

Original Research

QUANTITATIVE DETERMINATION OF ESSENTIAL AND TOXIC ELEMENTS
CONTENT IN PEACH FRUITS BY ICP-OES METHOD

DOI: 10.5937/EcoTER26456D

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Abstract

This paper deals with the contents of macroelements (K, Ca, Mg, Na, and P), microelements (Fe, Cu, Mn, B, Co, Cr, and Ni), and selected toxic elements (Al, As, Pb, and Cd) which were determined in peach fruits of several cultivars grown in Southeastern Serbia. The elemental composition was analyzed using the inductively coupled plasma optical emission spectrometry (ICP-OES) method. As expected, potassium was the most abundant macroelement, with the highest concentration recorded in the cultivar Adria (5944 mg kg⁻¹). The remaining macroelements were present at lower concentrations, without pronounced differences among the samples. In contrast, some variability was observed among microelements, particularly for iron (5.5–11.1 mg kg⁻¹) and copper (0.831–1.598 mg kg⁻¹), while manganese exhibited more stable levels. Nickel and chromium were detected only in trace amounts. Toxic elements were present at low concentrations; cadmium was not detected in any sample, while lead ranged from 0.009 to 0.024 mg kg⁻¹, which is significantly below established regulatory limits. Overall, the results indicate that the analyzed fruits are safe for consumption. The observed differences in elemental composition are most likely associated with cultivar characteristics, given that all samples originated from the same cultivation area.

Keywords: peach, minerals, ICP-OES determination.

INTRODUCTION

Metals in fruits are present as salts of corresponding organic and inorganic acids or in the form of complex compounds, which is of great importance for their bioavailability. In addition to air, soil, and water, the metal content in fruits may be influenced by agricultural practices, industrial processing, the use of preservatives and additives, and other factors. Elevated levels of certain heavy and toxic metals represent an important parameter both in assessing potential adverse effects on human health and as indicators of environmental pollution. The presence of metals in the human body is primarily a consequence of dietary intake; therefore, monitoring metal content in commonly consumed foods in relation to recommended daily intakes is essential.

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After gaseous toxins, metals rank second among the most significant causes of occupational diseases. Heavy metals are defined as metals with a density greater than 4 g cm^{-3} [1].

According to their biological function, metals are classified into:

1. Essential metals (Cu, Fe, Mn, Cr), which are indispensable for life. Their deficiency or insufficient intake may lead to severe physiological disorders or even death. They play crucial roles as structural components of enzymes and as enzymatic activators. These elements are present in very low concentrations and are therefore referred to as trace elements. They exert biological functions only within a narrow concentration range, while higher concentrations may result in toxicity.

2. Non-essential metals (Pb, Al, Cd, Hg, As), which have no known biological function and exhibit exclusively toxic effects [2]. The widespread occurrence of heavy metals in the environment represents a serious ecological and health concern due to their toxicity, non-biodegradability, long half-life in soil, and tendency to accumulate in living systems through the food chain. Heavy metals occur naturally in soils through weathering of parent rock but may also be introduced anthropogenically via industrial activities, fossil fuel combustion, agrochemical application, and atmospheric deposition, leading to long-term contamination of soil and water systems. In aquatic environments, metals can form poorly soluble carbonates, sulfates, and sulfites that accumulate in sediments. Plants absorb heavy metals from soil, water, fertilizers, and pesticides. Through plant consumption, these metals enter animal and human organisms, initiating processes such as bioaccumulation and biomagnification within the food chain.

Toxic metals are primarily associated with occupational and chronic poisoning resulting from exposure to metal vapors or particles during industrial processes. The main routes of exposure are the respiratory tract and skin for occupationally exposed individuals, and the respiratory and gastrointestinal tracts for the general population. Absorption of heavy metals from air occurs predominantly via inhalation, where aerosols or vapors enter the lungs, bind to plasma proteins, and are transported to target organs where toxic effects are exerted. Dermal absorption occurs through the epidermis, hair follicles, or sebaceous glands. Heavy metals are typically deposited in specific target organs; for example, cadmium accumulates in the kidneys with a biological half-life of 10–30 years, while lead accumulates in bones with a half-life of approximately 10 years. Metals are generally metabolically inert and do not undergo transformation in the body, except for metalloids (As, Sb, Se), whose organic and inorganic forms may be detected in urine [2]. Metal toxicity primarily arises from interactions with proteins, lipids, and nucleic acids, binding to functional groups such as amino, hydroxyl, carboxyl, and thiol groups, thereby inhibiting biological activity. Some metals promote the formation of free radicals, inducing oxidative stress. As protoplasmic toxins, they interact with intracellular structures, bind to sulfhydryl groups of proteins, and inactivate their function. Certain metals exhibit genotoxic and carcinogenic effects, while others may trigger hypersensitivity reactions [3].

MATERIALS AND METHODS

Sample collection and preparation

Healthy fruits of peach cultivars (Radmilovcanka, June Gold, Blake, Hale, Vesna, and Adria) were obtained directly from producers in Southeastern Serbia. The samples were harvested at full maturity during the 2025 growing season.

The accurately weighed samples (approximately 10 g) of previously homogenized fresh fruit material were transferred into porcelain crucibles and subjected to thermal treatment in an electric furnace. The furnace was programmed to increase the temperature from 50 °C to 450 °C over a period of 8 hours, followed by maintaining this temperature constant for an additional 12 hours. After the complete digestion the cooled dry residues were dissolved in 2.5 ml HNO₃ (1:1, v/v), filtered through Whatman No. 42 filter paper and transferred to a 50 ml volumetric flask with deionized water [4].

Instrumentation

Metal concentrations were determined by ICP-OES (iCAP 6000, Thermo Scientific, UK). Sample masses were measured using a Mettler Toledo (Switzerland) analytical balance, and high-purity water (0.05 µS cm⁻¹) was obtained using MicroMed high purity water system, Thermo Electron LED GmbH (Germany).

Measurements were conducted under optimized conditions (RF power 1150 W; pump rate 50 rpm; nebulizer gas flow 0.7 L min⁻¹; coolant gas flow 12 L min⁻¹; auxiliary gas flow 0.5 L min⁻¹). Emission lines were selected to minimize interferences and ensure optimal signal-to-background ratios.

An individual analytical method was developed through the selection of appropriate instrumental parameters. Calibration curves, expressing the dependence of relative emission intensity at a selected wavelength on analyte concentration, were constructed using a blank solution (deionized water) and two standard solutions of different concentrations were prepared by dilution of a primary reference standard. All measurements were performed in triplicate. The optimal (analytical) wavelength was selected based on the relative signal intensity as a measure of method sensitivity, the accuracy of the standard response, and the extent of spectral interferences arising from coexisting elements in this complex sample matrix. An inductively coupled plasma optical emission spectrometer (ICP-OES) was employed for the determination of metal ions in fruit samples. Owing to its high sensitivity (ppb level), wide linear dynamic range for numerous elements, low susceptibility to chemical interferences, and capability for simultaneous multielement analysis, ICP-OES represents a near-ideal technique for the determination of metal ions in fruit matrices. The analysis of mineral content in fruit is inherently challenging due to the complexity of the matrix. Minerals are typically present at very low concentrations and are associated with significant amounts of organic matter, necessitating careful and appropriate sample preparation. In this paper, a dry ashing procedure was applied. Dry ashing is an inexpensive, simple, and rapid digestion method most applied for the elemental analysis of organic and inorganic samples. This process converts a large amount of sample into a small quantity of ash composed of inorganic compounds (mainly oxides).

RESULTS AND DISCUSSION

In order to determine the mineral composition of peaches (*Prunus persica* L.), samples from six different cultivars were analysed. This selection aimed to evaluate whether differences in elemental composition are cultivar-dependent. Using optimized analytical conditions, the concentrations of selected elements were determined in the fruit samples. Tables 1, 2, and 3 present the mean values of elemental content obtained from three consecutive measurements $\pm$ standard deviation (SD), calculated on a wet weight basis (mg kg^{-1} ww).

Table 1 The content of essential macroelements $\pm$ sd (mg kg^{-1} ww) in peach fruit

Varieties	Ca	K	Mg	Na	P
Adria	166 $\pm$ 2	5944 $\pm$ 43	97.1 $\pm$ 0.6	54.6 $\pm$ 0.2	374 $\pm$ 3
Vesna	100 $\pm$ 1	5459 $\pm$ 41	96.8 $\pm$ 0.5	62.3 $\pm$ 0.3	402 $\pm$ 5
Hale	163 $\pm$ 2	1639 $\pm$ 24	92.5 $\pm$ 0.5	174 $\pm$ 1	313 $\pm$ 2
Blake	163 $\pm$ 2	4049 $\pm$ 36	108 $\pm$ 0.7	230 $\pm$ 2	335 $\pm$ 3
June Gold	122 $\pm$ 1	3620 $\pm$ 29	112 $\pm$ 0.8	140 $\pm$ 1	381 $\pm$ 4
Radmilovcanka	152 $\pm$ 2	4151 $\pm$ 31	96.4 $\pm$ 0.3	115 $\pm$ 1	373 $\pm$ 3

In contrast to the fact that all samples originated from the same locality, the content of macroelements (Ca, K, Mg, Na, and P) in the analyzed peach cultivars exhibited noticeable variations among different varieties. Potassium (K) was the predominant element in all samples, with the highest concentration observed in the Adria cultivar (5944 mg kg^{-1}) and the lowest in the Hale cultivar (1639 mg kg^{-1}). This finding is consistent with literature data indicating that potassium is the most abundant macroelement in fruit tissues [5]. The contents of calcium (Ca), magnesium (Mg), and phosphorus (P) showed more moderate variation, suggesting relatively stable regulation and well-defined physiological roles of these elements in plant metabolism. In contrast, sodium (Na) exhibited a wider range of variation, which may be attributed to differences in its availability in the soil, as well as cultivar-specific characteristics influencing its uptake and accumulation [6]. The results obtained in this study are in agreement with those reported by Basar *et al.* [7] for peaches cultivated in Turkey, as well as by Manzoor *et al.* [8] for peaches grown in Pakistan.

Sodium and potassium are key elements responsible for maintaining electrolyte balance in the human body and for regulating blood pressure. The recommended daily values for macrominerals, expressed as Daily Value percentages (% DV) for adults and children over four years of age, are as follows: Ca 60 mg kg^{-1} (6%), Mg 90 mg kg^{-1} (22.5%), P 200 mg kg^{-1} (20%), and K 1900 mg kg^{-1} (54.29%). These values, also referred to in the literature as Recommended Daily Intake (RDI), represent approximate intake levels of essential nutrients sufficient to meet the requirements of healthy individuals [9].

The results presented in this paper indicate a certain degree of variability in the content of the investigated microelements (B, Co, Cr, Cu, Fe, Mn and Ni) among the analysed peach cultivars, despite all samples originating from the same locality. Given the uniform environmental conditions, the observed differences can primarily be attributed to

cultivar-specific characteristics, particularly differences in metal uptake and accumulation capacity.

Table 2 The content of essential microelements $\pm$ sd (mg kg⁻¹ww) in peach fruit

Varieties	B	Co	Cr	Cu	Fe	Mn	Ni
Adria	7.5 $\pm$ 0.3	0.004 $\pm$ 0.000	0.075 $\pm$ 0.003	0.831 $\pm$ 0.033	6.1 $\pm$ 0.1	0.52 $\pm$ 0.03	0.091 $\pm$ 0.003
Vesna	7.9 $\pm$ 0.3	0.005 $\pm$ 0.000	0.118 $\pm$ 0.006	0.991 $\pm$ 0.040	8.9 $\pm$ 0.2	0.41 $\pm$ 0.02	0.081 $\pm$ 0.06
Hale	2.1 $\pm$ 0.1	0.001 $\pm$ 0.000	0.088 $\pm$ 0.004	0.914 $\pm$ 0.068	8.6 $\pm$ 0.2	0.42 $\pm$ 0.02	0.21 $\pm$ 0.02
Blake	5.8 $\pm$ 0.2	0.002 $\pm$ 0.000	0.084 $\pm$ 0.003	1.223 $\pm$ 0.039	11.1 $\pm$ 0.3	0.51 $\pm$ 0.03	0.16 $\pm$ 0.01
June Gold	5.6 $\pm$ 0.2	0.009 $\pm$ 0.001	0.079 $\pm$ 0.003	1.598 $\pm$ 0.053	9.7 $\pm$ 0.2	0.66 $\pm$ 0.03	0.57 $\pm$ 0.03
Radmilovcanka	5.1 $\pm$ 0.1	0.003 $\pm$ 0.000	0.084 $\pm$ 0.004	0.892 $\pm$ 0.039	5.5 $\pm$ 0.2	0.41 $\pm$ 0.02	0.18 $\pm$ 0.04

As far as iron is concerned, a relatively wide concentration range was observed, with the Blake cultivar exhibiting the highest Fe content (11.1 mg kg⁻¹), while the lowest concentration was found in the Radmilovcanka cultivar (5.5 mg kg⁻¹). Similar ranges have been reported in the literature for peaches and other fruits, indicating that the obtained values fall within typical limits [10]. Therefore, it can be assumed that the observed variations are not a consequence of external contamination but rather reflect intrinsic physiological differences among cultivars.

Copper content varied within a narrower range compared to iron. The June Gold cultivar showed the highest concentration (1.598 mg kg⁻¹), whereas the lowest value was recorded in the Adria cultivar (0.831 mg kg⁻¹). Overall, all measured values fall within ranges commonly reported for fruit [11]. Manganese (0.41–0.66 mg kg⁻¹) concentrations were relatively uniform across cultivars, suggesting tighter physiological regulation of these element in plant tissues. In contrast, boron exhibited somewhat greater variability, particularly between the Vesna and Hale cultivars. This finding is expected, as boron availability in plants is strongly influenced by soil physicochemical properties as well as cultivar-specific traits [12]. Manganese plays an important role in carbohydrate metabolism and acts as an antioxidant. Iron is a key component of erythrocytes and hemoglobin. Adequate intake contributes to reducing the toxic effects of cadmium, whereas excessive intake may inhibit the absorption of copper and iron. Copper is an essential microelement with a biocatalytic role, important for pigmentation, maintenance of central nervous system function, and prevention of anemia. However, excessive exposure may lead to adverse effects that are often underestimated. Nickel participates in iron metabolism, influences its absorption from food, and plays a significant role in erythropoiesis, as well as in the metabolism of carbohydrates, lipids, hormones, and cell membrane components.

Among the essential trace minerals present in the analysed samples, chromium and cobalt are of paramount importance. Chromium is well known for its role in maintaining normal blood glucose levels and is involved in the metabolism of carbohydrates, lipids, and proteins. Due to its relatively low absorption efficiency, higher dietary intake is required. The recommended daily intake of chromium [12] ranges from 0.2 µg for infants to 15 µg for children aged 4–8 years, 35 µg for adolescents and adult men, and 25 µg for adult women. Cobalt is a trace element that constitutes an integral part of vitamin B₁₂, which plays a crucial

role in protein synthesis, normal growth, maintenance of epithelial tissues, and erythrocyte formation. However, prolonged exposure to elevated cobalt levels may result in excessive erythrocyte production, cardiotoxic effects, and thyroid dysfunction. In the analysed samples, cobalt concentrations ranged from 0.001 to 0.009 mg/kg.

The recommended daily values for selected microelements, expressed as percentage of Daily Value (% DV), are as follows: Cu 0.68 mg kg⁻¹ (34%), Fe 2.5 mg kg⁻¹ (13.89%) and Mn 0.61 mg kg⁻¹ (30.5%) [10]. These values represent approximate intake levels sufficient to meet the nutritional requirements of healthy individuals.

The content of toxic metal in the analysed peach samples is essential as a parameter for assessing their safety for human consumption. The concentrations of Al, Cd, Pb, and As were determined, and the obtained results are presented in Table 3.

Table 3 The content of toxic elements $\pm$ sda (mg kg⁻¹ ww) peach fruit

Varieties	Al	As	Pb	Cd
Adria	6.8 $\pm$ 0.2	0.041 $\pm$ 0.002	0.009 $\pm$ 0.000	nd
Vesna	3.2 $\pm$ 0.1	0.034 $\pm$ 0.002	0.009 $\pm$ 0.000	nd
Hale	8.1 $\pm$ 0.2	0.065 $\pm$ 0.002	0.020 $\pm$ 0.001	nd
Blake	5.8 $\pm$ 0.1	0.058 $\pm$ 0.002	0.024 $\pm$ 0.002	nd
June Gold	6.2 $\pm$ 0.2	0.061 $\pm$ 0.003	0.015 $\pm$ 0.001	nd
Radmilovcanka	3.2 $\pm$ 0.1	0.044 $\pm$ 0.003	0.013 $\pm$ 0.001	nd

The results of the analysis of toxic elements (Al, As, Pb, and Cd) indicate that their concentrations are low in all examined samples. Cadmium (Cd) was not detected, while the lead (Pb) content ranged from 0.009 to 0.024 mg kg⁻¹, which is significantly below the maximum permissible level for fruit established by European Union regulations (0.10 mg kg⁻¹). Arsenic (As) and aluminium (Al) were present at low to moderate concentrations, without pronounced differences among cultivars. The obtained results are consistent with literature data, where toxic elements in fruits are typically detected at trace levels.

Although all samples were collected from the same locality, the observed differences in elemental composition indicate a significant influence of cultivar characteristics. On the other hand, the role of soil as the primary source of elements cannot be neglected, as its chemical properties and pH directly affect element bioavailability. Additionally, the potential influence of atmospheric deposition, particularly in areas near road traffic, may contribute to the presence of certain elements; however, in this study, no elevated concentrations were observed that would indicate significant anthropogenic impact.

CONCLUSION

The obtained results confirm that the analysed peach cultivars from Southeastern Serbia represent a valuable source of essential macro- and microelements, with potassium identified as the dominant macroelement (up to 5944 mg kg⁻¹ in the Adria cultivar). Iron and copper

contents exhibited greater variability among cultivars, whereas manganese was relatively uniform, and nickel and chromium were present only in trace amounts.

Toxic elements were detected at low concentrations; cadmium was not found in any sample, while lead levels (0.009–0.024 mg kg⁻¹) were significantly below the maximum permissible limits, confirming the safety of the analysed samples for human consumption.

Given the uniform sampling location, the observed differences in elemental composition can primarily be attributed to cultivar-specific characteristics, in accordance with the aim of the study. These findings highlight the importance of cultivar selection in the context of nutritional quality, while future research should focus on the influence of soil properties and agricultural practices on element accumulation. Based on the analysed parameters, the investigated peach cultivars can be considered both nutritionally valuable and safe for consumption.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support provided by the Academy of Applied Studies Southern Serbia.

REFERENCES

- [1] Duffus, J.H. Pure Appl Chem. 2002, 74 (5), 793–807.
- [2] Majkić N. Medicinska biohemija. Beograd: 2006. Grafopan doo, p. 605.
- [3] Bulat Z. Mehanizmi toksičnosti otrova. U: Toksikologija sa analitikom. Beograd; 2010/11.
- [4] Radojević M, Bashkin V. Practical Environmental Analysis. Cambridge, UK: The Royal Society of Chemistry; 1999.
- [5] FAO. Mineral composition of fruits and vegetables. FAO Report; 2018.
- [6] Kabata-Pendias A. Trace Elements in Soils and Plants. 4th ed. Boca Raton: CRC Press; 2011.
- [7] Basar, H. Elemental composition of various peach cultivars. Sci Hortic. 2006, 107, 259–263.
- [8] Manzoor, M., Anwar, F., Mahmood, Z., *et al.* Molecules. 2012, 17, 6491–6506.
- [9] U.S. Department of Agriculture, Agricultural Research Service. USDA Food Composition Databases: Peaches, raw (No. 09236). 2016.
- [10] AlJuhaimi, F., Akçay Kulluk, D., Gökmen Yılmaz, F. Biol Trace Elem Res. 2025, 203, 1676–1684.
- [11] Sardar, K., Ali, S., Hameed, S., *et al.* Greener J Environ Manage Public Saf. 2013, 2(4), 172–179.
- [12] Institute of Medicine. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Washington, DC: National Academy Press 2001:773 p.