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NUTRITIONALLY RELEVANT MINERALS IN PARSLEY ROOT: AN X-RAY FLUORESCENCE STUDY

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Abstract

Parsley (Petroselinum crispum Mill*.) is a plant valued for its high nutritional content and functional properties, being an important source of vitamins and essential minerals for human health. This study aims to evaluate the mineral composition of parsley root and assess its potential health benefits. The concentrations of macroelements (calcium, magnesium, potassium, and phosphorus) and microelements (iron, zinc, manganese, and copper) were determined using X-ray fluorescence spectrometry (XRF). Parsley root samples were collected from various supermarkets in Romania and the results were compared with data reported in the literature. The mineral analysis revealed a high and relatively consistent content of essential macro- and microelements across all samples. The measured levels of potassium, calcium, iron, manganese, and zinc were comparable to or slightly higher than those previously reported, highlighting the nutritional potential of parsley root as a natural mineral source. Variations among samples can be attributed to differences in soil composition and cultivation conditions, without significantly impacting the overall nutritional quality. These findings support the inclusion of parsley root as a valuable ingredient in balanced diets and functional food formulations.*

Key words: *health benefits, mathematical model, Petroselinum crispum, X-ray fluorescence spectrometry.*

INTRODUCTION

The vegetables with leaf and roots are valued due to their rich content in essential nutrients. They are also recognized for their significant contribution to human health. Among these, parsley (*Petroselinum crispum* Mill.), both the leaf and the root, represent a promising plant with relevant minerals content and considerable potential to facilitate various favorable health effects (Ahmed et al., 2025).

This work investigates the mineral composition of parsley roots using the X-ray fluorescence (XRF) technique.

Parsley *(Petroselinum crispum* Mill.*)* is an herbaceous leguminous plant that belongs to the Apiaceae family. According to the classification of A. L. de Jussieu, parsley (*Petroselinum crispum* Mill.) belongs to the Rosidae class and is known under the name of Umbelliferae. For this reason, it is often called the umbrella plant (Chauhan & Aishwarya, 2018). Native to Europe and western Asia it is currently widespread in many regions of the world (Mahmood et al., 2014). Parsley (*Petroselinum crispum* Mill.) is cultivated for its white taproot and intensely aromatic leaves. It is used for food, cosmetic, and pharmaceutical industries for their aromatic and culinary properties as well as for their medicinal benefits (Zaaboul & Liu, 2022). Also, it is wealthy in nutrients, vitamins, minerals (Zaaboul & Liu, 2022) and apiol, which is an organic compound found in parsley

seeds with therapeutic properties (Gogoaşă et al., 2014; Ajmera et al., 2019).

Parsley (*Petroselinum crispum* Mill.) is well known as an aromatic plant and it is widely used in both traditional and international cuisine. Generally, parsley is considered an auxiliary and decorative ingredient rather than a valuable source of nutrients (Ajmera et al., 2019; Bahramsoltani et al., 2024). The chemical composition of parsley root includes: 85% water, 3% protein, 6% carbohydrates, volatile oils and a significant amounts of minerals (especially potassium), phosphorus, magnesium, calcium, iron, as well as a number of vitamins (A, B, C). It is low in calories, one hundred grams of parsley root contains 36 kcal (Cozma et al., 2022; Wszelaczyńska et al., 2024). Among all root vegetables, parsley is characterized by a significant content of K (399 mg/100 g) and calcium (Ca) (43 mg/100 g). Moreover, parsley is also rich in folate (180 µg/100 g). Consumption of 100 g of parsley covers the daily requirement of folic acid by 30-40% (Knez et al., 2022).

Due to the diversity of bioactive compounds, parsley stands out as a vegetable with therapeutic potential and has been described in the scientific literature as exhibiting tonic, antianemia, antirachitic, antiasthmatic, anti-xerophthalmic, antiscorbutic, antifebrile, anti-inflammatory, mineralizing, depurative, diuretic, secretolytic, vasodilatory, expectorant, vermifuge, and uterotonic effects (Gogoaşă et al., 2014; Ajmera et al., 2019; Bahramsoltani et al., 2024).

Researcher's analyses have demonstrated the significance of dietary minerals, vital for disease prevention and maintaining overall good health. Although they constitute a relatively small proportion of approximately 4-6% of body weight, minerals are key components of the human diet (Özcan, 2004; Knez et al., 2022).

The minerals present in parsley have major importance, as each of them contributes significantly to the proper functioning of the body. Iron is a mineral vital for haemoglobin formation and oxygen transport in the blood. Magnesium plays an important role in the proper functioning of the nervous system, in regulating blood pressure, and has a relaxing effect on muscles. Calcium contributes to bone and dental health. Potassium has a key role in well function of hearth and blood pressure regulation, while zinc has beneficial effects to the immune system and protein synthesis, and phosphorus is essential for cellular energy production (Alobaidi, 2024).

The minerals present in parsley play an important role in maintaining optimal physiological functions, and their consumption contributes to overall health and helps prevent mineral deficiencies (Ajmera et al., 2019). Therefore, a healthy diet is based on a balanced and varied eating plan, which includes appropriate portions of vegetables, fruits and cereals rich in fiber and protein, along with a moderate consumption of fats, sugar and salt (Rădulescu et al., 2025).

To assess the mineral content of parsley roots and to identify variations determined by cultivation conditions and also by soil composition, it is necessary to apply an efficient and non-invasive analytical technique. Thus, X-ray fluorescence (XRF) is a rapid and precise method, which allows the simultaneous quantification of major minerals as well as trace elements without complex chemical preparation of the samples (Jenkins et al., 1995; Wszelaczyńska et al., 2024). The application of XRF in this study of parsley roots allows the determination of the complete mineral profile, thus providing valuable data for both nutrition and health as well as agricultural research.

MATERIALS AND METHODS

Parsley roots were purchased from five different supermarkets in Romania, then cleaned to remove impurities, scraped, and initially air-dried at room temperature. Subsequently, the roots were dried in an oven until the moisture content decreased below 5%, a level recommended for accurate mineral determination. The dried samples were then finely ground, packed in sterile airtight bags, properly labelled, and stored for further analyses and determinations.

For X-ray fluorescence (XRF) analyses, the powdered samples were examined using a Hitachi X-MET8000 portable spectrometer, which can measure a wide range of atomic elements, from sodium (Z11) to uranium (Z92), providing detection limits from a few parts per

million (ppm) up to high percentages (% by weight). This method was selected because XRF is an essential technique for the evaluation of soil and plant samples at medium air pressure, and it is frequently used for both qualitative and quantitative analyses. The method is based on the fact that each mineral present in the analysed material (parsley root) emits a characteristic set of fluorescent X-rays, a "fingerprint" specific to each element (Rădulescu et al., 2024). XRF spectrometry is advantageous because it provides rapid determination of elemental concentrations and presence, with high accuracy (Panebianco et al., 2023). Measurements were performed in triplicate to ensure precision and consistency, and the results were expressed in parts per million (ppm).

Statistical evaluation of the data was performed using PAST software, version 2.17c (Hammer et al., 2001). Data obtained from the mineral determinations were processed using descriptive statistics and expressed as mean values ± standard deviation.

RESULTS AND DISCUSSIONS

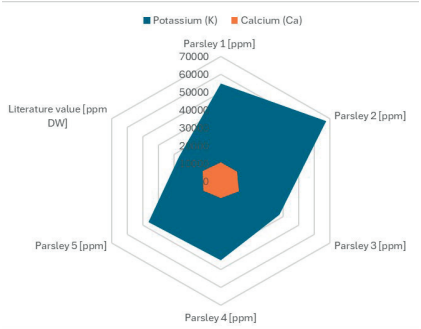
The analyzed parsley roots revealed high concentrations of several essential minerals, predominantly K and Fe, above literature reference values, demonstrating high nutritional potential. However, the increased levels of Cu, Ni, and Pb suggest possible environmental or soil-related contamination impacts. The variability between samples shows distinct geochemical or anthropogenic signatures connected with their provenience. Further soil–plant transfer factor assessment and comparison with regulatory maximum allowable limits are recommended to evaluate food safety implications (Table 1).

Table 1. Mineral composition of parsley root samples

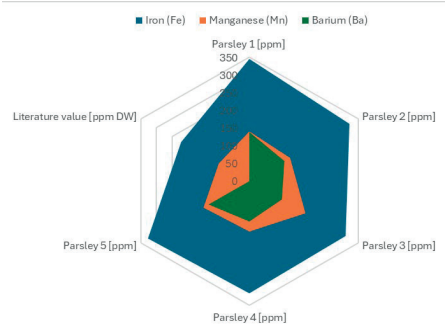
Mineral	Parsley 1 [mg/kg]	Parsley 2 [mg/kg]	Parsley 3 [mg/kg]	Parsley 4 [mg/kg]	Parsley 5 [mg/kg]	Literature value (mg/kg DW)
Potassium (K)	54707.00 ± 700.00	67462.00 ± 3,142.00	37,793.00 ± 930.00	44758.00 ± 315.00	46185.00 ± 1,690.00	63000.00 (Nutrition Data Hub, 2026)
Calcium (Ca)	10525.00 ± 19.00	10585.00 ± 779.00	11732.00 ± 396.00	9811.00 ± 285.00	10906.00 ± 197.00	1760.00 (Nutrition Data Hub, 2026)
Iron (Fe)	345.00 ± 8.00	323.00 ± 9.00	309.00 ± 7.00	317.00 ± 14.00	326.00 ± 18.00	539 (Nutrition Data Hub, 2026)
Copper (Cu)	34.00 ± 1.00	47.00 ± 0.00	39.00 ± 0.00	40.00 ± 0.01	31.00 ± 3.00	4.6 (Nutrition Data Hub, 2026)
Manganese (Mn)	140.00 ± 18.00	130.00 ± 23.00	181.00 ± 7.00	142.00 ± 21.00	149.00 ± 11.00	134 (Nutrition Data Hub, 2026)
Molybdenum (Mo)	13.00 ± 3.00	7.00 ± 2.00	7.00 ± 0.00	10.00 ± 3.00	7.00 ± 3.00	-
Zinc (Zn)	52.00 ± 4.00	56.00 ± 1.00	47.00 ± 0.00	54.00 ± 1.00	53.00 ± 0.00	61.1 (Nutrition Data Hub, 2026)
Nickel (Ni)	19.00 ± 1.00	ND	20.00 ± 4.00	22.00±0.00	ND	1.30 (Arsenov et al., 2021)
Barium (Ba)	138.00 ± 16.00	113.00 ± 0.00	104.00 ± 0.02	114.00 ± 0.03	131.00 ± 0.00	-
Strontium (Sr)	48.00 ± 0.00	60.00 ± 2.00	79.00 ± 5.00	44.00 ± 2.00	57.00 ± 2.00	-
Rubidium (Rb)	10.00 ± 0.00	44.00 ± 3.00	25.00 ± 0.00	16.00 ± 0.00	21.00 ± 0.00	-
Mercury (Hg)	5.00 ± 0.00	20.00 ± 0.00	22.00 ± 2.00	17.00 ± 0.00	24.00 ± 5.00	-
Lead (Pb)	4.00 ± 0.00	10.00 ± 0.00	6.00 ± 0.00	7.00 ± 2.00	6.00 ± 0.00	0.55 (Winiarska-Mieczan et al., 2023)

Data are presented as mean ± standard deviation
Legend: ND = Not Detected (below the detection limit of the XRF spectrometer).

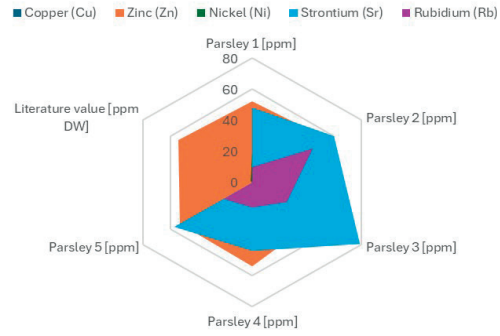
The five parsley root samples displayed diverse mineral fingerprints reflecting variances in their provenience (Figure 1). Parsley 2 was characterized by high K, Cu, Pb, and Rb, whereas Parsley 3 showed enrichment in Mn and Sr. The occurrence of Ni in only three samples supplementary supports site-specific soil influence. These results indicate that mineral composition in parsley roots is strongly designed by environmental and geochemical factors rather than solely by plant physiological control.



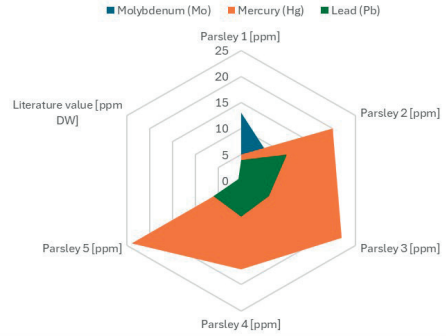
Comparative Mineral Profile of K and Ca in the investigated Parsley Root Samples



Comparative Mineral Profile of Fe, Mn and Ba in the investigated Parsley Root Samples



Comparative Mineral Profile of Cu, Zn, Ni, Sr and Rb in in the investigated Parsley Root Samples



Comparative Mineral Profile of Mo, Hg and Pb in in the investigated Parsley Root Samples

Figure 1. Mineral Fingerprint of Parsley Roots Based on Mineral Content

Each sample presents a distinct mineral fingerprint**,** indicating different soil characteristics and possibly different anthropogenic pressures. As we can observe, the mineral composition of the parsley roots is shaped by different particularities like: Physiological regulation (Ca, Zn stability); Soil fertility differences (K variability), Geochemical background (Ba, Sr, Rb) and local environmental influence (Ni, Pb, Hg).

Radar plot analysis revealed distinct mineral fingerprints among the five parsley root samples. While calcium and zinc displayed limited variability, indicating physiological regulation, potassium showed pronounced variation, with Parsley 2 exhibiting the highest concentration. Trace elements such as Ni, Pb, Hg, Rb, and Sr demonstrated strong inter-sample differences, suggesting provenance-dependent geochemical and environmental influences. Parsley 3 was characterized by elevated Mn and Sr, whereas Parsley 2 exhibited increased Cu, Pb, and Rb levels. These findings confirm that mineral accumulation patterns in parsley roots are primarily shaped by soil composition and local environmental conditions rather than intrinsic plant physiology alone.

The PCA biplot illustrates the mineral composition of the investigated parsley root samples after standardization (Figure 2). PC1 (the first principal component) represents the major source of variance in the dataset and primarily reflects differences in mineral enrichment, predominantly determined by K, Zn, Fe, Ba, and Mo. Along PC1, Parsley 1 indicates a relatively enriched mineral profile, while Parsley 3 is positioned on the opposite side, showing lower concentrations of several macro- and microelements. This separation suggests that PC1 presents the differences primarily related to soil fertility and mineral availability.

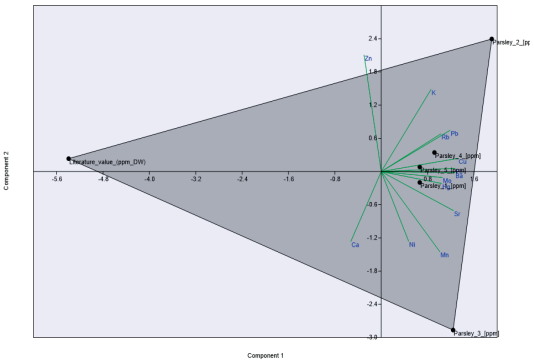


Figure 2. PCA Biplot of Mineral Composition in Parsley Roots Samples

PC2 (the second principal component) differentiates the samples based on the metals Pb, Rb, Cu, and Hg, which display stronger inter-sample variability and environmental sensitivity. Parsley 2 is clearly shifted upward along PC2, reflecting elevated Pb and Rb levels and thus a distinct geochemical signature. Parsley 3 appears in the lower quadrant, influenced more by Mn and Ca.

Parsley 2 is distinctly positioned in the positive PC2 quadrant, associated with high Pb and Rb levels, indicating a specific geochemical or environmental signature. In contrast, Parsley 3 appears in the lower quadrant, influenced more by Mn and Ca. The orientation and length of the vectors confirm that Rb, Pb, and Ni are among the strongest discriminant elements, contributing substantially to sample separation.

Overall, the PCA confirms that the mineral composition of parsley roots is governed by provenance-dependent factors. While some elements (e.g., Ca and Zn) appear relatively stable and physiologically regulated, others (notably Rb, Pb, Ni, and Mn) are responsible for the distinct mineral fingerprints observed among samples, highlighting the influence of soil geochemistry and localized environmental conditions.

CONCLUSIONS

The analysis of parsley roots indicated high levels of essential minerals, potassium (K) and iron (Fe), exceeding the reference values reported in the scientific literature, thus reflecting a high nutritional potential. Trace elements such as copper (Cu), nickel (Ni), and lead (Pb) were present only in some of the samples, their occurrence highlighting possible influences of the environment or soil on contamination. The differences between the five studied samples reflect distinct geochemical or anthropogenic fingerprints, particularly related to their provenance and soil conditions. XRF analysis proved to be a very efficient, rapid, and non-destructive method, allowing both qualitative and quantitative assessment of the mineral composition of the parsley samples. The results obtained from principal component analysis (PCA) demonstrate that this composition is largely influenced by the provenance of the samples: elements such as Ca and Zn appear relatively stable and physiologically regulated, while other elements, such as Rb, Pb, Ni, and Mn, generate distinct mineral fingerprints, reflecting the influence of soil geochemistry and localized environmental conditions. Considering the above, further studies are recommended to evaluate the soil–plant transfer factor and to compare the values with the maximum allowable limits established by regulations, in order to assess implications for food safety. The high concentrations of potassium (K) and iron (Fe) emphasize the nutritional value of parsley root, while the analysis of trace elements and mineral fingerprints through XRF and PCA provides relevant data on provenance and environmental influences, thereby confirming the potential of parsley root as a source of essential minerals and the need for monitoring food safety.

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