded the recommended limits. On the other hand, Pb levels in carrots and onions, and Cd levels only in onions and tomatoes were found above the limits. Consequently, they argued that the consumption of vegetables contaminated by these heavy metals would cause serious health problems [29].

TABLE 1
Parameters of the microwave heating program

Step	Arrival time (min)	Standby time (min)	Temperature (°C)
1	5	4	85
2	3	9	145
3	2	4	200
4	1	9	200
5	1	1	75

Owing to the toxicological and vital importance of these metals, the levels of some microelements (Fe, Mn, Zn, and Cu), macro elements (Ca, K, and Mg), and some toxic metals (Cr, Cd, Al, and Pb) were investigated in carrots, which are grown in Turkey. The examined carrot samples were taken from Beypazari (Ankara), Konya, and Hatay, and the findings are important because so far no regional studies have been conducted in Turkey for this purpose.

MATERIALS AND METHODS

Experimental sections. Carrot samples, one of the most consumed vegetable types in our country were obtained from the producers in Beypazari (Ankara), Konya, and Hatay. They were washed, passed through ultra-pure water, and kept in a refrigerator (+4 °C) in plastic storage bags until analysis. These samples were sliced with the help of a blender. They were weighed between 1,0–2,0 g and placed in Teflon vessels for microwave digestion. Then, 8.0 ml of 65% HNO₃ was placed on them and left for 5 minutes. After that, 2.0 ml of 30% H₂O₂ was added and the lids of the teflon vessels were closed after waiting for 5 minutes. They were placed in the microwave oven (Berghof Speedwave) after waiting for another 20 minutes. The microwave heating program parameters were adjusted and the digestion process was performed (Table 1). Three carrots were taken from each area, three samples were prepared from each of them (i.e., 9 solutions for each area) and their digestion was made. After the digested sample was cooled, it was filtered into teflon bottles using Whatman No 42 filter paper and completed with 50 mL of ultrapure water. Then, Shimadzu AA-6300 Flame Atomic Absorption Spectrophotometer (FAAS) [30,31] with an autosampler was used to measure the Cr, Cu, Cd, Fe, Al, Mn, Pb, K, Mg, Ca and Zn in digested carrot samples and BGC-D2 (Zeeman Background Correction Deuterium) was used to prevent interference. Specific parameters were set for each element. All dilutions and blanks were prepared by using 0.5% (v/v) HNO₃.

The absorbance values of carrot samples were measured in triplicate for each element under the spectrophotometric conditions of the experimental parameters of the AAS given in Table 2 (i.e., wavelength (nm), slit width (nm), lamp current

(mA), gas flow rate (min), lamp mode, and standard solution's names). Calibration curves were created by preparing standard solutions at different concentrations for each element using NIST SRM stock solutions. They were drawn with the help of absorbance values read against concentration values. The R² values for these curves have been calculated and are given in Table 2. When data belonging to the correlation coefficients were examined, R² values of the calibration curves were close to one. These values approve the acceptance criteria defined for this coefficient (R² ≥ 0.995). Consequently, it is probable to confirm that the sample is well-adjusted by linear equality in the series of concentrations studied.

RESULTS AND DISCUSSION

The results were evaluated statistically, and the validation study of the methods was carried out. LOD, LOQ, and recovery values were calculated using blanks and standard reference materials to determine the accuracy and sensitivity of the analytical method. Depending on the conditions under which the experiment was performed, percent relative standard deviation (RSD%) values were calculated from the performance and the repeatability of the method. Calculated LOQ and LOD values were given in Table 3. These findings indicate that the sensibility of this procedure is comparable to the other atomic spectroscopy technics. According to the Sanco document published by the European Commission, according to the acceptability criteria of the performance of a method; while the % recovery ratios should be between 70-120%, the % relative standard deviation (%RSD) value should be ≤ 20. The results obtained from our study for %RSD and % recovery according to our method are shown in Table 3. Our result values were found within these limits for each element.

The acceptance criteria of the performance of a method according to the Sanco document published by the European Commission are 70-120% recovery, ≤ 20% relative standard deviation. Our RSD (%) and recovery (%) values determined according to our method and shown in Table 3 were found within these limits for each element.

The heavy metals accumulated in the environment as a result of human activities and

environmental factors depend on the selective carried through absorption mechanisms of molecules and ions and are taken up by plants that were the first producers of the ecosystem. In these ways, they endanger people's lives by being included in the food chain [15,32]. For this reason, micro, macro, and heavy metal analysis of foods, vegetables, and fruits have been important studies when the effects of these metals on humans are taken into account.

In this study, the amounts of elements in carrot samples obtained from three different provinces were compared with the limit values determined by the World Health Organization (WHO), Turkish Food Codex (TGK), The Ministry of Agriculture, and Forestry, and Dietary Reference Intakes. The data from this study revealed that heavy metal concentrations in carrot samples were under and between the limit values set by the WHO, the TGK, the Ministry of Agriculture and Forestry, and Dietary Reference Intakes.

The accumulating of elements, whether or not beneficial to humans and plants depends on many factors such as plant type, age, root development,

physical, chemical, and biological properties of soil, genus, and levels of useful elements in soil, applied agricultural processes, weather conditions [33]. When these factors are taken into consideration, the accumulation of toxic elements has negative effects on human health due to consumption, especially plants.

Consequently, the determination of these elements in carrots' content is expected to help determine how much metal can accumulate in vegetables and fruits and how much daily intake limits of required elements will be met depending on human consumption.

In this study, we focus on the carrot, a vegetable that is widely grown in Beypazari (Ankara), Konya, and Hatay rich in minerals and beneficial to human health. The results obtained from the elements in all carrot samples were calculated in milligrams per 100 grams of fresh weight ($\text{mg } 100 \text{ g}^{-1}$) (Tables 4 and 5). Figure 1 (a-g) provides a comparison of the quantities of the elements measured in carrot samples obtained from three different regions.

TABLE 2
Spectrophotometric conditions belonging to experimental parameters of the AAS, the names of the standard solutions used for the elements, and the calculated R^2 values

Element	Wavelength (nm)	Slit width (nm)	Lamp current (mA)	Gas flow rate (min) Air- C ₂ H ₂	Lamp mode	Standard solutions names	R ² values
Al	309.3	0.7	12	7.0- 11.0	BGC- D ₂	NS 3101a	0.9994
Ca	422.7	0.7	10	2.0- 15.0	BGC- D ₂	NS 3109a	0.9999
Cd	228.8	0.7	8	1.8- 15.0	BGC- D ₂	NS 3108	1.0000
Cr	357.9	0.7	10	2.8- 15.0	BGC- D ₂	NS 3112a	0.9996
Cu	324.8	0.7	6	1.8- 15.0	BGC- D ₂	NS 3114	0.9998
Fe	248.3	0.2	13	2.2- 15.0	BGC- D ₂	NS 3126a	0.9990
K	766.5	0.7	10	2.0- 15.0	NON-BGC	NS 3141a	0.9996
Mg	285.2	0.7	8	1.8- 15.0	BGC- D ₂	NS 3131a	0.9990
Mn	279.5	0.2	10	2.0- 15.0	BGC- D ₂	NS 3132	0.9998
Pb	283.3	0.7	10	2.0- 15.0	BGC- D ₂	NS 3128	0.9997
Zn	213.9	0.7	8	2.0- 15.0	BGC- D ₂	NS 3168	0.9998

NS: Standart Reference Material (NIST SRM)

TABLE 3
The main analytical performance parameters for the applied FAAS method

Element	LOD (mg L ⁻¹)	LOQ (mg L ⁻¹)	Recovery (%)	RSD (%)	Linearity range (mg L ⁻¹)
Al	0.2477	0.8258	102.98	8.9797	1.00–10.00
Ca	0.3780	1.2600	96.95	8.5484	1.00–20.00
Cd	0.0086	0.0285	98.41	1.6420	0.01–0.40
Cr	0.0116	0.0388	104.93	7.2915	0.05–1.00
Cu	0.0046	0.0154	97.09	3.5199	0.05–1.00
Fe	0.0280	0.0934	111.14	6.7216	0.10–1.00
K	0.0066	0.0220	99.38	8.3351	0.05–1.00
Mg	0.0026	0.0085	92.87	8.0692	0.01–0.50
Mn	0.0096	0.0319	92.43	8.0037	0.05–1.00
Pb	0.0312	0.1038	102.31	10.5081	0.10–1.00
Zn	0.0022	0.0074	95.14	1.8234	0.01–0.40

The maximum acceptable limit determined by the World Health Organization/Food and Agriculture Organization (WHO/FAO) for copper, which acts as a cofactor in many mechanisms in human and plant structures, is $4.0 \text{ mg } 100\text{g}^{-1}$. As can be seen in Table 5, the copper amounts measured in the carrot samples are below this value. According to the Dietary Reference Intakes data, the daily consumption of copper elements is $0.20\text{--}1.30 \text{ mg}$ [12]. When the measured copper amounts in the carrot samples are compared according to the regions, it is seen that there is little difference ($0.5762\text{--}0.8639 \text{ mg } 100 \text{ g}^{-1}$) between the three regions (Table 5 and Figure 1a). This difference was thought to be due to pesticide (CuSO_4) application.

The deficiency of zinc, which is necessary for both human health and plant growth, causes growth retardation in humans and adversely affects the auxin hormone responsible for growth in plants. The

maximum acceptable zinc value determined by WHO/FAO in many metabolic functions is $9.94 \text{ mg } 100\text{g}^{-1}$, and the values obtained in our study ($0.5649\text{--}1.5936 \text{ mg } 100 \text{ g}^{-1}$) were found to be below this value. Similarly, the daily intake limits determined according to Dietary Reference Intakes data are $2.0\text{--}13.0 \text{ mg}$ [26,34]. High lime in the soil is an important factor limiting agricultural production and makes it difficult to absorb micro elements, especially phosphorus and zinc, from the soil. When the measured Zn amounts in the carrot samples are compared according to the regions, they are close to each other in the samples obtained from Beypazari and Konya (1.4140 and $1.5936 \text{ mg } 100 \text{ g}^{-1}$), while they are quite low in the samples obtained from Hatay ($0.5656\text{--}0.6579 \text{ mg } 100 \text{ g}^{-1}$) (Figure 1b). This situation can be explained by the difference in the amounts of lime in the region's soil(35,36).

TABLE 4
Heavy metal contents ($\text{mg } 100 \text{ g}^{-1}$) of carrot samples were obtained from three different regions Beypazari(B1, B2, B3), Hatay(H1, H2, H3), and Konya(K1, K2, K3)

Region	Al	Cd	Cr	Pb	Mn
B1	< LOD	< LOD	< LOD	< LOD	< LOD
B2	< LOD	< LOD	0.2107 ± 0.033	< LOD	< LOD
B3	< LOD	< LOD	< LOD	< LOD	< LOD
H1	< LOD	< LOD	< LOD	< LOD	< LOD
H2	< LOD	< LOD	< LOD	< LOD	< LOD
H3	< LOD	< LOD	0.2095 ± 0.0380	< LOD	< LOD
K1	< LOD	< LOD	< LOD	< LOD	< LOD
K2	< LOD	< LOD	< LOD	< LOD	< LOD
K3	< LOD	< LOD	0.2140 ± 0.0418	< LOD	< LOD

TABLE 5
Micro and macro element contents ($\text{mg } 100 \text{ g}^{-1}$) of carrot samples were obtained from three different regions (Beypazari, Hatay, and Konya).

Region	Fe	Zn	Cu	Ca	K	Mg
	($\text{mg } 100 \text{ g}^{-1}$)					
B1	2.6063 ± 0.2953	1.3454 ± 0.0253	0.8639 ± 0.0518	406.2766 ± 7.5487	245.3385 ± 2.9069	75.8533 ± 0.9742
B2	2.2433 ± 0.1232	1.1486 ± 0.0358	0.7862 ± 0.0247	391.1673 ± 5.2251	234.2430 ± 5.7677	79.0000 ± 1.0507
B3	2.2967 ± 0.0104	1.4140 ± 0.0268	0.8222 ± 0.0565	413.5450 ± 3.7558	201.2290 ± 0.8200	78.2800 ± 1.2273
H1	2.4739 ± 0.1376	0.5656 ± 0.0193	0.6476 ± 0.0090	172.0616 ± 2.8634	91.4830 ± 2.4617	109.2548 ± 0.5972
H2	2.8439 ± 0.2095	0.5649 ± 0.0258	0.5762 ± 0.0487	178.1060 ± 2.8870	104.6970 ± 2.8605	115.9302 ± 0.9843
H3	2.9113 ± 0.2781	0.6579 ± 0.0183	0.6804 ± 0.0213	179.6705 ± 2.3418	110.3400 ± 9.1408	112.3031 ± 1.2345
K1	3.0463 ± 0.2802	1.2468 ± 0.0225	0.7636 ± 0.0226	219.1507 ± 1.5161	375.9910 ± 1.6705	89.2290 ± 0.5882
K2	0.4607 ± 0.0657	1.5936 ± 0.0034	0.6471 ± 0.0386	228.7554 ± 4.8925	606.8500 ± 6.0231	94.9669 ± 0.6598
K3	2.8406 ± 0.0938	1.4047 ± 0.0351	0.7048 ± 0.0057	227.7075 ± 5.0337	565.4860 ± 4.0416	93.1523 ± 0.5386

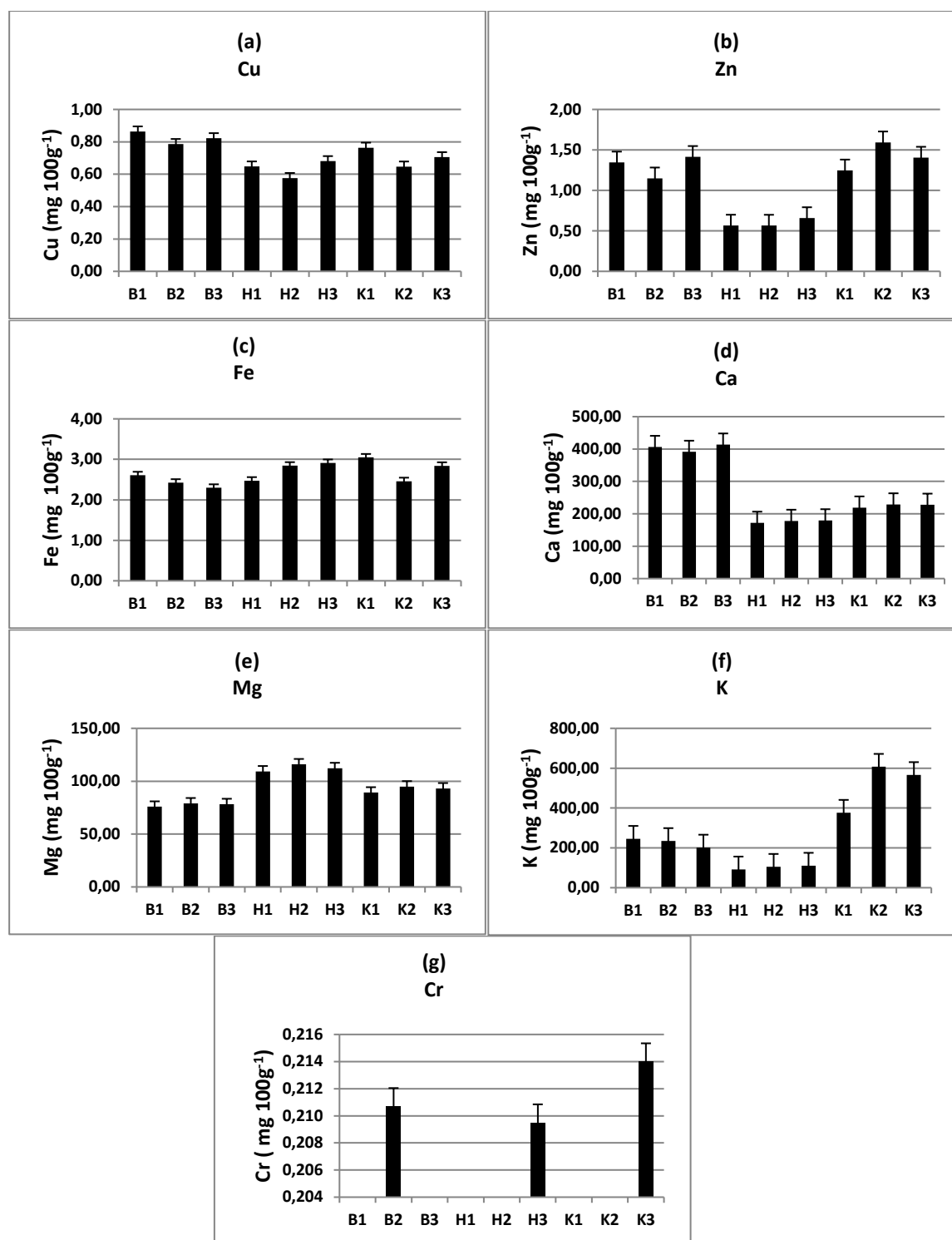


FIGURE 1 (a, b, c, d, e, f, g)

Comparison of the measured elements in carrot samples obtained from three different regions.

Iron is one of the important micro elements in terms of being the building block of hemoglobin in human metabolism and taking part in the photosynthesis reaction mechanism in plants. Plants cannot benefit from iron in regions with such soils due to the high amount of calcium in the soil (due to limestone) and soil conditions that are not suitable for ventilation [34,36]. The daily intake limits determined according to Dietary Reference Intake

data are 0.27-27.00 mg [34,37]. The iron amounts we determined in our study were found to be between the lower limits of these values, and the maximum acceptable iron values according to WHO/FAO and TKG are in the range of 1.50-42.50 mg 100 g⁻¹. When comparing the iron content in carrot samples obtained from the three regions, it can be seen that the averages did not differ significantly from each other (3.0463-2.2967 mg 100 g⁻¹) (Figure. 1c).

Calcium is one of the essential elements of the cell walls in plants and is necessary for a healthy life [38]. Calcium values were found to be above the acceptable limit values for human consumption, especially in Bey pazarı (Ankara) carrots and, in the other regions was found between these values according to the Ministry of Agriculture and Forestry and Dietary Reference Intake limits (200–1300 mg daily allowable amount and 32.0–38.0 mg acceptable value in 100 g carrots). When comparing the amount of calcium found in carrot samples by region, it is $B > K > H$ ($413.5450 > 227.7075 > 179.6705$) ($\text{mg } 100 \text{ g}^{-1}$) (Figure. 1d). It is known that most of the Central Anatolian lands are rich in lime [36]. The high calcium values we measured in the carrot samples obtained from Bey pazarı (Ankara) may be caused by the calcareous soil.

Magnesium in chlorophyll structure in plants is an important macro element for photosynthesis and according to WHO/FAO, the maximum acceptable limit value is $500 \text{ mg } 100 \text{ g}^{-1}$. According to the Dietary Reference Intakes, the daily intake limits for magnesium, which is involved in many reactions such as DNA production, protein, and carbohydrate metabolism in the human body are 30.0–320.0 mg. Our values were found to be among the accepted daily intake limit values [39,40]. In this study, this value was found below the value accepted by WHO/FAO. When we compare the regions, the ranking is $H > K > B$, that is, the amount of magnesium was found to be high in the samples obtained from Hatay. (Figure 1e). The soils in the Eastern Mediterranean region are clayey and have high Mg content, as they have wetland and lake areas. [41]. Since Hatay is in this region, the Mg content was found to be high ($115.9302 \text{ mg } 100 \text{ g}^{-1}$). Mg amounts were found to be low in the carrots obtained from Konya ($94.9669 \text{ mg } 100 \text{ g}^{-1}$) and Bey pazarı ($79.0000 \text{ mg } 100 \text{ g}^{-1}$) regions. As a matter of fact, in a study of fertility status in the region soils, it was stated that these soils were poor in terms of Mg. [42].

Potassium, which is responsible for maintaining water balance in the plant, is one of the important macro elements that act as cofactors in many vital cellular mechanisms within the human body [32]. According to the data from the Ministry of Agriculture and Forestry, acceptable potassium values in 100 g carrot are 239.0–325.0 mg. The data of the Dietary Reference Intakes acceptable daily intake limits for potassium are 400.0–510.0 mg and the values obtained in the study were above these values in Konya carrots and below those values in Bey pazarı and Hatay carrots ($K > B > H$) (Figure 1f). A very large part of the Central Anatolia Region lands (94.4%) has too much potassium levels. This is due to the hot and dry weather conditions and low rainfall in the region [37]. In a study conducted to determine the productivity of the agricultural lands where carrots are grown in Konya

province, it was determined that the soil samples generally have clay structure, neutral reaction, and contain too much lime. In addition, 90.62% of the soils were found to be high in absorbable potassium [34]. Therefore, the amount of K in carrots obtained from the Konya region ($606.8500 \text{ mg } 100 \text{ g}^{-1}$) was higher than that obtained from Bey pazarı and Hatay regions ($110.3400\text{--}245.3385 \text{ mg } 100 \text{ g}^{-1}$).

The chromium element is one of the heavy metals, which is not required for plants and humans. It causes various chronic diseases when taken into the human body while inhibiting the growth of the plant by affecting seed germination when taken into the plant at toxic levels. According to WHO/FAO, the maximum acceptable chromium value is $0.23 \text{ mg } 100 \text{ g}^{-1}$, and in our study, chromium was detected only in B2, H3, and K3 carrot samples ($0.2107\text{--}0.2095\text{--}0.2140 \text{ mg } 100 \text{ g}^{-1}$) (Figure. 1g), these are lower than the values accepted by WHO/FAO (Table 4) [34,43,44].

In a study by Karanlık et al, Fe, Zn, Cu, Ni, Mn, Pb, Cd, and Cr contents of some vegetables (parsley, onion, potato, lettuce, carrot, and spinach) grown in Amik Plain were measured and the values determined for Fe, Zn, Cu, Ni, and Mn were found within the maximum limits allowed by WHO/FAO. However, Cr in 27% and Pb in 83% of the samples, and Cd in all samples were determined to be higher than the maximum allowed limits [45]. When we compared our results, they found Cr, Mn, and Pb above the maximum limit values.

Heavy metals and toxic pollutants such as lead, aluminum, cadmium, and manganese can cause diseases such as cancer, DNA damage, kidney and liver damage, Alzheimer's, Parkinson's, and dementia if taken into the human body in excessive amounts. The maximum acceptable limit value for Mn, which acts as a catalyst in many important reactions such as chlorophyll synthesis in plants, is $50 \text{ mg } 100 \text{ g}^{-1}$ according to WHO/FAO. The maximum limit value allowed by WHO/FAO and TGK for Pb and Cd is $0.01 \text{ mg } 100 \text{ g}^{-1}$ while for Al it is $2.0\text{--}10.0 \text{ mg}/100 \text{ g}^{-1}$ [37,46]. In our study, the amounts of Pb, Cd, Al, and Mn in carrot samples obtained from three different regions could not be measured because were below the detection limit of the method (Table 4).

CONCLUSIONS

As a result, it was determined that the micro, macro and heavy metal amounts in the carrots examined in this study did not differ much between regions (except for K). Also, according to the findings, there is no harm in consuming these carrots since their toxic heavy metal contents are below the maximum allowable limits. Potassium, a macro element abundant in vegetables, is high in Konya carrot, and if these amounts are supported by studies

to determine the rate of toxic effects on living cells, it will protect people who consume this carrot against various health problems. The high potassium levels in Konya carrot samples show that they will meet the daily potassium requirement when consumed carefully. Micro element (Fe, Mn, Zn, and Cu) and macro element (Ca, K, and Mg) contents of carrots grown in three different regions (Bey pazari, Hatay, and Konya) in Turkey are sufficient.

The findings of this research can be evaluated as an indication that the carrots studied are grown in lands far from the industry, in clean air, and with clean irrigation water. Finally, It is recommended that such studies should be carried out in a controlled and regular manner to determine whether metals, which are abundant in vegetables and fruits such as carrots, accumulate and to what extent people are exposed to these metals. When health risk assessment is done for consumers, heavy metal risks from other metals and all food groups, soil, air, and water sources should also be taken.

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CORRESPONDING AUTHOR

Gulbin Erdogan

Marmara University, Faculty of Pharmacy, Analytical Chemistry Department,
34854 Maltepe Istanbul – Turkey

e-mail: gerdogan@marmara.edu.tr