*Chemia Naissensis, Vol 7, Issue 1, RESEARCH ARTICLE, 1-8,* https://doi.org/10.46793/ChemN7.1.01D

# Selected nutrient elements in commercial samples of salads

**Marija Dimitrijević[1*], Luka Petrić[1], Dragoljub Miladinović[1]**

*1 - University of Nis, Faculty of Medicine, Department of Pharmacy, Nis, Serbia*

Marija Dimitrijević: marija.dimitrijevic@pmf.edu.rs, https://orcid.org/0000-0003-1816-0400
Luka Petrić: lukapetrickl@gmail.com
Dragoljub Miladinović: dragoljubm@gmail.com, https://orcid.org/0000-0003-4849-1067

## ABSTRACT

This study investigates the element composition, including potassium, sodium, calcium, magnesium, and selenium, in six different leafy vegetable species commonly consumed in salads. The vegetables analyzed were *Lactuca sativa* (lettuce), *Spinacia oleracea* (spinach), *Cichorium intybus* (radicchio), *Valerianella locusta* (lamb's lettuce), *Cichorium endivia* (endive), and *Eruca sativa* (eruca). The contribution of the mentioned elements in the diet by consuming a portion of 100 g fresh salad was evaluated by the recommended daily intake. The results revealed significant variations in element content among the species. Given the recommended daily intake of selenium, these vegetables can contribute significantly to meeting daily selenium requirements (35.9% – 60.5%). The elevated selenium concentrations in *L. sativa* (3.327 mg/kg) and *V. locusta* (2.467 mg/kg) indicate that regularly consuming these foods may be an effective means of boosting dietary selenium intake, thereby supporting its vital role in human health. Other results demonstrate the diverse element content across different leafy vegetables, which can provide varying health benefits depending on the mineral requirements. Based on the elemental content across the samples, *L. sativa* has the greatest content of calcium (12302 mg/kg), while *S. oleracea* has the highest magnesium and potassium content (6131 mg/kg and 22854 mg/kg), *C. endivia* stands out for its high sodium content (20840 mg/kg).

*Keywords: nutrient elements, commercial salads, ICP OES*

[*] Corresponding author: marija.dimitrijevic@pmf.edu.rs

## Introduction

Plants have always been used for food, as spices, teas, and in traditional medicine; therefore, it is important to examine their chemical content. Diet rich in fruits and vegetables is widely recommended for its health-promoting properties (Barmmer, 2022). Fruits and vegetables have historically been in dietary guidance because of their concentrations of vitamins (i.e. vitamins C and A), minerals (electrolytes), and more recently phytochemicals, especially antioxidants (Revoredo-Giha, 2021). Additionally, fruits and vegetables are recommended as a source of dietary fiber (Slavin et al., 2012). In addition to organic, plants also contain various inorganic components. Inorganic components are less abundant in plants, but they are equally important. The trace elements found in living organisms may be essential, i.e., indispensable for growth and health, or they may be nonessential, fortuitous reminders of our geochemical origins or indicators of environmental exposure (Özcan, 2004). Minor elements have very important functions, and they are proven as a key component of proteins such as hemoprotein and hemoglobin which play a role in biochemical functions and essential enzyme systems even in low doses (Imelouane et al., 2011). Although the required levels of micronutrients are usually permanently fixed, they can vary depending on many factors, such as plant species, genotype and growth conditions, different organs and tissues of the same plant (Ražić et al., 2005).

Salads can be a vital part of a healthy diet, offering numerous nutritional benefits that support overall well-being, such as a wide array of vitamins, minerals, and antioxidants. These nutrients help protect the body from oxidative stress and support immune function. The variety of salads provides numerous flavors, textures, and nutritional benefits. The diversity of ingredients in salads makes them suitable for different dietary preferences and can help achieve various health goals, from weight management to boosting immunity.

Six plant samples purchased in the same megamarket were used in this research: *Lactuca sativa* (fam. Asteraceae) (lettuce), *Spinacia oleracea* (fam. Amaranthaceae) (spinach), *Cichorium intybus* var. foliosum (fam. Asteraceae) (radicchio), *Valerianella locusta* (fam. Valerianaceae) (lamb's lettuce), *Cichorium endivia* var. Crispum (fam. Asteraceae) (endive)and *Eruca sativa* (fam. Brassicaceae) (eruca). The aim of this study was to determine the content of potassium, sodium, calcium, magnesium, and selenium, in these samples, and the contribution of the mentioned elements in the diet by consuming a portion of salad.

## Experimental

### Chemicals and instruments

All reagents used for digestion were analytical grade, purchased from Sigma-Aldrich Chemical Company (Germany).
The measurements of elements were carried out in an Inductively Coupled Plasma Optical Emission Spectroscopy, ICP-OES (Thermo Scientific,UK), model 6500 Duo, equipped with a CID86 chip detector. Ultra-scientific ICP multi-element standard solutions were used as a stock solution for calibration.

### Sample collection

All samples *Lactuca sativa* L. (fam. Asteraceae), *Spinacia oleracea* L. (fam. Amaranthaceae), *Cichorium intybus* L. var. foliosum (fam. Asteraceae), *Valerianella locusta* L. (fam. Valerianaceae), *Cichorium endivia* L. var. Crispum (fam. Asteraceae) and *Eruca sativa* L. (fam. Brassicaceae)) purchased in the local market.

### Sample preparation

Prior to analysis, plants were air-dried at room temperature. Once dried, the samples were ground into a fine powder using a stainless-steel grinder and stored in polypropylene bags until further analysis. Samples were prepared through wet digestion, following a modified version of the procedure outlined by Tüzen, 2003. One gram of each salad species was combined with 15 mL oxi-acidic mixture composed of $HNO_3$, $H_2SO_4$, and $H_2O_2$ in a 4:1:1 ratio. The mixture was then heated to 150 °C for 4 hours before being diluted to a final volume of 25 mL with deionized water. A blank sample was processed in the same manner for comparison.

## Results and Discussion

The obtained results of each element (mg/kg dry weight) represent a mean value of three measurements ± SD (Table 1). The results indicated differences in element concentrations based on the species.

**Table 1.** Element content (mg/kg dry weight) of analyzed salads as mean ± standard deviation

| Samples | K | Na | Ca | Mg | Se |
|---|---|---|---|---|---|
| *L. sativa* | 19832±438 | 16523±324 | 12302±153 | 3981±59 | 3.3±0.12 |
| *S. oleracea* | 22854±115 | 3668±44 | 6745±122 | 6131±126 | 2.04±0.03 |
| *C. intybus* | 12468±327 | 14480±196 | 8334±65 | 1942±100 | 1.97±0.01 |
| *V. locusta* | 20607±4883 | 8605±122 | 8269±76 | 2775±78 | 2.47±0.02 |
| *C. endivia* | 14806±130 | 20840±35 | 4628±86 | 1915±102 | 2.328±0.009 |
| *E. sativa* | 15866±287 | 2086±44 | 14243±116 | 2240±102 | 1.89±0.07 |

Also, the content of elements in the selected types of salad was calculated per 100 g of fresh salad (USDA, Food Data Centrtal, 2020) and expressed as a percentage of the daily intake. When recalculating the nutritional content of a fresh salad, it was taken that approximately 90% of its weight is water. It was obtained using the mean value of three measurements for each element, and the results are shown in Table 2. A portion of salads contribution is considered to be significant if it provides 15% of the recommended daily intake (RDI) of nutritionally valuable elements (Stefanović, 2016).

**Table 2.** The element content in the analyzed samples shown per 100 g of fresh salad and % of daily intake

| Sample | K | | Na | | Ca | | Mg | | Se | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **mg K/100g fs** | **%** | **mg Na/100 g fs** | **%** | **mg Ca/100g fs** | **%** | **mg Mg/100 g fs** | **%** | **mg Se/100g fs** | **%** |
| *L. sativa* | 198.3 | 9.9 | 165.2 | 11.0 | 123.0 | 15.4 | 39.8 | 10.0 | 0.033 | 60.5 |
| *S. oleracea* | 228.5 | 11.4 | 36.7 | 2.4 | 67.5 | 8.4 | 61.3 | 15.3 | 0.020 | 37.1 |
| *C. intybus* | 124.7 | 6.2 | 144.8 | 9.7 | 83.3 | 10.4 | 19.4 | 4.9 | 0.020 | 35.9 |
| *V. locusta* | 206.1 | 10.3 | 86.1 | 5.7 | 82.7 | 10.3 | 27.8 | 6.9 | 0.025 | 44.9 |
| *C. endivia* | 148.1 | 7.4 | 208.4 | 13.9 | 46.3 | 5.8 | 19.2 | 4.8 | 0.023 | 42.3 |
| *E. sativa* | 158.7 | 7.9 | 20.9 | 1.4 | 142.4 | 17.8 | 22.4 | 5.6 | 0.019 | 34.4 |

fs-fresh salad

The analysis of element content in various leafy vegetables reveals notable differences across the samples. While potassium does not become a part of the chemical structure of plants, it plays many important regulatory roles in development. It increases crop yield and improves quality. It is required for numerous plant growth processes (Prajapati et al., 2012). Potassium is the third most abundant mineral in the human body and plays an important role in many metabolic processes, including the proper functioning of the brain, heart and muscles. It is the most abundant cation in the human body, yet only 2% of total body potassium is contained in the extracellular fluid, a compartment accessible to clinical assessment. Its concentration in extracellular fluid is tightly regulated between 3.5 and 5.0 mmol/L. Most of the potassium (98%) is located intracellularly (mainly in muscle) at concentrations between 100 and 150 mmol/L, depending on cell type (Besouw et al., 2019).

Among the analyzed species, *S. oleracea* had the highest concentration of potassium (22854 mg/kg dw), and *C. intybus* had the lowest (12468 mg/kg dw). The RDI for potassium for adults is 2000 mg (EEC, 2008). Table 2 shows that all analyzed samples do not have a significant contribution of potassium by consuming a portion of 100 g, as it does not exceed 15% of the daily intake. Consuming a portion of 100 g of fresh species provides from 6.2% (*C. intybus*) to 11.4% (*S. oleracea*) of the daily K requirement.

A proper balance of sodium levels in every part of our body is vital; the osmotic pressure of the extracellular fluids of our body is dictated for 90% by sodium ions and their counter-ions, largely chloride. Tight regulation of the sodium levels in our blood plasma and interstitial fluids is crucial for the essential physiological functions of virtually all cells in our body, as many transport processes depend on it. Slight deviations affect the electrical activity of muscle and nerve cells, renal function, capillary exchange, and cardiac output, impacting blood pressure in multiple ways. (Dötsch et al., 2009)

All analyzed samples showed different sodium levels, ranging from 2086-20840 mg/kg dw. *C. endivia* is had the highest sodium content (20840 mg/kg dw), whereas the lowest was in *E. sativa* (2086 mg/kg dw). The RDI for sodium is 1500 mg. (EFSA, 2019) Consuming a portion of 100 g of fresh salad provides from 1,39 % to 13,9% sodium per day.

Calcium is an essential plant nutrient. $Ca^{2+}$ it is required for structural roles in the cell wall and membranes, as a counter-cation for inorganic and organic anions in the vacuole, and as an intracellular messenger in the cytosol. (Marschner, 1995) It is an essential nutrient necessary for many human health functions. Calcium is the most abundant mineral in the body with 99% found in teeth and bone. Only 1% is found in serum. The serum calcium level is tightly monitored to remain within normal range by a complex metabolic process. Calcium metabolism involves other nutrients, including protein, vitamin D, and phosphorus. (Beto, 2015)

Calcium occurs in very similar concentrations in almost all samples, in the 4628 - 8334 mg/kg dw range. The *L. sativa* and *E. sativa* were separated with a higher calcium content, 12302 mg/kg dw and 14243 mg/kg dw, respectively. The RDI of calcium for adults is 800 mg. (EC, 2008) From Table 2 it can be seen some analyzed samples significantly contribute calcium from a portion of 100 g of fresh salad because it exceeds 15 %. Consuming a portion of 100 g of fresh *E. sativa* and *L. sativa* can provide a maximum of 17.8% and 15.4% of calcium daily intake.

Magnesium is most important to plants; about 75% of the leaf magnesium is involved in protein synthesis, and an amount between 15 % and 20 % of total Mg is associated with chlorophyll pigments, mainly acting as a cofactor of a series of enzymes involved in photosynthetic carbon fixation and metabolisms. (Guo et al., 2016) There are two major roles for magnesium in biological systems. It can form chelates with important intracellular anionic ligands, notably ATP, and it can compete with calcium for binding sites on proteins and membranes. There are about 300 magnesium activated enzymes. Among the enzyme-catalysed reactions in which magnesium acts as an essential cofactor are those concerned with glycolysis, cell respiration and transmembrane transport of other cations such as sodium and calcium. In particular, the activity of membrane bound Na-K-ATPase depends on magnesium. (Ryan, 1991)

The concentration of Mg in the analyzed samples ranged from 1915 mg/kg dw (*C. endivia*) to 6131 mg/kg dw (*S. oleracea*). Among the tested samples, *S. oleracea* had the highest content of magnesium, 6131 mg/kg, and consuming a portion of 100 g of fresh *S. oleracea*, can provide a significant of 15.3% of magnesium daily intake.

Selenium cycles through food systems, being removed from soils by plants and micro-organisms which can take up the element into their tissue proteins and convert some of it to volatile metabolites (e.g. dimethylselenide) that enter the atmosphere ultimately to be brought down with precipitation and airborne particulates (Shrift, 1964; Allaway et al. 1967; Stork et al. 1999). As selenocysteine, the 21$^{st}$ amino acid, selenium is a component of selenoproteins, some of which have important enzymic functions.

Among the tested samples, the highest content of selenium was shown by the species *L. sativa* (3.327 mg/kg dw). In contrast, the minimum content was observed in the *E. sativa* (1.89 mg/kg dw). The Institute of Medicine of the American National Academies (U.S. National Academies, Institute of Medicine, 2001) recommends a daily Se intake of 0.055 mg. Based on the results, it can be noticed that all analyzed samples have a significant contribution to the daily intake of selenium (> 15 %), and the species *L. sativa* has the highest value, 60.5 %.

## Conclusion

These results demonstrate the diverse nutrient compositions across different leafy vegetables, which can provide varying health benefits depending on the mineral requirements. Among the vegetables tested, *L. sativa* exhibited the highest concentrations of selenium and calcium, making it a rich source of these essential minerals. A portion of this salad provides a significant contribution of these elements, especially selenium (60.5%). *S. oleracea*, on the other hand, had a relatively higher magnesium and potassium content, along with a balanced distribution of selenium, which constitutes a significant daily intake. *C. intybus* and *V. locusta* presented moderate levels of minerals. *C. endivia* had a unique profile, with higher sodium content compared to other samples, while *E. sativa* had a low selenium and sodium, but higher calcium content. Overall, these findings highlight the diverse mineral compositions in leafy vegetables, with each offering specific nutritional benefits depending on the mineral of interest.

## Acknowledgement

This work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, grant numbers 451-03-65/2024-03/200113 and SANU, grant numbers O-02-17.

## Conflict-of-Interest Statement

The authors declare no conflict of interest.

## References

Allaway, W.H., Cary, E.E., & Ehlig, C.F. (1967). The cycling of low levels of selenium in soils, plants and animals. In O. H. Muth, J. E. Oldfield and P.H. Weswig (Ed.), Selenium in Biomedicine, pp. 273-296 Westport, CN: AVI Publishing Co.

Barmmer, A. (2022). Nutrition: The Overlooked Factor in Male Fertility. Alternative Medicine, 63, 26-27.

Besouw, M. T. P., & Bockenhauer, D. (2019). Chapter 3 - Potassium Metabolism. Nephrology and Fluid/electrolyte Physiology (Third Edition), 31-46.

Beto, J. A. (2015). The role of calcium in human aging. Clinical nutrition research, 4, 1-8.

Dötsch, M., Busch, J., Batenburg, M., Liem, G., Tareilus, E., Mueller, R., & Meijer, G. (2009). Strategies to Reduce Sodium Consumption: A Food Industry Perspective. Critical Reviews in Food Science and Nutrition, 49, 841-851.

EEC (2008) Amending Council Directive 90/496/EEC on nutrition labelling for foodstuffs as regards recommended daily allowances, energy conversion factors and definitions. Official Journal of the European Union, Commission Directive 2008/100/EC.

EFSA, (2019). European Food Safety Authority, Dietary Reference Values for sodium.

Guo, W., Nazim, H., Liang, Z., & Yang, D. (2016). Magnesium deficiency in plants: An urgent problem. The Crop Journal, 4, 83-91.

Imelouane, B., Tahri, M., Elbastrioui, M., Aouinti, F., & Elbachiri, A. (2011). Mineral Contents of Some Medicinal and Aromatic Plants Growing in Eastern Morocco. Journal of Materials and Environmental Science, 2, 104-111.

Marschner, H. (1995). Mineral nutrition of higher plants 2nd edn. Institute of Plant Nutrition University of Hohenheim: Germany.

Özcan, M. (2004). Mineral contents of some plants used as condiments in Turkey. Food Chemistry, 84, 437-440.

Prajapati, K., & Modi, H.A. (2012). The Importance of Potassium in Plant Growth—A Review. Indian Journal of Plant Sciences, 2-3, 177-178.

Ražić, S., Onjia, A., Đogo, S., Slavković, L., & Popović, A. (2005). Determination of metal content in some herbal drugs - Empirical and chemometric approach. Talanta, 67, 233-239.

Revoredo-Giha, C. (2021). Nutritional and Environmental Assessment of Increasing the Content of Fruit and Vegetables in the UK Diet. Sustainability, 13, 1076.

Ryan, M. F. (1991). The role of magnesium in clinical biochemistry: an overview. Annals of clinical biochemistry, 28, 19-26.

Shrift, A. (1964). A selenium cycle in nature? Nature, 201, 1304-1305.

Slavin, J. L., & Lloyd, B. (2012). Health benefits of fruits and vegetables. Advances in Nutrition, 3, 506-516.

Stefanović, V. M. (2016). Određivanje sadržaja makroelemenata i mikroelemenata u uzorcima pečurke macrolepiota procera i zemljišnim supstratima iz rasinskog okruga. Univerzitet u Beogradu.

Stork, A., Jury, W.A., & Frankenberger, W.T. Jr (1999). Accelerated volatilization of selenium from different soils. Biological Trace Element Research, 69, 217-234.

Tüzen, M. (2003). Determination of heavy metals in soil, mushroom and plant samples by atomic absorption spectrometry. Microchemical Journal, 74, 289-297.

U.S. National Academies, Institute of Medicine, (2001). Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. The National Academies Press, Washington, USA.

USDA. (2020). FoodData Central.