Agrobiodiversity for Improving Nutrition, Health and Life Quality

Research Article OPEN ACCESS

# Bioactive Compounds, Antioxidant Activity, and Potentially Toxic Elements in Onion (*Allium cepa* L.) Cultivars

Judita Lidiková[1], Natália Čeryová*[1], Jana Jakubčinová[1], Olga Grygorieva[2], Simona Gallisová[1], Magdaléna Zimmermannová[1]

[1]Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Institute of Food Sciences, Nitra, Slovakia
[2]M. M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine, Department of Fruit Plants AcclimatisationKyiv, Ukraine

Judita Lidiková: https://orcid.org/0000-0001-9922-4300
Natália Čeryová: https://orcid.org/0000-0002-1865-5131
Jana Jakubčinová: https://orcid.org/0000-0002-3759-1372
Olga Grygorieva: https://orcid.org/0000-0003-1161-0018



Article Details:
Received: 2026-03-26
Accepted: 2026-05-07
Available online: 2026-05-31

DOI: https://doi.org/10.15414/ainhlq.2026.0010

Onion (*Allium cepa* L.) is one of the most widely consumed vegetables globally, valued not only for its culinary applications but also for its nutritional and functional properties. It is a rich source of bioactive compounds, particularly phenolic substances, which are strongly associated with antioxidant activity and potential health benefits. However, onions may also accumulate potentially toxic elements from the environment, posing risks to food safety. This study aimed to evaluate the total polyphenol content (TPC), antioxidant activity (AA), vitamin C content, and the concentrations of selected potentially toxic elements (cadmium, lead) in three onion cultivars (Medusa, Conservor F1, Karmen). Significant differences ($p < 0.05$) were observed among cultivars for all evaluated parameters. The highest TPC and AA were recorded in the cultivar Karmen (781.3 mg GAE·kg$^{-1}$, 1.54 mmol TE·kg$^{-1}$), followed by Konzervor (597.8 mg GAE·kg$^{-1}$, 0.49 mmol TE·kg$^{-1}$) and Medusa (512.2 mg GAE·kg$^{-1}$, 0.32 mmol TE·kg$^{-1}$), confirming the strong association between phenolic compounds and antioxidant capacity. Vitamin C content showed less pronounced variability, with a range from 68.3 to 75.3 mg·kg$^{-1}$. Regarding food safety, Cd concentrations ranged from 0.02 to 0.09 mg·kg$^{-1}$, and Pb concentrations from 0.29 to 0.36 mg·kg$^{-1}$. When compared with the maximum levels established by Commission Regulation (EU) 2023/915, all samples exceeded the Pb limits, and all samples except one exceeded the Cd limits. Overall, the results demonstrate that onions serve as both a valuable source of bioactive compounds and a potential pathway for dietary exposure to toxic elements, highlighting the need for continuous monitoring and optimized agricultural practices to ensure food safety and nutritional quality.

**Keywords:** *Allium cepa*, onion, antioxidant, cadmium, lead

***Corresponding Author:** Natália Čeryová, Institute of Food Sciences, Faculty of Biotechnology and Food Sciences, Slovak University of Agriculture in Nitra, Tr. Andreja Hlinku 2, 949 76 Nitra, Slovakia
natalia.ceryova@uniag.sk

## Introduction

The onion (*Allium cepa* L. var. *cepa*) is among the oldest cultivated and most widely consumed vegetable crops worldwide. Its extensive production and consumption are driven by increasing consumer demand, largely attributable to its recognized nutritional value and functional properties. In addition to its role as a staple food ingredient, onion has a long history of use in traditional medicine and is generally regarded as safe for human consumption, having been utilized both as a vegetable and as a therapeutic agent since ancient times (Zhao et al., 2021; Ullah et al., 2022). Shallot onion (*Allium cepa* L. var. *aggregatum*) is a closely related botanical variety of onion. The two forms are interfertile and readily cross-pollinate, producing fertile offspring. They also exhibit strong cytological and morphological similarities, reflecting their close genetic relationship (Tabor, 2018). Archaeological evidence indicates that onion was already in use more than 5,000 years ago, with findings documented in the Dead Sea region. Historical records further demonstrate its early significance; for example, Pliny the Elder described the onion in the first century AD, noting the existence of multiple cultivated varieties at that time. Additional evidence of its cultural and symbolic importance is provided by depictions in ancient Egyptian funerary art, as well as its presence among burial items, including within the cranial and thoracic cavities of mummies (Brewster, 2008; Block, 2010).

Onions are rich in a diverse array of phytochemicals, including organosulfur compounds, phenolic compounds, polysaccharides, and saponins, many of which contain functionally active groups contributing to their biological activity. The health-promoting properties of onions are largely attributed to these bioactive constituents. Among them, sulfur-containing compounds, particularly S-alk(en)yl-L-cysteine sulfoxides (ACSOs) and derivatives such as onionin A, represent the predominant class, alongside phenolic compounds such as flavonoids (e.g., quercetin and its glycosides, rutin). The composition and concentration of these bioactive compounds are strongly influenced by genetic and varietal factors (Zhao et al., 2021; Czech et al., 2022).

Numerous studies have documented its broad spectrum of biological activities, including antifungal, antiviral, anti-inflammatory, antihypertensive, antidiabetic, antiallergic, and hypolipidemic effects. These properties are primarily attributed to the presence of phenolic compounds, flavonoids, and other bioactive molecules (Liu et al., 2022). Regular consumption of onions has been associated with multiple health benefits, including a reduced risk of chronic diseases such as cardiovascular disorders, diabetes mellitus, certain types of cancer, and neurodegenerative conditions (Matrella et al., 2022).

However, vegetables may also accumulate potentially toxic elements (PTEs), which can pose a risk to human health. PTE contamination is a global environmental and public health concern due to the toxicological risks posed by elevated metal concentrations. The presence of potentially toxic elements in soils arises from both natural processes, such as the weathering of metal-rich parent materials, and anthropogenic inputs, including industrial emissions, mining activities, and agricultural practices (Abdu et al., 2017). When contaminated soils are used for crop production, these elements can be taken up by plants and subsequently enter the food chain, potentially leading to adverse health effects in humans at elevated concentrations (Oves et al., 2016).

Therefore, this study aimed to investigate the relationship between the bioactive composition (total polyphenols, vitamin C, and antioxidant activity) of *Allium cepa* and the accumulation of potentially toxic elements (Cd and Pb), with a focus on evaluating both nutritional value and food safety implications.

## Material and Methodology

### Plant samples

In this study, onion cultivars belonging to *Allium cepa* var. *cepa* (Medusa and Karmen) and *Allium cepa* var. *aggregatum* (Conservor F1) were used. The samples were purchased from a local supermarket.

### Extract preparation

Homogenized fresh plant samples (25 g) were extracted with 50 mL of 80% (v/v) methanol for 16 h at laboratory temperature. The extracts were subsequently filtered through quantitative filter paper and used for further analyses.

### Total polyphenol content

Total polyphenol content (TPC) was determined using the Folin–Ciocalteu method as described by Lachman et al. (2003). The reaction mixture consisted of 0.1 mL of extract, 0.85 mL of Folin–Ciocalteu reagent (Merck, Germany), and, after 3 min, 5 mL of 20% (w/v) $Na_2CO_3$ solution (Sigma-Aldrich, USA). The mixture was transferred to a 50 mL volumetric flask and diluted to volume with distilled water. After incubation for 2 h at room temperature, absorbance was measured at 765 nm using a Shimadzu UV–Vis spectrophotometer against a reagent blank. Results were expressed as mg gallic acid equivalents (GAE) per kg of sample, based on a calibration curve ($R^2$ = 0.998).

### Antioxidant activity

Antioxidant activity (AA) was determined using the DPPH radical scavenging assay according to Brand-Williams et al. (1995). A 6 × $10^{-5}$ solution of DPPH• (2,2-diphenyl-1-picrylhydrazyl) was prepared in methanol (Sigma-Aldrich, USA). An aliquot of 0.1 mL of extract was mixed with 3.9 mL of DPPH solution, vortexed, and incubated in the dark for 10 min. The decrease in absorbance was measured at 515 nm using a Shimadzu UV–Vis spectrophotometer against a blank. Antioxidant activity was expressed as mmol Trolox equivalents per kg of sample, based on a calibration curve ($R^2$ = 0.995).

### Vitamin C content

For vitamin C analysis, 2 g of homogenized fresh plant material was accurately weighed and extracted with 20 mL of 3% (w/v) meta-phosphoric acid prepared in ultrapure water to stabilize ascorbic acid and precipitate proteins. The mixture was vortexed for 1 min and subsequently filtered through a 0.45 µm PVDF syringe filter (Millipore Corporation, Bedford, MA, USA).

Vitamin C content was determined by high-performance liquid chromatography (HPLC) using an Agilent 1260 Infinity II system (Agilent Technologies, Waldbronn, Germany) equipped with a quaternary pump, degasser, autosampler, column thermostat, and diode array detector (DAD). Separation was performed on a reversed-phase C18 column (Cortecs, 150 × 3.0 mm, 2.7 µm; Waters, USA). The mobile phase consisted of methanol and 0.1% (v/v) $H_3PO_4$ in deionized water. Isocratic elution was performed at a composition of 20% methanol and 80% acidified water for 10 min. The flow rate was set to 0.6 mL·min$^{-1}$, and the injection volume was 10 µL. The column temperature was maintained at 30 °C, while samples were kept at 8 °C in the autosampler. Detection was carried out at 256 nm. Data acquisition and processing were performed using Agilent CDS software for LC 3D systems.

### Heavy metal content

Homogenized dried plant samples were subjected to microwave-assisted acid digestion using a MARS Xpress 5 closed-vessel system (CEM Corp., Matthews, NC, USA). Approximately 0.5 g of each sample was digested in a mixture of 5 mL of $HNO_3$ Suprapur® (Merck, Darmstadt, Germany) and 5 mL of deionized water (conductivity 0.054 µS·cm$^{-1}$). The digestion program consisted of a temperature ramp to 160 °C over 15 min, followed by a 10 min holding period at constant temperature. After cooling, the digests were filtered through Filtrak 390 quantitative filter paper (Munktell GmbH, Bärenstein, Germany) and diluted to a final volume of 50 mL with deionized water.

Cadmium (Cd) and lead (Pb) concentrations were determined by graphite furnace atomic absorption spectrometry (GFAAS) using a VARIAN AASpectra DUO 240Z spectrophotometer (Varian Ltd., Mulgrave, VIC, Australia). The obtained concentrations were evaluated against the maximum permissible levels for contaminants in vegetables established by Commission Regulation (EU) 2023/915 in order to assess food safety compliance.

### Statistical analysis

Statistical analyses were performed using XLSTAT software (Lumivero, 2025). Data are presented as mean ± SD (n = 4). Normality and homogeneity of variance were assessed using Shapiro-Wilk and Levene's tests. Differences among cultivars were evaluated using one-way ANOVA followed by Tukey's HSD test ($p < 0.05$). When assumptions were not met, the Kruskal–Wallis test with Dunn's post hoc test was applied. Relationships between variables were assessed using Pearson correlation.

## Results and Discussion

Significant differences ($p < 0.05$) were observed among the evaluated onion cultivars in the monitored parameters (Table 1).

The highest total polyphenol content (TPC) was recorded in the cultivar Karmen (781.3 ±14.7 mg GAE·kg$^{-1}$), followed by Konzervor (597.8 ±29.7 mg GAE·kg$^{-1}$) and Medusa (512.1 ±20.6 mg GAE·kg$^{-1}$), with all cultivars differing significantly from each other. A similar trend was observed for antioxidant activity (AA), where Karmen exhibited the highest value (1.54 mmol TE·kg$^{-1}$), significantly exceeding the cultivar Medusa (0.32 mmol TE·kg$^{-1}$), while Konzervor showed intermediate values without significant differences from either group (0.49 mmol TE·kg$^{-1}$). Previous studies have demonstrated that antioxidant activity and phenolic compound content in onions can vary considerably depending on species, cultivar,

**Table 1** Biocative compounds and antioxidant activity of the samples

| Cultivars | Fresh weight | | | Dry weight | | |
|---|---|---|---|---|---|---|
| | TPC (mg GAE·kg$^{-1}$) | AA (mmol TE·kg$^{-1}$) | vitamin C (mg·kg$^{-1}$) | TPC (mg GAE·kg$^{-1}$) | AA (mmol TE·kg$^{-1}$) | vitamin C (mg·kg$^{-1}$) |
| **Medusa** | 512.1 ±20.6$^{a}$ | 0.32 ±0.06$^{a}$ | 75.3 ±2.8$^{b}$ | 3,444 ±1,38.7$^{a}$ | 2.18 ±0.38$^{a}$ | 506.4 ±18.8$^{b}$ |
| **Conservor F1** | 597.8 ±29.7$^{b}$ | 0.49 ±0.06$^{ab}$ | 68.3 ±0.66$^{a}$ | 3,496 ±174.0$^{ab}$ | 2.86 ±0.34$^{ab}$ | 399.2 ±3.85$^{a}$ |
| **Karmen** | 781.3 ±14.7$^{c}$ | 1.54 ±0.2$^{b}$ | 75.6 ±0.58$^{b}$ | 5192 ±97.9$^{b}$ | 10.2 ±1.35$^{b}$ | 502.6 ±3.84$^{b}$ |

Notes: Values are expressed as mean ±SD (n = 4). Different superscript letters within a column indicate statistically significant differences ($p < 0.05$)

and methodological factors. For instance, Kisa et al. (2022) highlighted that variability in results among *Allium* species is influenced by the plant part analyzed, as well as by the extraction solvent and methodology employed. Reported total polyphenol content (TPC) values in onions show substantial variability. Andrejiová et al. (2011) observed TPC values ranging from 105.19 to 1,347 mg·kg$^{-1}$, reflecting differences in cultivar and experimental conditions. Likewise, Dalaram (2016) reported TPC values in onion samples ranging from 322.83 to 626.61 mg·kg$^{-1}$. In terms of varietal differences, Chernukha et al. (2022) found that red onion cultivars had the highest polyphenol content, which is consistent with their elevated levels of flavonoids and anthocyanins. Kavalcová et al. (2015) reported that the total polyphenol content in yellow onion cultivars ranged from 441.32 to 455.22 mg·kg$^{-1}$. Similarly, Kavalcová et al. (2014) reported total polyphenol content in onions in the range of 389.64 to 429.58 mg GAE·kg$^{-1}$. Kim et al. (2024) reported 495.2–570.8 mg GAE·kg$^{-1}$ in different onion cultivars. Dalamu et al. (2010) evaluated 34 Indian onion genotypes of different bulb colors (white, pink, and red) and reported the highest total phenolic content in red cultivars (867.8 mg GAE·kg$^{-1}$), followed by pink (702.0 mg GAE·kg$^{-1}$) and white (165.0 mg GAE·kg$^{-1}$) onions. Lisanti et al. (2016) reported total phenolic content in onion bulbs ranging from 4710 to 6610 mg GAE.g$^{-1}$ DW, which is comparable to the values obtained in the present study. Similarly, Lee et al. (2016) observed a broader range of total phenolic content, from 4,020 to 23,120 mg GAE.g$^{-1}$ DW, indicating substantial variability among onion samples. Bibi et al. (2022) demonstrated that the total polyphenol content and antioxidant activity of onion bulbs are significantly influenced by both genetic factors (cultivar) and environmental conditions. According to Khalili et al. (2022), the determined total polyphenol content and antioxidant activity are also significantly influenced by the extraction solvent used.

Regarding vitamin C content, the lowest concentration was determined in Konzervor (68.3 ±0.66 mg·kg$^{-1}$), which differed significantly from Medusa (75.3 ±2.8 mg·kg$^{-1}$) and Karmen (75.6 ±0.58 mg·kg$^{-1}$), between which no significant difference was observed. Matějková and Petříková (2010) reported vitamin C content in onions ranging from 94 to 104 mg·kg$^{-1}$, with the highest value observed in red onions (104 mg·kg$^{-1}$) and slightly lower levels in yellow cultivars (94–99 mg·kg$^{-1}$). In contrast, Petrovic-Pokluda (2020) reported substantially lower vitamin C contents, with 17.5 mg·kg$^{-1}$ in red onions and 35.4–44.4 mg·kg$^{-1}$ in yellow onions. Bystrická et al. (2010) reported vitamin C contents of 53.85 mg·kg$^{-1}$ in red onions, 28.93 mg·kg$^{-1}$ in yellow onions, and 19.98 mg·kg$^{-1}$ in white onions, indicating a decreasing trend from red to white cultivars. Compared with these findings, the vitamin C levels determined in the present study are higher. Kim et al. (2024) reported total ascorbic acid contents in onion cultivars 72.3–215.1 mg·kg$^{-1}$.

Regarding potentially toxic elements, cadmium (Cd) concentrations were highest in Karmen (0.09 mg·kg$^{-1}$), significantly exceeding the levels in Conservor

**Table 2** Cadmium and lead content of samples (mg·kg$^{-1}$)

| Cultivars | Fresh weight | | Dry weight | |
|---|---|---|---|---|
| | Cd | Pb | Cd | Pb |
| **Medusa** | 0.04 ±0.003$^{ab}$ | 0.29 ±0.02$^{a}$ | 0.27 ±0.02$^{ab}$ | 1.95 ±0.13$^{a}$ |
| **Konzervor** | 0.02 ±0.001$^{a}$ | 0.36 ±0.03$^{b}$ | 0.12 ±0.01$^{a}$ | 2.11 ±0.18$^{a}$ |
| **Karmen** | 0.09 ±0.005$^{b}$ | 0.30 ±0.02$^{a}$ | 0.60 ±0.03$^{b}$ | 1.99 ±0.13$^{a}$ |
| **Max. level*** | 0.03 | 0.10 | – | – |

Notes: Values are expressed as mean ± SD (n = 4). Different superscript letters within a column indicate statistically significant differences ($p < 0.05$).
*Maximum level according to Commission Regulation (EU) 2023/915 of 25 April 2023

(0.02 mg·kg$^{-1}$), while Medusa (0.04 mg·kg$^{-1}$) exhibited intermediate concentrations and did not differ significantly from either of the other cultivars. Reported cadmium (Cd) concentrations in onions vary widely across studies. Bibi et al. (2021) reported Cd levels ranging from 0.017 to 0.066 mg·kg$^{-1}$. Oprea et al. (2022) reported from 0.007 to 0.106 mg·kg$^{-1}$. Studies expressed on a dry matter (DM) basis indicate similar variability, with Bystrická et al. (2015) reporting values between 0.02 and 0.04 mg·kg$^{-1}$ DM, and Ametepey et al. (2018) reporting a range of 0.03 to 0.06 mg·kg$^{-1}$ DM. Lidiková et al. (2021), observed Cd concentrations from below the limit of detection (LOD) to 0.04 mg·kg$^{-1}$ DM. Lazović et al. (2023) reported values from <LOD to 0.0409 mg·kg$^{-1}$ FW. In contrast, Shokri et al. (2022) reported a substantially broader range of Cd concentrations (0.0006 to 0.526 mg·kg$^{-1}$ DM), indicating considerable variability across different environmental or agronomic conditions. Conversely, Habu et al. (2021) reported Cd levels in onions below the LOD.

Lead (Pb) content was highest in Conservor (0.36 mg·kg$^{-1}$), significantly differing from Medusa (0.29 mg·kg$^{-1}$) and Karmen (0.30 mg·kg$^{-1}$), which did not differ significantly from each other. Reported lead (Pb) concentrations in onions show considerable variability across studies. Bibi et al. (2021) reported Pb levels ranging from 0.055 to 0.576 mg·kg$^{-1}$, while Oprea et al. (2022) observed values between 0.009 and 0.136 mg·kg$^{-1}$. Similarly, Lazović et al. (2023) reported concentrations ranging from below the limit of detection (LOD) to 0.0799 mg·kg$^{-1}$ FW. Studies expressed on a dry matter (DM) basis also demonstrate a wide range of values. Bystrická et al. (2015) reported Pb concentrations between 0.05 and 0.21 mg·kg$^{-1}$ DM, while Bystrická et al. (2016) observed values from 0.11 to 0.60 mg·kg$^{-1}$. Lidiková et al. (2021) reported a range of 0.07 to 0.23 mg·kg$^{-1}$ DM, and Shokri et al. (2022) found concentrations between 0.05 and 0.297 mg·kg$^{-1}$ DM. In contrast, studies by Habu et al. (2021) and Ametepey et al. (2018) reported Pb concentrations below the limit of detection.

All analyzed samples exceeded the maximum permissible levels for lead (Pb), while for cadmium (Cd), all samples except one exceeded the established limits according to Commission Regulation (EU) 2023/915 of 25 April 2023. These findings indicate a potential food safety concern, particularly given repeated dietary exposure. Although onions are generally consumed in moderate quantities, their regular inclusion in the diet may contribute to cumulative intake of these elements. The consistent exceedance of Pb limits across all samples suggests a possible common source of contamination, such as soil characteristics or environmental pollution, whereas the variability observed for Cd may reflect differences in cultivar-specific uptake or localized growing conditions. These results underline the necessity for continuous monitoring of potentially toxic elements in vegetables, as well as the implementation of appropriate agronomic and environmental control measures to reduce contamination at the source.

The correlation analysis (Table 3) revealed several strong relationships among the evaluated variables; however, due to the limited number of samples, most of these correlations were not statistically significant. The only statistically significant correlation ($p < 0.05$) was observed between total polyphenol content (TPC) and antioxidant activity (AA) ($r = 0.999$), indicating a positive association. This result confirms that phenolic compounds are the dominant contributors to the antioxidant capacity of the analyzed onion samples. Although not statistically significant, several high correlation coefficients were observed. Notably, strong positive relationships were found between TPC and Cd ($r = 0.943$) and between AA and Cd ($r = 0.925$), suggesting a potential co-accumulation pattern that warrants further investigation. Similarly, vitamin C showed a strong negative correlation with Pb ($r = -0.971$), and moderate-to-strong positive correlations with Cd ($r = 0.722$) and TPC ($r = 0.449$).

**Table 3** Pearson correlation matrix

| Variable | TPC | AA | Vitamin C | Cd | Pb |
|---|---|---|---|---|---|
| **TPC** | 1 | | | | |
| **AA** | 0.999 | 1 | | | |
| **Vitamin C** | 0.449 | 0.404 | 1 | | |
| **Cd** | 0.943 | 0.925 | 0.722 | 1 | |
| **Pb** | -0.223 | -0.174 | -0.971 | -0.535 | 1 |

Notes: Values in bold are statistically significant (p <0.05)

## Conclusions

This study demonstrated that *Allium cepa* cultivars differ significantly in their bioactive composition and accumulation of potentially toxic elements. Among the evaluated cultivars, Karmen exhibited the highest total polyphenol content and antioxidant activity, confirming the strong relationship between phenolic compounds and antioxidant capacity. In contrast, vitamin C content showed less pronounced variability and did not correlate significantly with antioxidant activity, suggesting a secondary role in the overall antioxidant potential of onions. From a food safety perspective, the findings raise concerns regarding the accumulation of potentially toxic elements. All analyzed samples exceeded the maximum permissible levels for lead (Pb), and all samples except one exceeded the limits for cadmium (Cd) established by Commission Regulation (EU) 2023/915. Overall, the results highlight the dual nature of onions as both a valuable source of health-promoting compounds and a potential vector of contaminant intake. These findings emphasize the importance of continuous monitoring of heavy metal contamination, careful selection of cultivation sites, and consideration of varietal differences in future research and agricultural practices. Further studies with a larger number of samples and more detailed environmental characterization are recommended to better elucidate the factors influencing both the bioactive compound composition and metal accumulation.

### Conflict of interest

The authors have no competing interests to declare.

### Ethical statement

This article doesn't contain any studies that would require an ethical statement.

### Funding

This research was supported by the Slovak Scientific Grant Foundation under the Grant n. 1/0071/25

### Acknowledgements

The authors are thankful to the International Scientific Network AgroBioNet for their support and collaboration.

## References

Abdu, N., Abdullahi, A. A., & Abdulkadir, A. (2017). Heavy metals and soil microbes. *Environmental chemistry letters*, 15(1), 65–84. https://doi.org/10.1007/s10311-016-0587-x

Ametepey, S. T., Cobbina, S. J., Akpabey, F. J., Duwiejuah, A. B., & Abuntori, Z. N. (2018). Health risk assessment and heavy metal contamination levels in vegetables from Tamale Metropolis, Ghana. *International Journal of Food Contamination*, 5(1), 5. https://doi.org/10.1186/s40550-018-0067-0

Andrejiová, A., Kóňa, J., & Barátová, S. (2011). Effect of fertilization and cultivar on total polyphenol content in onion (*Allium cepa* L.). In *Nutrition and health: Proceedings from the conference* (pp. 12–17). SUA in Nitra.

Bibi, N., Shah, M. H., Khan, N., Al-Hashimi, A., Elshikh, M. S., Iqbal, A., & Abbasi, A. M. (2022). Variations in total phenolic, total flavonoid contents, and free radicals' scavenging potential of onion varieties planted under diverse environmental conditions. *Plants*, 11(7), 950. https://doi.org/10.3390/plants11070950

Bibi, N., Shah, M. H., Khan, N., Mahmood, Q., Aldosari, A. A., & Abbasi, A. M. (2021). Analysis and health risk assessment of heavy metals in some onion varieties. *Arabian Journal of Chemistry*, 14(10), 103364. http://doi.org/10.1016/j.arabjc.2021.103364

Block, E. (2010). *Allium* botany and cultivation, ancient and modern. In *Garlic and other alliums: The lore and the science* (pp. 1–32). Royal Society of Chemistry.

Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). Use of a free radical method to evaluate antioxidant activity. *LWT – Food Science and Technology*, 28(1), 25–30. https://doi.org/10.1016/S0023-6438(95)80008-5

Brewster, J. L. (2008). *Onions and other vegetable alliums* (Vol. 15). CABI.

Bystricka, J., Arvay, J., Musilova, J., Vollmannova, A., Toth, T., & Lenkova, M. (2016). The investigation of sensitivity of different types of onion to heavy metal intake from contaminated soil. *International Journal of Environmental Research*, 10(3), 427–440. https://doi.org/10.22059/ijer.2016.58762

Bystrická, J., Musilová, J., Tomáš, J., Tóth, T., Kavalcová, P., & Šiatkovský, O. (2015). Intake of heavy metals in selected varieties of onion (*Allium cepa* l.) Grown in the different locations/Akumulacja metali ciężkich w wybranych odmianach cebuli (*Allium cepa* L.) uprawianych w różnych warunkach. *Environmental Protection and Natural Resources*, 26(3), 17–21. https://doi.org/10.1515/OSZN-2015-0017

Bystrická, J., Tomáš, J., Árvay, J., Harangozo, Ľ., Lahučký, L., & Siatkovský, O. (2010). Chemical components of onion (*Allium cepa* L.) with the benefit for human health. *Potravinárstvo Slovak Journal of Food Sciences*, 4, 264–271.

European Commission. (2023). Commission Regulation (EU) 2023/915 of 25 April 2023 on maximum levels for certain contaminants in food and repealing Regulation (EC) No 1881/2006. *Official Journal of the European Union*, L 119, 103–157. https://eur-lex.europa.eu/eli/reg/2023/915/oj/eng

Czech, A., Szmigielski, M., & Sembratowicz, I. (2022). Nutritional value and antioxidant capacity of organic and conventional vegetables of the genus *Allium*. *Scientific Reports*, 12(1), 18713. https://doi.org/10.1038/s41598-022-23497-y

Dalamu, Kaur, C., Singh, M., Walia, S., Joshi, S., & Munshi, A. D. (2010). Variations in phenolics and antioxidants in Indian onions (*Allium cepa* L.) Genotype selection for breeding. *Nutrition & Food Science*, 40(1), 6–19. https://doi.org/10.1108/00346651011015863

Dalaram, I. S. (2016). Content of total polyphenols and antioxidant activity in varieties of onion and garlic. *Slovak Journal of Food Sciences/Potravinarstvo*, 10(1). https://potravinarstvo.com/journal1/index.php/potravinarstvo/article/view/658

Habu, M. A., & Usman, B. A. W. A. (2021). Health risk assessment and heavy metal bioaccumulation in vegetables irrigated with waste water in Kano State, Nigeria. *Notulae Scientia Biologicae,* 13(1), 10890–10890. https://doi.org/10.15835/nsb13110890

Chernukha, I., Kupaeva, N., Kotenkova, E., & Khvostov, D. (2022). Differences in antioxidant potential of *Allium cepa* husk of red, yellow, and white varieties. *Antioxidants*, 11(7), 1243. https://doi.org/10.3390/antiox11071243

Kavalcová, P., Bystrická, J., Tomáš, J., Karovičová, J., & Kuchtová, V. (2014). Evaluation and comparison of the content of total polyphenols and antioxidant activity in onion, garlic and leek. *Slovak Journal of Food Sciences/ Potravinarstvo*, 8(1). http://doi.org/10.5219/394

Kavalcová, P., Bystrická, J., Tóth, T., Trebichalský, P., Hrstková, M., Lenková, M., & Šiatkovský, O. (2015). Content of total polyphenols and antioxidant activity in selected varieties of onion (*Allium cepa* L.). *Slovak Journal of Food Sciences/Potravinarstvo*, 9(1). http://dx.doi.org/10.5219/524

Khalili, S., Saeidi Asl, M. R., Khavarpour, M., Vahdat, S. M., & Mohammadi, M. (2022). Comparative study on the effect of extraction solvent on total phenol, flavonoid content, antioxidant and antimicrobial properties of red onion (*Allium cepa*). *Journal of Food Measurement and Characterization*, 16(5), 3578–3588. https://doi.org/10.1007/s11694-022-01446-7

Kim, Y., Kim, Y. J., & Shin, Y. (2024). Comparative analysis of polyphenol content and antioxidant activity of different parts of five onion cultivars harvested in Korea. *Antioxidants*, 13(2), 197. https://doi.org/10.3390/antiox13020197

Kısa, D., Kaya, Z., İmamoğlu, R., Genç, N., Taslimi, P., & Taskin-Tok, T. (2022). Assessment of antimicrobial and enzymes inhibition effects of *Allium kastambulense* with in silico studies: Analysis of its phenolic compounds and flavonoid contents. *Arabian Journal of Chemistry*, 15(6), 103810. http://doi.org/10.1016/j.arabjc.2022.103810

Lachman, J., Pronek, D., Hejtmánková, A., Dudjak, J., Pivec, V., & Faitová, K. (2003). Total polyphenol and main flavonoid antioxidants in different onion (*Allium cepa* L.) varieties. *Horticultural Science*, 30(4), 142–147.

Lazović, M., Tomović, V., Vasiljević, I., Kecojević, I., Tomović, M., Martinović, A., & Đorđević, V. (2023). Cadmium, lead, mercury and arsenic in fresh vegetables and vegetable products intended for human consumption in the Republic of Serbia, 2015–2017. *Food Additives & Contaminants: Part B*, 16(2), 102–119. https://doi.org/10.1080/19393210.2023.2169359

Lee, D. J., Han, J. A., & Lim, S. T. (2016). Enhancement of antioxidant activity of onion powders by browning during drying process. *Korean Journal of Food Science and Technology*, 48(1), 15–19. http://doi.org/10.9721/KJFST.2016.48.1.15

Lidiková, J., Čeryová, N., Šnirc, M., Vollmannová, A., Musilová, J., Brindza, J., & Fehér, A. (2021). Comparison of Heavy Metal Intake by Different Species of the Genus *Allium* L. *Biological trace element research*, 199(11), 4360–4369. https://doi.org/10.1007/s12011-020-02536-7

Lisanti, A., Formica, V., Ianni, F., Albertini, B., Marinozzi, M., Sardella, R., & Natalini, B. (2016). Antioxidant activity of phenolic extracts from different cultivars of Italian onion (*Allium cepa*) and relative human immune cell proliferative induction. *Pharmaceutical Biology*, 54(5), 799–806. https://doi.org/10.3109/13880209.2015.1080733

Liu, G., Wang, Y., Hu, L., & He, H. (2022). Characterization of the volatile compounds of onion with different fresh-cut styles and storage temperatures. *Foods*, 11(23), 3829. https://doi.org/10.3390/foods11233829

Lumivero. (2025). *XLSTAT statistical and data analysis solution* (Version 2025.2.0) [Computer software]. https://www.xlstat.com

Matějková, J., & Petříková, K. (2010). Ascorbic acid contents in selected vegetables in relation to variety, growing site, year and storage. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 58(1), 95–100.

Matrella, M. L., Valletti, A., Marra, F., Mallamaci, C., Cocco, T., & Muscolo, A. (2022). Phytochemicals from red onion, grown with eco-sustainable fertilizers, protect mammalian cells from oxidative stress, increasing their viability. *Molecules*, 27(19), 6365. https://doi.org/10.3390/molecules27196365

Oprea, B. Ș., Motelică, D. M., Vrînceanu, N. O., Costea, M., Plopeanu, G. I., & Carabulea, V. (2022). Research on the heavy metal content in onion bulbs correlated with soil from private households located in the Copșa Mică area, Central Romania. *Journal of Applied Life Sciences and Environment*, 55(1), 92–99. https://doi.org/10.46909/alse-551049

Oves, M., Saghir Khan, M., Huda Qari, A., Nadeen Felemban, M., & Almeelbi, T. (2016). Heavy metals: biological importance and detoxification strategies. *Journal of Bioremediation and Biodegradation*, 7(2), 1–15. http://doi.org/10.4172/2155-6199.1000334

Petrovic, B., & Pokluda, R. (2020). Influence of organic fertilizers on onion quality. *Polish Journal of Environmental Studies*, 29(1), 517–523. http://doi.org/10.15244/pjoes/99909

Shokri, S., Abdoli, N., Sadighara, P., Mahvi, A. H., Esrafili, A., Gholami, M., & Yousefi, M. (2022). Risk assessment of heavy metals consumption through onion on human health in Iran. *Food Chemistry*: X, 14, 100283. https://doi.org/10.1016/j.fochx.2022.100283

Tabor, G. (2018). Development of seed propagated shallot (*Allium cepa* L var. *aggregatum*) varieties in Ethiopia. *Scientia Horticulturae*, 240, 89–93. https://doi.org/10.1016/j.scienta.2018.05.046

Ullah, H., Minno, A. D., Santarcangelo, C., Tantipongpiradet, A., Dacrema, M., Matteo, R. D., & Daglia, M. (2022). *In vitro* bioaccessibility and anti-inflammatory activity of a chemically characterized *Allium cepa* L. extract rich in quercetin derivatives optimized by the design of experiments. *Molecules*, 27(24), 9065. https://doi.org/10.3390/molecules27249065

Zhao, X. X., Lin, F. J., Li, H., Li, H. B., Wu, D. T., Geng, F., & Gan, R. Y. (2021). Recent advances in bioactive compounds, health functions, and safety concerns of onion (*Allium cepa* L.). *Frontiers in Nutrition*, 8, 669805. https://doi.org/10.3389/fnut.2021.669805