Original Article

Heavy Metals' Uptake from Soil in Potato Tubers: an Ionomic Approach

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Abstract

Genetically determined, plant ionome has a major impact on the quality of plant-origin raw materials for food, feed or pharmaceutical final products. Since plants take up of the mineral nutrients they require from the soil, the ionomic profile of plants grown in a certain environment will reflect adaptations to that, while the composition of food products obtained from raw materials of plant origin will reflect that ionomic profile. Environmental contamination with heavy metals has lead in recent years to an increase of the consumers' interest on the quality of food products, being well known that each heavy element is hazardous outside a certain range of concentrations. In this context, the major objective of the present research was to establish the degree of contamination with lead, cadmium, zinc and copper for potato tubers (Roclas cultivar). Experimental cultures were established for three consecutive years in three locations: one with historical pollution with heavy metals caused by SC Sometra SA Copşa Mica, located in Seica Mare, another one contaminated from diffuse sources located in Cluj-Napoca and a reference, unpolluted experimental field of USAMV Cluj-Napoca close to the Jucu village. The targeted heavy metals were determined using a Shimadzu AA-6300 double beam spectrophotometer. Lead concentrations ranged from 0.01 to 2.53 □g/kg, with maximum values recorded for samples originating from Şeica Mare. For cadmium, the concentrations ranged from 0.01 to 0.06 □g/kg. Zn concentrations ranged between 2.80 mg/kg (Jucu) and 4.25 mg/kg (Şeica Mare) while copper concentrations were between 0.52 mg/kg (Jucu) and 2.10 mg/kg (Cluj Napoca). These values revealed a low contamination of potato tubers with heavy metals, all of them being under the maximum allowed limits established by The European Commission Regulation nr.1881/2006.

Keywords: *cadmium, lead, copper, zinc, heavy metals, potato.*

1. Introduction

Heavy metals have a known toxic potential for living organisms, each one being hazardous outside a certain range of concentrations; their accumulation in plants and animals' bodies poses a risk to public health [7].

Animals, particularly herbivores, may take them from the plants, while people are exposed to heavy metals both dietary and occupationally [10].

The soil is the main depository of heavy metals, given the surface it exposes and its structure; it accumulates anthropic influences, depending on its adsorptive and exchange properties [14]. The studies on the behavior of heavy metals in soils have shown that their bioavailability for plant bodies is considerably reduced in time because of the

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interaction between these contaminants and soil components [4, 8, 15].

Plant ionome is genetically determined, having a major impact on the quality of plant-origin raw materials for food, feed or pharmaceutical products [2, 12, 13, 16].

Since plants take up the mineral nutrients they require from soil, the ionomic profile of plants grown in a certain environment will reflect adaptations to that, while the composition of food products obtained from a given range of raw materials of plant origin will reflect that ionomic profile [1, 3, 5, 17].

In this context, the major objective of the present research was to establish the degree of contamination with four heavy metals of concern (lead, cadmium, zinc and copper) for Roclas potato tubers.

2. Material and Method

The biological material was potato (*Solanum tuberosum*) - Roclas cultivar.Experimental cultures were established for three consecutive years in three different locations: one with historical pollution with heavy metals caused by SC Sometra SA Copşa Mica, located in Seica Mare (46°01'52" N/ 24°09'39" E), one contaminated from diffuse sources located in Cluj-Napoca (46°45'57" N/ 23°34'01" E) and a reference experimental field of USAMV Cluj-Napoca situated close to the Jucu village (46°52'16" N/ 23°45'27" E); soils were not fertilized during the studied period.

Representative potato tubers' samples were peeled, cut in pieces and subjected to microwave-assisted digestion in a Berghoff Microwave Digestion System MWS-3+ (Eningen, Germany). Lead, cadmium, copper and zinc were determined by atomic absorption spectrometry (AAS) using a double beam spectrophotometer Shimadzu AA-6300 (Shimadzu, Japan), with both flame and graphite furnace atomization, equipped with deuterium lamp for background correction and hollow-cathode lamps for each of the studied elements [9].

Calibration curves were prepared using five concentrations, the obtained correlation coefficients ranging between 0.9780-0.9983. The operation conditions were those recommended for each metal in the instrument's method. All measurements were carried out in triplicates. Besides, in 2012 the metal profile of the samples was established also by inductively coupled plasma-atomic emission spectroscopy (ICP-AES), using a Perkin Elmer Optima 5300 DV instrument (Perkin Elmer, Waltham, USA).

3. Results and Discussions

During the research period, the heavy metal content determination in potato tubers leads to the values that are summarized in tables 1-4. ICP-AES determination accomplished in the first year of the study revealed that maximum concentrations of heavy metals of concern were recorded for samples in Şeica Mare and Cluj Napoca, reflecting the composition of soil substrate (Table 1).

Table 1. The average metal content in potato tubers recorded in 2012 (ICP-AES)

Metals	Units	Cluj-Napoca	Şeica Mare	Jucu
Pb	□g/kg	0.04	1.94	0.03
Cd	□g/kg	0.02	0.06	0.01
Cr	□g/kg	842.89	731.75	259.46
Ni	□g/kg	135.30	196.72	100.31
Cu	mg/kg	2.00	1.53	0.73
Mn	mg /kg	1.27	1.46	1.35
Zn	mg /kg	3.89	3.32	2.95
Fe	mg /kg	20.17	7.31	5.20
Al	mg /kg	28.76	37.15	20.12
K	mg /kg	251.26	452.51	401.27
Na	mg /kg	63.74	180.12	160.25
Mg	mg /kg	183.50	220.17	205.27
Ca	mg /kg	240.07	125.18	92.18

During the three experimental years, lead concentrations ranged from 0.01 to 2.53 mg/kg, with maximum values recorded for samples originating from Șeica Mare (Tables 2 - 4). For cadmium, the concentrations ranged from 0.01 to 0.06 mg/kg. Zn ranged between 2.80 mg/ kg (Jucu) and 4.25 mg/ kg (Șeica Mare) while copper concentrations were between 0.52 mg/kg (Jucu) and 2.10 mg/ kg (Cluj-Napoca) (Tables 2 - 4). For all experimental locations we recorded a decreasing tendency of the heavy metal concentrations in potato tubers during the three years period, due to factors such as phytoextraction, levigation and some minor anthropic contributions (Tables 2 - 4).

Table 2. The average content of heavy metals from potato samples from Jucu (AAS)

Metal	Units	2012	2013	2014	Average
Pb	g/kg	0.04	0.05	0.02	0.04
Cd	g/kg	0.02	0.01	0.01	0.01
Cu	mg/kg	2.00	2.10	1.79	1.96
Zn	mg /kg	3.89	3.17	2.85	3.30

Table 3. The average content of heavy metals from potato samples from Cluj-Napoca (AAS)

Metal	Units	2012	2013	2014	Average
Pb	g/kg	0.03	0.02	0.01	0.02
Cd	g/kg	N.D.	N.D.	N.D.	-
Cu	mg/kg	0.73	0.61	0.52	0.62
Zn	mg /kg	2.95	3.10	2.80	2.95

*Note: N.D. – not detected

Table 4. The average content of heavy metals from potato samples from Șeica Mare (AAS)

Metal	Units	2012	2013	2014	Average
Pb	g/kg	1.94	2.53	2.15	2.21
Cd	g/kg	0.06	0.06	0.04	0.05
Cu	mg/kg	1.55	1.34	1.01	1.30
Zn	mg /kg	3.32	4.25	3.29	3.62

All the experimental data revealed a low contamination of potato tubers with heavy metals, being under the maximum allowed limits established by The European Commission Regulation nr.1881/2006 (0.1 mg/ kg for lead, 0.05 mg/kg for cadmium); the main contributor for these is the historical soil pollution, given the direct relation between the content of microelements in the soil solution and their uptake by the plants [16, 18]. The obtained results are comparable with those reported by similar studies [2, 11]. Maximum levels of contamination with heavy metals of high concern lead (2.53 mg/kg) and cadmium (0,06 mg/kg) were recorded in potato tubers originating from Seica Mare; these can be explained by the historical pollution due to the former S.C. Sometra S.A from Copsa Mica, situated at a small distance (11 km).

Conclusion

The experimental data revealed low concentrations of heavy metals in potato tubers, under the maximum allowed limits established by The European Commission Regulation nr.1881/2006.The maximum levels of contamination with heavy metals of high concern lead (2.53 mg/kg) and cadmium (0.06 mg/kg) were recorded in potato tubers originating from Seica Mare, the main contributor for these being the historical soil pollution.

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