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Original scientific paper

THE ASSESSMENT OF CADMIUM AND LEAD IN ORGANIC AND CONVENTIONAL ROOT AND TUBER VEGETABLES FROM THE SERBIAN MARKET

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Abstract: Global organic agriculture and consumption of organic food has continuously increased over the past decades. The aim of the research was to determine and compare cadmium (Cd) and lead (Pb) concentrations in organic and conventional root and tuber vegetables from the Serbian market. Samples of three root and tuber vegetables commonly consumed in Serbia, including potatoes, carrots and beetroots, were collected at two green markets and four supermarkets in the territory of the city of Belgrade, Serbia. Concentrations of Cd and Pb in fresh weight were determined by atomic absorption spectroscopy (AAS). Mean concentrations of Cd and Pb in two types of vegetables were compared by the t-test. Cd and Pb concentrations in both types of vegetables were below allowable limits. Potato mean Cd concentration was significantly lower in the organic than in the conventional type (0.021 mg kg^{-1} and 0.037 mg kg^{-1}, respectively). In carrots, it was the opposite, Cd concentration was higher in the organic type, but the difference was not significant either between the two types or for beetroots. Results indicated lower Pb levels in organic potatoes and beetroots, and higher Pb levels in organic carrots, but differences between means were not significant in all tested vegetables. Obtained results are not conclusive, but they indicate lower or similar concentrations of both metals in organic vegetables in comparison to conventional types.

Key words: vegetables, cadmium, lead.

Introduction

Organic agriculture is currently practiced in 187 countries, and the organic share of total agricultural land is 1.5% globally (Willer et al., 2021). Over the past decade, global organic food and drink sales increased from 54.9 to 106.4 billion US dollars (Sahota, 2011; Sahota, 2021). A remarkable increase in the organic market is associated with consumers' demand for organic food. Numerous studies have

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been carried out to evaluate consumers' practices and food choice motives. Organic food consumers are highly motivated by the environment, ethics and health aspects (Kesse-Guyot et al., 2013). In addition, they are relatively highly educated and more physically active than other food consumer groups (Kesse-Guyot et al., 2013). Organic product consumption is also associated with specific diet characteristics, including more fruits and vegetables (Eisinger-Watzl et al., 2015). Studies conducted in Serbia indicated that organic food consumers are motivated to buy organic food mostly by health aspects and the support to organic producers (Vlahović and Šojić, 2016; Vehapi, 2015).

Demand for organically grown vegetables has also increased due to consumers' interest in food safety. Although the consumption of vegetables provides essential nutrients for humans, heavy metal contamination of vegetables causes a great concern regarding human health. An increased level of heavy metals such as cadmium (Cd) and lead (Pb) in vegetables has been reported in China (Huang et al., 2014), India (Gupta et al., 2008; Sharma et al., 2008), and other countries.

Cd and Pb concentrations in crops vary, with leafy and root vegetables generally having higher concentrations than fruits or seeds. The source of contamination of vegetables with Cd and Pb can be soil, water or air (Elgallal et al., 2016; El-Kady and Abdel-Wahhab, 2018). Chen et al. (2013) showed that the application of large amounts of low-grade fertilizers could be a source of heavy metals in soil. Also, a long-term application of Cd-containing phosphate fertilizers can increase Cd concentrations in vegetative and also reproductive plant parts (Grant et al., 2010). However, post-harvest vegetable contamination with heavy metals during transport, storage and marketing has also been shown (Kassouf et al., 2013). High exposure to these metals has negative effects on human health. Thus the excess Cd can damage kidneys, while the excess Pb can affect the neurodevelopment in children (Satarug, 2018; Gundacker et al., 2021).

Available data on Cd and Pb in organic and conventional vegetables are often controversial. While synthetic agrochemicals are much lower in organic than in conventional fruits and vegetables, usually, there is no difference between them in environmental pollutants such as heavy metals. It is generally accepted that they cannot be avoided through organic farming practices (see review by Magkos et al., 2006). Based on an assessment of Cd and Pb in a variety of organically produced foodstuffs available in the Greek market, Karavoltsos et al. (2008) suggested that the majority of certified organic products may have a lower level of Cd and Pb.

According to the author's best knowledge, there is no available data on Cd and Pb in organic vegetables in Serbia. This study aimed to compare concentrations of Cd and Pb in commonly consumed root and tuber vegetables in Serbia, including potato (*Solanum tuberosum* L.), carrot (*Daucus corota* L.) and beetroot (*Beta vulgaris* L. ssp. *vulgaris*) from the Serbian market.

Material and Methods

The collection and preparation of samples

Samples of edible parts of commonly consumed root and tuber vegetables, including organic and conventional potatoes, carrots and beetroots, were collected in March 2016 from two green markets and four supermarkets located in the territory of the city of Belgrade, Serbia. All available organic products originated from different producers, and the same number of samples of conventional products was collected. Samples of both organic and conventional vegetables were collected as follows: five potato samples, five carrot samples, and four beetroot samples. All collected organic vegetables were labeled with a national symbol for organic products, or an organic certificate was available.

All samples were washed with tap water to remove soil particles and then rinsed with deionized water. Afterwards, samples were placed on the cellulose paper to remove excess water. Each sample consisted of three roots or tubers. Samples were peeled, chopped into small pieces, and ground in a high-speed blender. In total, 14 samples of each organic and conventional vegetable were prepared.

The digestion of samples and analyses

Samples of 1 g of fresh weight were digested with 7 ml of HNO_3 + 2 ml of H_2O_2 in a microwave oven (Ethos EZ, Milestone). After digestion, samples were transferred to 50-ml flasks, and deionized water was added. The concentration of cadmium and lead was determined by AAS (GBC SensAA).

Results and Discussion

In the present study, vegetables were selected based on the edible part, root or tuber. The number of samples was determined based on the availability of organic vegetables at that moment. According to the Serbian Regulation and Commission Regulation (EU) 2021/1323, the maximum level of Cd in potatoes and carrots is 0.10 mg kg^{-1} fresh weight, and for beetroots, it is 0.06 mg kg^{-1} fresh weight. According to the Serbian Regulation and Commission Regulation (EU) 2021/1317, the maximum level of Pb in root and tuber vegetables is 0.10 mg kg^{-1} fresh weight.

Although Pajević et al. (2018) recently reported both Cd and Pb concentrations above the maximum level by Serbian and EU legislations in potatoes, carrots and beetroots, in the present study, this was not the case (Tables 1, 2 and 3). Based on mean values, Cd and Pb concentrations varied considerably between examined vegetables. While potatoes had the highest level of both metals, the means for carrots and beetroots were similar.

In organic potatoes, the Cd level ranged from 0.014 to 0.030 mg kg^{-1}, whilst in conventional potatoes, the span was from 0.019 to 0.057 mg kg^{-1}. The t-test showed that the mean Cd concentration was significantly lower in organic than in conventional potatoes (0.021 mg kg^{-1} and 0.037 mg kg^{-1}, respectively) ($p<0.05$) (Table 1). This is in accordance with results by Hadayat et al. (2018), who evaluated metals in organic and conventional potatoes collected from supermarkets in Florida, USA. On the other hand, the mean Cd concentration in carrots was 2-fold higher in the organic than in the conventional type (0.006 and 0.003 mg kg^{-1}, respectively), but the difference was not significant (Table 2), whilst in both types of beetroots, it was 0.004 mg kg^{-1} (Table 3).

Table 1. Cd and Pb concentrations in commercially available organic and conventional potatoes.

Sample #	Cd (mg kg^{-1} FW)		Pb (mg kg^{-1} FW)	
	Organic	Conventional	Organic	Conventional
1	0.014	0.019	0.063	0.100
2	0.019	0.032	0.100	0.097
3	0.021	0.047	0.027	0.066
4	0.030	0.057	0.064	0.069
5	0.024	0.030	0.024	0.049
Mean	0.021	0.037	0.056	0.076
Median	0.021	0.032	0.063	0.069
t-test	*		ns	

*indicates a significant difference ($p<0.05$); ns – not significant; # – number.

Table 2. Cd and Pb concentrations in commercially available organic and conventional carrots.

Sample #	Cd (mg kg^{-1} FW)		Pb (mg kg^{-1} FW)	
	Organic	Conventional	Organic	Conventional
1	0.002	0.003	0.028	0.009
2	0.003	0.005	0.010	0.010
3	0.021	0.002	0.028	0.013
4	0.002	0.002	0.012	0.012
5	0.002	0.003	0.013	0.009
Mean	0.006	0.003	0.018	0.010
Median	0.002	0.002	0.013	0.009
t-test	ns		ns	

*indicates a significant difference ($p<0.05$); ns – not significant; # – number.

A meta-analysis performed by Hoefkens et al. (2009) also indicated that the Cd level was significantly lower in organic than in conventional potatoes, whilst the opposite was for carrots. However, Hadayat et al. (2018) reported much lower Cd concentrations in organic than in conventional carrots, whilst no differences between the two were observed in the Czech Republic by Krejčová et al. (2016).

Table 3. Cd and Pb concentrations in commercially available organic and conventional beetroots.

Sample #	Cd (mg kg^{-1} FW)		Pb (mg kg^{-1} FW)	
	Organic	Conventional	Organic	Conventional
1	0.003	0.005	0.016	0.017
2	0.007	0.006	0.018	0.022
3	0.004	0.004	0.013	0.014
4	0.002	0.003	0.010	0.018
Mean	0.004	0.004	0.014	0.017
Median	0.003	0.004	0.014	0.017
	ns		ns	

[*] indicates a significant difference (p<0.05); ns – not significant; # – number.

In the present study, Pb concentrations in organic and conventional potatoes ranged from 0.024 to 1.00 mg kg^{-1}, and from 0.049 to 1.00 mg kg^{-1}, respectively (Table 1). Although the mean Pb concentration in organic potatoes was lower than in the conventional type (0.056 and 0.076 mg kg^{-1}, respectively), the difference between them was not significant (p<0.05). In organic carrots, Pb had a wider span than in the conventional type, ranging from 0.010 to 0.028 mg kg^{-1}, and from 0.009 to 0.013 mg kg^{-1}, respectively, and the mean Pb concentration was higher in the organic than in the conventional type (0.018 and 0.010 mg kg^{-1}, respectively) (Table 2). These results are supported by Hoefkens et al. (2009), who reported much lower Pb concentrations in organic potatoes, but those were higher in organic carrots in comparison to the conventional type. Results by Malmauret et al. (2002) also indicated the Pb level in organic carrots that exceeded the maximum level in France. On the other hand, in the present study, the mean Pb concentration in beetroots was slightly higher in the conventional than in the organic type (0.017 and 0.014 mg kg^{-1}, respectively). Differences between organic and conventional carrots and beetroots in the mean Pb concentration were not significant (p<0.05) (Tables 2 and 3). Similar results for carrots were reported by Krejčová et al. (2016). In addition, a recent study by Cámara-Martos et al. (2021) indicated no differences in heavy metals between organic and conventional Brassicaceae vegetables.

Conclusion

Concentrations of Cd and Pb in organic and conventional potatoes, carrots and beetroots were below the maximum level determined by the Serbian and the EU Regulations. Obtained results are not conclusive, but they indicate a lower or similar concentration of both metals in organic vegetables in comparison to conventional types. Further research with a large number of samples is needed to evaluate the quality of organic vegetables in terms of toxic metals.

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KADMIJUM I OLOVO U ORGANSKOM I KONVENCIONALNOM KORENASTOM I KRTOLASTOM POVRĆU NA TRŽIŠTU U SRBIJI

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R e z i m e

Organska poljoprivreda i konzumiranje organske hrane u svetu su u stalnom porastu prethodnih decenija. Cilj istraživanja je bio da se odrede i uporede koncentracije kadmijuma (Cd) i olova (Pb) u organskom i konvencionalnom povrću, dostupnom na tržištu u Srbiji. Uzorci korenastog i krtolastog povrća – krompira, mrkve i cvekle sakupljeni su na dve zelene pijace i četiri supermarketa na teritoriji grada Beograda. Concentracije Cd i Pb u svežoj masi merene su metodom atomske apsorpcione spektrofotometrije (AAS). Srednje vrednosti koncentracija Cd i Pb dva tipa povrća su poređene t-testom. Koncentracije Cd i Pb u oba tipa povrća bile su niže od maksimalno dozvoljenih. Srednja vrednost Cd bila je značajno niža u organskom nego u konvencionalnom krompiru (0,021 mg kg^{-1} odnosno 0,037 mg kg^{-1}). Suprotni rezultati su dobijeni za mrkvu, koncentracija Cd je bila viša u organskoj mrkvi, ali razlika između dva tipa nije bila značajna, kao ni za cveklu. Rezultati su ukazali na niži nivo Pb u organskom krompiru i cvekli, i njegov viši nivo u organskoj mrkvi, ali razlike između dva tipa nisu bile značajne. Na osnovu dobijenih rezultata ne može se izvesti nedvosmislen zaključak, ali rezultati ukazuju na niži ili sličan nivo oba metala u organskom u odnosu na konvencionalno povrće.

Ključne reči: povrće, kadmijum, olovo.

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