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ORIGINAL PAPER

THE CONTENT OF SELECTED HEAVY METALS IN FRUITING BODIES OF *AGARICUS BISPORUS* (LANGE) IMBACH. WILD GROWING IN POLAND*

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Abstract

The aim of the study was to determine the content of selected heavy metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn) present in the fruiting bodies of *Agaricus bisporus* (Lange) Imbach., depending on the site of picking and on a geographical region of Poland. Mushroom samples were collected in selected regions of Poland: Lower Silesia, Silesia, Pomerania and Kujawy, Wielkopolska, Lubuskie. Samples of *Agaricus bisporus* were wet mineralized in a 3:1 mixture of concentrated HNO_3 (ultra pure) and $HClO_4$ (AR). The content of heavy metals was determined with atomic absorption spectroscopy FASS using an AAS Zeiss apparatus. The content of heavy metals in the fruiting bodies of *Agaricus bisporus* (Lange) Imbach. growing wild in Poland was varied and amounted to: Cd 0.68-6.14; Cr 0.38-6.93; Cu 1.90-101.71; Fe 33.01-432.24; Mn 2.86-387.43; Ni 0.20-3.09; Pb 0.98-42.83; Zn 31.87-124.84 (mg kg^{-1}). Excessive levels of Cd, above the permissible content, were detected in the fruiting bodies collected from whole Silesia. Concentrations of CD above the permissible Cd content were observed in the fruiting bodies picked in Silesia region in four out of eleven locations: Katowice (Murcki), Pszczyna (Kobiór), Sośniowice (Biały Dwór), Pawonków (Dziewicza Góra). In the other regions, the permissible content of cadmium and lead in the fruiting bodies of *Agaricus bisporus* (Lange) Imbach. was not exceeded. The concentrations of micronutrients (Zn, Cu, Mn, Fe) and pollutants (Cd, Cr, Pb, Ni) were strictly dependent on tge sampling sites as well as geographical regions of Poland.

Keywords: mushrooms, environment pollution, concentration.

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INTRODUCTION

The presence of bioactive components, especially polysaccharides, triterpenoids and phenol compounds, in mushrooms influences their healthfulness (Siwulski et al. 2014). The authors also claim that the high nutritional value of mushrooms results from the presence of highly digestible peptides, polysaccharides, essential non-saturated fatty acids as well as mineral components and vitamins. However, mushrooms can also accumulate heavy metals.

In recent years, numerous studies have been carried out concerning the content of heavy metals in many species of edible mushrooms, both naturally growing and cultivated (Falandysz, Frankowska 2007, Falandysz, Chojnacka 2007, Wojciechowska-Mazurek et al. 2011, Adamiak et al. 2013, Pająk 2016, Chowaniak et al. 2017, Kuziemska et al. 2018). The only naturally growing edible mushroom is *Agaricus bisporus* (Lange) Imbach.

The aim of the study was to determine the content of selected heavy metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn) present in the fruiting bodies of *Agaricus bisporus* (Lange) Imbach., depending on the site of picking and a region in Poland.

MATERIAL AND METHODS

Samples of *Agaricus bisporus* were picked up in randomly chosen places across Poland, between 2010-2015. The mushrooms represented by 55 medium-size samples (from 10-20 fruiting bodies) picked from the examined sites (each sample of an equal sample weight, in three repetitions) were first washed in distilled water, later dried at 105°C for 48 h and finally wet mineralized in a 3:1 mixture of concentrated HNO_3 (ultra pure) and $HClO_4$ (AR) (Bosiacki, Roszyk 2010). Next, the content of heavy metals was determined with the technique of atomic absorption spectroscopy FASS using an AAS Zeiss apparatus. The content of heavy metals determined in blind trials was subtracted from the results. The accuracy and precision of analytic measurements were checked by analyzing Rye Grass ERM®-CD281 and *Pseudevernia furfuracea* BCR®-482/2009 reference material, (certified by the European Commission, Joint Research Centre, Institute for Reference Materials and Measurements /IRMM, Geel BE/) – Table 1.

Results of the content of individual heavy metals were statistically elaborated by calculating maximum and minimum values, standard deviation as well as coefficients of variation.

The classification of types of sites and geographical regions chosen for the sampling of *Agaricus bisporus* (Lange) Imbach. sccording to concentrations of absorbed pollutants and micronutrients was based on cluster analysis was performed with MVPS v. 3.1 software.

Table 1

Content of heavy metals in reference material

Metal	Reference material certified content		Digestion		
	(mg kg^{-1})	+/-	content (mg kg^{-1})	recovery (%)	difference (mg kg^{-1})
	Rye grass				
Cd	0.120	0.007	0.11	91.67	0.01
Cu	10.2	0.5	9.11	89.31	1.09
Fe	180	-	175.14	97.30	4.86
Mn	82	4	79.85	97.37	2.15
Ni	15.2	0.6	13.95	91.78	1.25
Pb	1.67	0.11	1.34	80.24	0.33
Zn	30.5	1.1	27.41	89.87	3.09
	Pseudevernia furfuracea				
Cr	4.12	0.15	3.98	96.60	0.14

RESULTS AND DISCUSSION

According to Kwapuliński et al. (2009), naturally growing mushrooms can be a bio-indicator of environmental pollution with heavy metals. A natural source of heavy metals in soils is the bedrocks and the amounts of metals from this source constitute the geochemical background, which does not pose a threat to soil fertility (Bosiacki et al. 2014). The type of soil, its particle size composition, pH, content of organic substance, sorption properties and red-ox potential all influence transformation of the chemical forms of heavy metals and their availability to living organisms (Herms, Brümmer 1991, Chłopecka 1994, Tyler, Olsson 2001, Łabętowicz, Rutkowska 2001, Blake, Goulding 2002, Bosiacki, Tyksiński 2006). The main source of pollution with heavy metals in individual layers of the soil is the anthropogenic influence (Strączyńska, Strączyński 2000).

The smallest content of cadmium (0.68 mg kg^{-1}) in *Agaricus bisporus* was found in the localities Podwilczyn, situated in the municipality of Dębnica Kaszubska, in the Province of Pomerania and Kujawy (*województwo kujawsko-pomorskie*) – Table 2, and Borowina, located in the municipality of Milicz, in Lower Silesia (*województwo dolnośląskie*) – Table 3. The highest content of this metal (6.14 mg kg^{-1}) was detected in Murcki, a locality situated within the limits of the municipality of Katowice, in Silesia (*województwo* śląskie) – Table 4. While comparing the average content of cadmium in *Agaricus bisporus* growing in the examined locations, the highest result was found in Silesia (2.28 mg kg^{-1}) and the lowest one was in Pomerania and Kujawy (Table 5). The highest differentiation of the cadmium content in *Agaricus bisporus* was observed in Silesia (CV = 58,91%) – Table 4 and Wielkopolska (*województwo wielkopolskie*) (CV = 48.34%) – Table 6, and the smallest one appeared in Lubuskie (*województwo lubuskie*) (CV = 13.27%) – Table 7.

Table 2

Heavy metal content in Agaricus bisporus growing in Pomerania and Kujawy

Region	Commune	Locality	Place of picking	(mg kg^{-1} DM)							
				Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Pomerania and Kujawy	Borne Sulinowo	Borne Sulinowo	the edge of the woods	0.72	0.42	23.58	54.03	4.83	0.40	0.98	59.44
	Brusy	Czernica	domestic garden	0.92	0.48	21.78	40.21	3.20	0.73	3.45	46.49
	Człopa	Człopa	town green	1.00	0.69	18.02	62.82	4.96	0.90	5.32	66.31
	Gdańsk	Klukowo	ditch by the road	0.95	0.82	29.96	108.18	5.48	0.93	6.24	70.37
	Puck	Muza	the edge of the woods	0.82	0.44	19.78	43.41	3.79	0.53	1.98	46.54
	Dębnica Kaszubska	Podwilczyn	meadow	0.68	0.38	21.06	47.01	4.48	0.60	4.60	55.90
	Kartuzy	Bór	clearing in the woods	0.92	0.42	30.87	54.85	5.74	0.65	3.08	60.48
	Osie	Tleń	wasteland	1.10	0.45	34.74	75.97	6.08	0.53	1.59	68.28
	Szemud	Grabowiec	meadow	1.25	0.46	35.35	53.18	5.00	0.81	3.37	77.68
	Chojnice	Drzewicz	farmland	1.30	0.46	15.70	33.01	3.58	0.91	6.19	35.62
	Brusy	Parzyn	meadow	1.39	0.47	23.44	47.51	4.02	0.93	4.96	50.95
	Koczała	Stara Brda	meadow	0.91	0.60	21.53	47.11	5.00	0.41	1.23	65.10
Minimum content				0.68	0.38	15.70	33.01	3.20	0.40	0.98	35.62
Maximum content				1.39	0.82	35.35	108.18	6.08	0.93	6.24	77.68
Standard deviation (SD)				0.21	0.12	6.22	19.03	0.85	0.19	1.80	11.50
Coefficient of variation (CV) %				21.50	24.51	25.24	34.23	18.19	27.80	50.30	19.63

The smallest content of chromium (0.38 mg kg^{-1}) in *Agaricus bisporus* was found in Podwilczyn, in the municipality of Dębnica Kaszubska (Pomerania and Kujawy) – Table 2. The highest content of this metal (6.93 mg kg^{-1}) was observed in Wodnica, located in the municipality of Wołów (Lower Silesia). While comparing the average content of chromium in *Agaricus bisporus* growing in the examined locations, the highest value was found in Lower Silesia (1.50 mg kg^{-1}) and the smallest one (0.51 mg kg^{-1}) appeared in Pomerania and Kujawy**.** The greatest differentiation in the chromium content in *Agaricus bisporus* was observed in Lower Silesia (CV = 137.59%) – Table 3, and the smallest one was in Lubuskie (CV = 23.55%) – Table 7.

The smallest content of copper (1.90 mg kg^{-1}) in fruiting bodies of *Agaricus bisporus* was found in Smolno Małe, a village in the municipality of Sulechów commune (Lubuskie) – Table 7, whereas the highest content of this metal (101.71 mg kg^{-1}) was observed in the municipality and the city of

Table 3

Heavy metal content in *Agaricus bisporus* growing in Lower Silesia

Region	Commune	Locality	Place of picking	(mg kg^{-1} DM)							
				Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Lower Silesia	Polkowice	Dąbrowa	forest duct	1.43	0.78	42.28	62.20	5.28	2.96	5.12	91.94
	Wołów	Wodnica	farmland	1.73	6.93	39.21	59.41	5.37	3.09	7.26	83.01
	Wołów	Wrzosy	farmland	1.71	0.73	39.36	63.95	5.23	1.80	3.11	82.48
	Osiecznica	Kliczków	the edge of the woods	0.94	0.49	39.65	55.71	4.98	2.47	3.34	81.81
	Węgliniec	Zagajnik	meadow	1.90	0.93	20.51	78.84	5.23	1.19	7.07	52.24
	Milicz	Borowina	clearing in the woods	0.68	0.51	15.33	44.67	387.43	0.20	2.79	31.87
	Twardogóra	Gola Wielka	farmland	1.96	1.00	39.98	56.50	5.06	0.98	6.36	71.79
	Milicz	Gruszeczka	farmland	1.58	0.61	16.16	37.34	2.86	1.33	4.60	40.04
Minimum content				0.68	0.49	15.33	37.34	2.86	0.20	2.79	31.87
Maximum content				1.96	6.93	42.28	78.84	387.43	3.09	7.26	91.94
Standard deviation (SD)				0.43	2.06	11.14	11.71	126.53	0.95	1.68	21.03
Coefficient of variation (CV %)				28.70	137.59	35.31	20.43	240.18	54.38	33.92	31.44

Table 4

Heavy metal content in *Agaricus bisporus* growing in Silesia

Region	Commune	Locality	Place of picking	(mg kg^{-1} DM)							
				Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Silesia	Mikołów	Mikołów	meadow	1.55	1.10	22.07	47.15	4.40	1.83	28.33	65.49
	Katowice	Murcki	wasteland	6.14	1.51	34.20	370.87	13.97	1.42	8.79	124.84
	Pszczyna	Kobiór	meadow	3.08	0.43	33.11	66.54	4.64	0.90	4.21	69.66
	Sośniowice	Biały Dwór	farmland	2.51	0.61	21.49	37.83	4.11	1.45	5.19	65.71
	Pawonków	Dziewicza Góra	meadow	2.37	0.52	37.47	59.24	5.00	1.84	4.38	76.15
	Tułowice	Ligota Tułowicka	farmland	1.12	0.39	15.89	35.37	3.21	1.26	20.20	39.26
	Tarnowskie Góry	Pniowiec	meadow	1.90	0.90	22.30	40.53	4.45	1.35	13.89	60.50
	Katowice	Katowice	town green	1.37	1.09	25.05	58.29	4.67	1.49	20.30	54.93
	Żory	Kleszczówka	clearing in the woods	1.48	0.74	19.31	47.64	4.07	1.56	30.42	48.38
	Kuźnia Raciborska	Rudy	farmland (balk)	1.44	1.01	27.83	68.57	5.39	1.43	14.22	67.27
	Pszczyna	Pszczyna	meadow	2.11	0.87	22.74	61.65	5.02	0.95	5.97	61.76
Minimum content				1.12	0.39	15.89	35.37	3.21	0.90	4.21	39.26
Maximum content				6.14	1.51	37.47	370.87	13.97	1.84	30.42	124.84
Standard deviation (SD)				1.34	0.32	6.46	92.24	2.78	0.28	9.10	20.83
Coefficient of variation (CV %)				58.91	38.75	25.24	113.54	51.88	20.21	64.19	31.21

Table 5

Mean content of heavy metals in *Agaricus bisporus* growing in selected regions in Poland

Region	(mg kg-1 DM)							
	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Silesia	2.28	0.83	25.59	81.24	5.36	1.41	14.17	66.72
Lower Silesia	1.49	1.50	31.56	57.33	52.68	1.75	4.96	66.90
Wielkopolska	1.44	0.83	28.19	77.52	5.23	1.12	7.99	63.13
Pomerania and Kujawy	1.00	0.51	24.65	55.61	4.68	0.69	3.58	58.60
Lubuskie	1.40	0.77	24.34	52.49	4.53	1.06	5.37	61.87

Table 6

Heavy metal content in *Agaricus bisporus* growing in Wielkopolska

Region	Commune	Locality	Place of picking	(mg kg-1 DM)							
				Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Wielkopolska	Oborniki	Podlesie	meadow	0.78	0.51	36.74	69.11	6.66	2.42	1.76	91.94
	Lubasz	Klempicz	the edge of the woods	0.91	0.60	21.53	47.11	5.00	0.41	1.23	65.10
	Oborniki	Stobnica	farmland	0.71	0.42	15.09	34.03	3.82	0.46	8.95	45.26
	Jaraczewo	Brzostów	farmland	1.43	0.54	21.70	39.54	4.46	1.00	9.39	64.05
	Miłosław	Miłosław	meadow	0.83	0.59	17.80	54.01	3.98	0.28	1.17	46.47
	Poznań	Poznań	town green	3.83	1.77	101.71	432.24	15.24	1.54	9.57	86.50
	Jarocin	Roszków	meadow	1.11	0.62	23.73	73.69	4.34	1.01	7.87	68.73
	Jarocin	Jarocin	town green	1.56	0.82	15.78	38.55	3.24	2.21	42.83	43.63
	Wieleń	Miały	farmland	1.55	1.12	29.01	51.49	5.24	1.23	6.82	66.88
	Wieleń	Mniszek	meadow	1.61	0.68	19.43	45.09	4.47	0.96	6.00	59.17
	Kościan	Stary Lubosz	meadow	1.61	1.25	40.20	60.45	5.51	1.18	7.30	79.32
	Duszniki	Niepruszewo-Huby	farmland	1.45	1.02	17.08	36.39	2.87	1.47	6.50	46.72
	Murowana Goślina	Głęboczek	clearing in the woods	1.08	0.52	16.44	80.50	4.99	0.50	1.57	53.45
	Witkowo	Piaski	meadow	1.34	1.30	28.17	77.46	4.52	1.45	9.03	71.45
	Powidz	Zielątkowo	farmland	1.79	0.46	30.12	59.49	5.30	0.33	1.35	75.14
	Osieczna	Grzybowo	meadow	1.51	1.04	16.57	41.14	4.00	1.52	6.55	46.29
Minimum content				0.71	0.42	15.09	34.03	2.87	0.28	1.17	43.63
Maximum content				3.83	1.77	101.71	432.24	15.24	2.42	42.83	91.94
Standard deviation (SD)				0.70	0.37	20.37	92.74	2.73	0.62	9.51	14.88
Coefficient of variation (CV %)				48.34	44.84	72.26	119.64	52.28	55.28	118.96	23.57

Table 7

Heavy metal content in *Agaricus bisporus* growing in Lubuskie

Region	Commune	Locality	Place of picking	(mg kg⁻¹ DM)							
				Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Lubuskie	Sulechów	Smolno Małe	meadow	1.54	0.54	1.90	63.26	4.79	0.80	3.76	64.25
	Babimost	Leśniki	clearing in the woods	1.12	0.49	38.17	57.19	5.09	0.83	3.54	75.43
	Łagów	Kosobudki	wasteland	1.19	0.82	26.63	49.87	3.78	0.95	5.39	57.90
	Lubniewice	Lubniewice	town green	1.25	0.81	24.61	58.45	4.88	1.37	7.84	60.93
	Skwierzyna	Dobrojewo	farmland	1.64	1.01	24.89	43.92	4.72	0.94	6.48	61.71
	Lubsko	Osiek	meadow	1.53	0.95	26.96	51.98	4.23	0.85	5.72	57.74
	Zielona Góra	Zielona Góra	urban forest	1.57	0.64	30.99	45.80	4.68	0.83	6.16	66.67
	Zielona Góra	Zielona Góra	cemetery	1.32	0.92	20.59	49.43	4.07	1.92	4.07	50.29
Minimum content				1.12	0.49	1.90	43.92	3.78	0.80	3.54	50.29
Maximum content				1.64	1.01	38.17	63.26	5.09	1.92	7.84	75.43
Standard deviation (SD)				0.19	0.18	9.78	6.21	0.42	0.37	1.40	6.90
Coefficient of variation (CV %)				13.27	23.55	40.19	11.83	9.32	34.62	26.10	11.15

Poznań (Wielkopolska). When comparing the average content of copper in *Agaricus bisporus* growing in the examined locations, the highest one was found in Lower Silesia (31.56 mg kg^{-1}) and the smallest one (24.34 mg kg^{-1}) appeared in Lubuskie (Table 5). The biggest differentiation in the copper content was observed in Wielkopolska (CV = 72.26%) – Table 6, and the smallest one was in Silesia (CV = 25.24%) – Table 4, and in Pomerania and Kujawy (CV = 25.24%) – Table 2.

The smallest content of iron (33.01 mg kg^{-1}) in *Agaricus bisporus* was found in Drzewicz, a village in the municipality of Chojnice (Pomerania and Kujawy) – Table 2, whereas the highest content of this metal (432.24 mg kg^{-1}) was observed in the municipality and city of Poznań (Wielkopolska) – Table 6. While comparing the average content of iron in *Agaricus bisporus* growing in the examined locations, the highest content was found in Silesia (81.24 mg kg^{-1}) and the smallest one (52.49 mg kg^{-1}) was detected in Lubuskie (Table 5). The biggest differentiation in iron content was observed in Wielkopolska (CV = 119.64%) – Table 6, and in Silesia (CV = 113.54%) – Table 4, and the smallest one was in Lubuskie (CV = 11.83%) – Table 7.

The smallest content of manganese (2.86 mg kg^{-1}) in fruiting bodies of *Agaricus bisporus* was found in the municipality of Milicz, the locality called Gruszeczka (Lower Silesia) – Table 3, and the highest content of this metal (397.43 mg kg^{-1}) was detected in the same municipality of Milicz, in the locality called Borowina (Lower Silesia) – Table 3. While comparing the average content of manganese in *Agaricus bisporus* growing in the examined locations, the highest one was found in Lower Silesia (52.68 mg kg^{-1}) and the lowest (4.53 mg kg^{-1}) occurred in Lubuskie (Table 5). The highest differentiation of the manganese content in *Agaricus bisporus* was observed in Lower Silesia (CV = 240.18%) – Table 4, and the smallest one was in Lubuskie (CV = 9.32%) – Table 7.

The smallest content of nickel (0.20 mg kg^{-1}) in fruiting bodies of *Agaricus bisporus* was found in the municipality of Milicz, the village of Borowina (Lower Silesia) – Table 3, and the highest content of this metal (3.09 mg kg^{-1}) was detected in the municipality of Wołów, the village Wodnica (Lower Silesia) – Table 3. While comparing the average content of nickel in *Agaricus bisporus* growing in the examined locations, the highest one was found in Lower Silesia and the lowest one (0.69 mg kg^{-1}) was determined in Pomerania and Kujawy (Table 5). The highest differentiation of the nickel content was observed in Wielkopolska (CV = 55.28%) – Table 6 and Lower Silesia (CV = 54.38%) – Table 4, whereas the lowest one was in Silesia (CV = 20.21%) – Table 4.

The smallest content of lead (0.98 mg kg^{-1}) in *Agaricus bisporus* was found in the municipality of Borne Sulinowo, the village Borne Sulinowo (Pomerania and Kujawy) – Table 2, and the highest content of this metal (42.83 mg kg^{-1}) was detected in the municipality of Jarocin, the locality Jarocin (Wielkopolska) – Table 6. While comparing the average content of lead in *Agaricus bisporus* growing in the examined locations, the highest one was found in Silesia (14.17 mg kg^{-1}) and the lowest one (3.58 mg kg^{-1}) was determined in Pomerania and Kujawy (Table 5). The highest differentiation of the lead content was observed in Wielkopolska (CV = 118.96%) – Table 6, and the smallest one was in Lubuskie (CV = 26.10%) – Table 7.

The smallest content of zink (31.87 mg kg^{-1}) in fruiting bodies of *Agaricus bisporus* was found in the municipality of Milicz, the village Borowina (Lower Silesia) – Table 3. The highest content of this metal (124.84 mg kg^{-1}) was detected in the municipality of Katowice, the locality Murcki (Silesia) – Table 4. While comparing the average content of zinc in *Agaricus bisporus* growing in the examined locations, the highest values were found in Lower Silesia (66.90 mg kg^{-1}) and Silesia (66.72 mg kg^{-1}), and the lowest one (58.60 mg kg^{-1}) was in Pomerania and Kujawy (Table 5). The highest differentiation of the zinc content was observed in Lower Silesia (CV = 31.44%) and Silesia (CV = 31.21%) – Table 2, and the smallest one was in Lubuskie (CV = 11.15%) – Table 7.

According to the binding regulations of the Commission of the European Communities – Commission Regulation (EC) No. 1881/2006 on maximum levels of chemical and biological contamination which can be present in food (cultivated mushrooms), an acceptable/permissible content in mg kg^{-1} of fresh mass is 0.30 for Pb and 0.20 for Cd. In the conducted experiment, the heavy metal content was given in milligrams for one kilogram of dry mass. According to SOBIERALSKI et al. (2007), in the early 20th c. the fruiting bodies of *Agaricus bisporus* contained around 12.6% of the dry substance, while in the 1980s this percentage declined to around 6%.

The permissible content of Pb and Cd for one kilogram of fresh mass was recalculated for the content per kilogram of dry mass, assuming that *Agaricus bisporus* contains 9.3% of dry mass on average. After recalculations, the acceptable content amounts to 3.22 for lead, and 2.15 mg for cadmium in kg^{-1} dry mass. An exceeded acceptable content of Pb was detected in the fruiting bodies of *Agaricus bisporus* picked up from the whole region of Silesia, but the permissible amount of cadmium was exceeded in the fruiting bodies picked up in four out of eleven locations from this area: Katowice (Murcki), Pszczyna (Kobiór), Sośniowice (Biały Dwór), Pawonków (Dziewicza Góra) – Table 4. In the other examined regions of Poland, the permissible content of cadmium was not observed to have been exceeded.

Exceeding the acceptable content of Pb in the fruiting bodies of *Agaricus bisporus* in Lower Silesia was detected in six out of eight locations: Polkowice (Dąbrowa), Wołów (Wodnica), Osiecznica (Kliczków), Węgliniec (Zagajnik), Twardogóra (Gola Wielka) and Milicz (Gruszeczka) – Table 3. In Wielkopolska, the acceptable content of Pb was exceeded in the fruiting bodies of mushrooms picked up from eleven locations: Oborniki (Stobnica), Jaraczewo (Brzostów), Poznań (Poznań), Jarocin (Roszków and Jarocin), Wieleń (Miały and Mniszek), Kościan (Stary Lubosz), Duszniki (Nieprusze-wo-Huby), Witkowo (Piaski), Osieczna (Grzybowo) – Table 6.

A cluster analysis of the concentrations of micronutrients (Zn, Cu, Mn, Fe) in *A. bisporus* indicated the highest similarity (98%) between samples taken from farmland and urban forest (Figure 1). Then, the most similar were samples from the edge of woods and meadows. The second group was formed from samples picked on village greens and farmland (balk), which were *ca.* 90% similar to the first group. The third group included samples from domestic gardens and cemeteries, while the fourth group originated from roadside ditches and wasteland, representing an over 90% similarity.

Concerning the pollutionundesirable in food (caused by Pb, Cd, Ni, Cr), there was a higher similarity in the accumulation of the mentioned pollutants in *A. bisporus* taken from urban forest and meadow (97%) than in mushrooms from roadside ditches (93%) and wasteland (89%) – Figure 2.

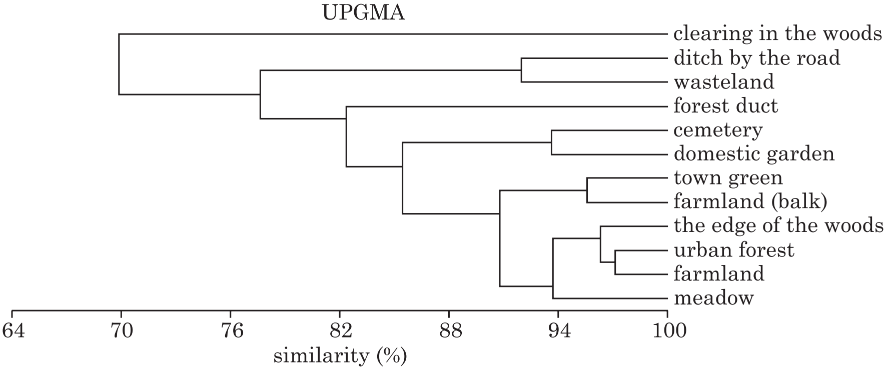

Fig. 1. Hierarchical cluster analysis based on similarity of concentrations of micronutrients (Zn, Cu, Mn, Fe) in *Agaricus bisporus* (Lange) Imbach. dependent on sampling sites

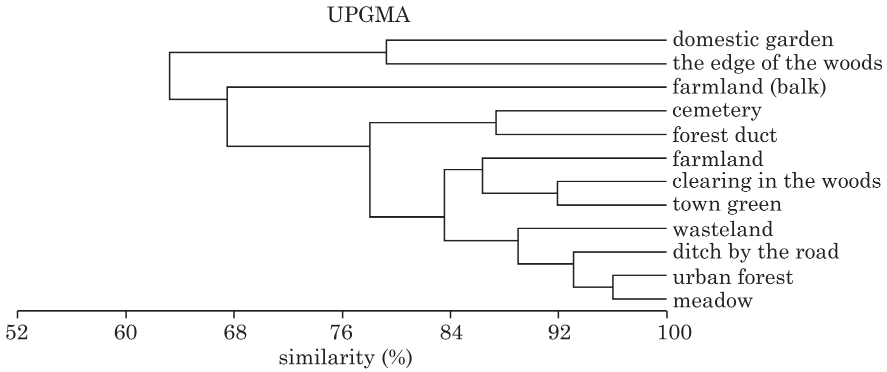

Fig. 2. Hierarchical cluster analysis based on similarity of absorbed pollutants (Cd, Cr, Pb, Ni) in *Agaricus bisporus* (Lange) Imbach. dependent on sampling sites

The samples taken from urban forest and clearings in the woods as well as farmland (92%) formed the second group. These two groups were similar to each other at 84%. Another group included samples from a cemetery and a forest duct. The last group combined samples from domestic gardens and the edge of woods, which were the least similar to the other samples.

The concentrations of micronutrients, desirable in human diet, determined in the analyzed mushrooms varied between the Polish regions (Figure 3).

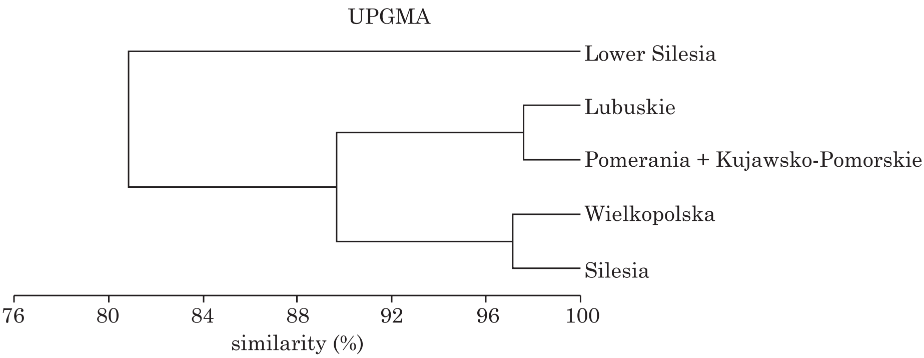

Fig. 3. Hierarchical cluster analysis based on similarity of concentrations of micronutrients (Zn, Cu, Mn, Fe) in *Agaricus bisporus* (Lange) Imbach. dependent on geographical regions of Poland

The most similar micronutrient composition appeared in *A. bisporus* from Lubuskie and Pomerania and Kujawy (*ca.* 98%). A separate group was distinguished from samples picked in Wielkopolska and Silesia (97%). Regarding the pollutants, the samples were grouped more differently (Figure 4). The composition of pollutants in *A. bisporus* was most similar in Lower Silesia and Lubuskie (90%), then in Wielkopolska (83%) and Pomerania and Kujawy (74%). Silesia was the least similar to the other regions in this respect.

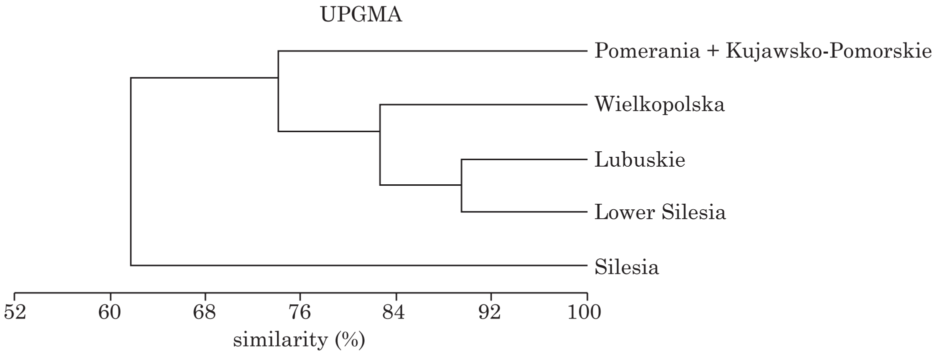

Fig. 4. Hierarchical cluster analysis based on similarity of absorded pollutants (Cd, Cr, Pb, Ni) in *Agaricus bisporus* (Lange) Imbach. dependent on geographical regions of Poland

CONCLUSIONS

1. The content of heavy metals in the fruiting bodies of *Agaricus bisporus* (Lange) Imbach. growing wild in Poland reached: Cd 0.68-6.14; Cr 0.38-6.93; Cu 1.90-101.71; Fe 33.01-432.24; Mn 2.86-387.43; Ni 0.20-3.09; Pb 0.98-42.83; Zn 31.87-124.84 (in mg kg^{-1}).

2. Exceeding the permissible content of Cd occurred in the fruiting bodies collected from whole Silesia.

3. Exceeding the permissible content of Cd was observed in the fruiting bodies picked from four out of eleven locations in Silesia: Katowice (Murcki), Pszczyna (Kobiór), Sośniowice (Biały Dwór), Pawonków (Dziewicza Góra).

4. In the remaining regions. the permissible content of cadmium and lead were not exceeded in the fruiting bodies of *Agaricus bisporus* (Lange) Imbach.

5. The concentrations of micronutrients (Zn, Cu, Mn, Fe) and pollutants (Cd, Cr, Pb, Ni) were strictly dependent on sampling sites as well as on geographical regions of Poland.

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