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ORIGINAL SCIENTIFIC PAPER

Cadmium in Potato Crops: Differences Among Varieties

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Summary
Cadmium (Cd) is considered as one of the most ecotoxic metals, posing risks to humans, animals, and plants. Vegetables such as turnips, carrots, and potatoes represent major dietary sources of Cd. Cd accumulation varies among different vegetable species and varieties. This study aimed to evaluate Cd concentration in 19 potato varieties grown under identical field conditions in 2024 and 2025. Results showed varietal differences; KIS Kokra had the highest Cd levels (mean of both years: 0.1307 mg/kg FM, exceeding the EU maximum level of 0.1 mg/kg FM), while Messi, Peter Pan, Elland, Jelly had the lowest (mean of both years: 0.0567–0.0670 mg/kg FM). Cd concentrations were consistently higher in 2024, indicating environmental influence. These results highlight the importance of variety selection to reduce Cd intake.

Keywords: *Solanum tuberosum*, concentration, environmental conditions, Cd intake

Introduction

Cadmium (Cd) is one of the most ecotoxic metals, with harmful effects on humans, animals and plants. The International Agency for Research on Cancer (IARC) classifies Cd as a carcinogen (IARC, 2025). The presence of Cd in food is due to soil and water contamination. Cd is transferred from soil and water to plants and aquatic organisms and accumulates in the food chain (NIJZ, 2023). European Commission Regulation 2023/915 (OJ EU L 119/103, 2023) sets maximum levels for certain contaminants in food, including Cd, with the maximum level for Cd in fresh and peeled potatoes set at 0.1 mg/kg FM. Cd is not an essential element for plants, but it could be highly available in soils, and some plant species have a greater affinity to adsorb Cd (Kabata-Pendias and Pendias, 2001; Kabata-Pendias and Mukherjee, 2007). Globally, the average Cd content in soils ranges between 0.06 and 1.1 mg/kg, and it is a relatively mobile and bioavailable element (Kabata-Pendias and Mukherjee, 2007).

Plant species differ in their affinity for Cd uptake (Kabata-Pendias and Pendias, 2001; Alexander et al., 2006; Fang et al., 2019). Vegetables belonging to the Brassicaceae, Asteraceae, Apiaceae, and Convolvulaceae families generally exhibit higher Cd uptake, whereas those from the Liliaceae and Amaranthaceae families tend to accumulate lower amounts of Cd (Fang et al., 2019). Leafy vegetables, as well as root and tuber vegetables such as turnips, carrots, and potatoes, represent major dietary sources of Cd (Kabata-Pendias and Pendias, 2001). Cd accumulation varies significantly not only among different vegetable species but also among varieties within, particularly in leafy vegetables such as spinach (Kong et al., 2024). Differences in Cd uptake among plant varieties have been widely reported. For example, Alexander et al. (2006) observed variability among carrot and pea varieties, Zhu et al. (2007) reported differences among asparagus bean varieties, and Chen et al. (2012) and Wang et al. (2014) identified significant variation among pakchoi cultivars. Similarly, Brengi et al. (2021) found considerable differences in Cd concentrations in tubers among potato cultivars, Smolnikar et al. (2024) reported differences in Cd accumulation among garlic varieties, while Sana et al. (2024) reported variable responses of chili varieties grown under Cd stress.

To evaluate Cd concentration in potato tubers of different varieties grown under identical field conditions, we analysed 19 varieties and present the results in this paper.

Material and Methods

In 2024 and 2025, within the framework of potato variety trials conducted at the experimental fields of the Agricultural Institute of Slovenia (IC Komenda), samples were collected to determine Cd content and assess differences among varieties. The soil characteristics of the experimental field before the setup of the trials in 2024 (sampled in March 2024) were: pH 5.8 in KCl, 3.7% organic matter, 13 mg P_2O_5 100/g of available phosphorus, and 21 mg K_2O 100/g of available potassium. In both years, the same 19 varieties were analysed. All varieties were grown in the same field under identical agronomic conditions. Planting was carried out at the end of April and harvesting at the end of October in both years. Potatoes from year 2024 were sampled in mid-March 2025, whereas from 2025 they were sampled in mid-February 2026, after the storage. A representative sample of tubers (1 kg) was collected for analysis, and the potatoes were peeled before further processing. For the determination of Cd, homogenised potato tubers (weight 0.250 g) were digested using a high-pressure microwave oven (Milestone ETHOS 1600) with 5 ml 65 % nitric acid (HNO_3, SUPRAPUR, Merck) and 1 ml 30 % hydrogen peroxide (H_2O_2, SUPRAPUR, Merck). Cd in digested samples was analyzed with ICP-MS (Agilent 7900) in helium (He) collision mode to eliminate potential interferences. Results are presented as two-year mean Cd concentrations (2024–2025) calculated for each variety.

Results and Discussion

Cd concentrations varied among potato varieties and between the environments (fields-soils + year). KIS Kokra showed the highest Cd concentrations in both years, varieties such as Messi and Peter Pan showed lower values. These observations suggest potential varietal differences in Cd accumulation. In 2024, 9 varieties exceeded the European Commission Regulation 2023/915 limit set for Cd at 0.1 mg/kg FM, while in 2025 no varieties exceeded the limit. KIS Kokra had the highest Cd concentration in tubers 0.1775 mg/kg FM in 2024 (Table 1). In 2024 Cd concentrations in tubers ranged from 0.255 to 0.789 mg/kg DW, with KIS Kokra showing the highest value, followed by Twister, KIS Sora, and Marabel. In 2025 Cd concentrations were generally lower, ranging from 0.173 to 0.435 mg/kg DW, with the highest values observed in Labella, KIS Mangart, and KIS Slavnik, while Messi and Desiree showed the lowest concentrations. Our results align with findings from Brengi et al. (2021), who reported significant differences in Cd accumulation among peeled tubers of three potato cultivars, with Cd contents ranging from 0.08 to 0.21 mg/kg DW across field sites and seasons, and a mean value of 0.145 mg/kg DW. Öztürk et al. (2011) reported that 16 potato cultivars showed considerable variation in heavy metal concentrations, including Cd (0.08-0.32 mg/kg). Analysis of tubers from 10 potato cultivars grown in the same field revealed a significant difference in mean Cd concentrations among the cultivars, concentrations varied from 0.05 to 0.21 mg/kg DW (Ashrafzadeh et al., 2017).

Crops of 19 potato varieties accumulated Cd at different levels. For all varieties, Cd concentrations were consistently higher in 2024 than in 2025 on a fresh weight (FW) basis. The variety KIS Kokra had the highest Cd concentration in both years, particularly in 2024, while varieties such as Messi, Peter Pan, and Elland showed relatively lower Cd concentrations. When comparing Cd concentrations on a dry matter (DM) basis, the differences between years are smaller but still noticeable for some varieties (Table 1). This suggests that part of the observed decrease in Cd from 2024 to 2025 on a FW basis may be attributed to longer storage of the 2024 crop, which likely caused greater water loss and a concentration effect, rather than reflecting just differences in uptake from the soil.

Table 1. Cadmium concentrations (in mg/kg fresh matter and dry matter) in potato tubers of 19 varieties grown in 2024 and 2025.

VARIETY	Cd 2024 (mg/kg FM)	Cd 2024 (mg/kg DM)	Cd 2025 (mg/kg FM)	Cd 2025 (mg/kg DM)	Cd mean of 2024 and 2025 (mg/kg FM)
Messi	0.0719	0.341	0.0416	0.196	0.0567
Peter Pan	0.0599	0.255	0.0565	0.276	0.0582
Elland	0.0730	0.304	0.0567	0.291	0.0648
Jelly	0.0801	0.424	0.0538	0.268	0.0670
Desiree	0.0992	0.430	0.0355	0.173	0.0674
Alouette	0.0783	0.351	0.0578	0.301	0.0680
Maris Bard	0.0959	0.398	0.0482	0.211	0.0721
KIS Tamar	0.0875	0.431	0.0592	0.238	0.0733
Labella	0.0740	0.376	0.0761	0.435	0.0750
Soraya	0.1027	0.650	0.0556	0.304	0.0791
Levante	0.1039	0.550	0.0570	0.294	0.0805
KIS Blegoš	0.0869	0.383	0.0827	0.369	0.0848
KIS Slavnik	0.1005	0.529	0.0744	0.404	0.0874
Agria	0.1238	0.604	0.0554	0.281	0.0896
KIS Mangart	0.1112	0.601	0.0852	0.412	0.0982
Marabel	0.1215	0.710	0.0754	0.406	0.0984
Twister	0.1213	0.783	0.0802	0.399	0.1007
KIS Sora	0.1370	0.678	0.0765	0.361	0.1068
KIS Kokra	0.1775	0.789	0.0840	0.370	0.1307

Environmental conditions also likely contributed to the observed differences. The 2024 crop was grown at Lahovče and the 2025 crop at Zgornji Brnik. Average temperature and precipitation were higher in 2024, with mean temperatures 0.7 °C higher than in 2025, creating warmer and wetter conditions that may have promoted higher Cd accumulation. Yi et al. (2020) reported that temperature is a key climatic factor affecting crop Cd uptake, as elevated temperatures accelerate chemical reactions and mineral weathering, increasing Cd availability, while also enhancing plant transpiration. This effect is most pronounced in spring and summer, when temperatures exceed 20 °C (Drabesch et al., 2024). In contrast, 2025 experienced more heat waves and drought stress, which may have reduced Cd uptake, consistent with findings by Xiao et al. (2023) showing that drought stress can limit Cd accumulation in wheat seedlings through altered root morphology and decreased Cd in roots. The combination of storage duration and environmental factors likely explains the observed year-to-year differences in Cd concentrations in potato tubers.

Conclusion

The results of this study confirm that Cd concentration in potato tubers is strongly influenced by varietal differences, even when grown under identical agronomic conditions. Among the 19 analyzed varieties, KIS Kokra consistently exhibited the highest Cd concentrations and can therefore be considered a high-risk variety in terms of Cd accumulation. In contrast, varieties such as Messi, Peter Pan, Elland and Jelly showed lower Cd levels and may represent more suitable choices for minimizing Cd intake. In addition to genetic factors, environmental conditions also played an important role, as evidenced by the consistently lower Cd

concentrations observed in 2025 compared to 2024 across all varieties. This suggests that year-to-year variability, likely related to soil and climatic conditions, can significantly influence Cd uptake. Overall, the findings highlight the importance of selecting low-accumulating potato varieties as a practical strategy to mitigate Cd entry into the food chain, particularly in regions with elevated soil Cd levels.

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