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NUTRITIONAL ELEMENTS AND ALUMINIUM ACCUMULATION IN *XEROCOMUS BADIUS* MUSHROOMS

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ABSTRACT

Introduction. This paper constitutes a supplementary study of the research conducted to assess accumulation efficiency of selected trace elements by *Xerocomus badius* fruiting bodies picked in some regions of Poland in selected years.
Material and methods. Atomic absorption/emission spectrometry techniques (FAAS and AES) were applied to determine in the fruiting bodies of this mushroom species the total contents of Ca, K, Mg and Na, as well as Al as a metal capable of entering into easy interactions with nutritional elements and inhibiting their proper action in the human organism.
Results. The highest concentrations of Al, K and Mg were determined in mushroom fruiting bodies collected in the Lower Silesia Voivodeship, amounting to 28.08 ±5.81 mg·kg^{-1} d.w., 2.39 ±0.21 g·kg^{-1} d.w. and 372.31 ±90.55 mg·kg^{-1} d.w., respectively. On the other hand, the highest concentrations of Ca (78.08 ±24.64 mg·kg^{-1} d.w.) were recorded in mushrooms from the Łódź Voivodeship, while the highest concentrations of Na (77.03 ±20.46 mg·kg^{-1} d.w.) – in those from the Pomeranian Voivodeship were observed. In general, BCF > 1 was found only for K accumulation.
Conclusion. Concentrations of nutritional elements determined in this study revealed that the consumption of *X. badius* fruiting bodies supplied only small quantities of these constituents in comparison with the amounts consumed in other products. The detected Al concentrations showed that fruiting bodies of this mushroom species consumed in Poland during the past 20 years could not lead to health problems caused by the presence of this metal.

Key words: accumulation, aluminium, macroelements, mushroom, *Xerocomus badius*

INTRODUCTION

Mushrooms, for their proper growth, require appropriate quantities of minerals. These minerals are absorbed by the mycelium from the substrate and translocated to the fruiting bodies. There are many abiotic and biotic factors, which influence mineral contents in the soil. Some of them are characteristic of the species, e.g. the amounts and activity of specific enzymes as well as chelating agents [Jarzyńska and Falandysz 2012].

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With respect to external factors, we need to mention here the quantity and availability of minerals in substrates [Demirbas 2001]. The content of minerals in carpophores depends on geochemical properties of soil, but it also exhibits seasonal variability [Zhang et al. 2010]. Accumulation of a specific chemical element in individual parts of the fruiting body may vary. In a majority of performed investigations, concentration of more minerals was higher in the caps than stipes [Rudawska and Leski 2005, Falandysz et al. 2007].

Mushroom fruiting bodies contain considerable amounts of K, Ca, Na, Mg, Fe and Mn [Genccelep et al. 2009]. The above-mentioned elements play a significant role in biological systems and organisms of mushrooms; they act, among others, as coenzymes [Carlile et al. 2001, Uzun et al. 2011]. Edible mushrooms are better sources of minerals in the human diet than other products of plant origin [Bernaś et al. 2006, Kalac 2010]. There is ample evidence in the literature concerning concentrations of nutritional elements, especially K and Ca, in such species of cultivated mushrooms as *Agaricus bisporus*, *Pleurotus ostreatus* and *Lentinula edodes* [Mattila et al. 2001, Akyuz and Kirbag 2010, Abrefah et al. 2011].

The content of minerals in wild-growing species was investigated in many research projects conducted in Europe and some countries worldwide [Sanmee et al. 2003, Kalyoncu et al. 2010, Gucia et al. 2012 a]. These investigations were focused on the determination of contents of elements in different mushroom species, such as *Boletus edulis* [Frankowska et al. 2010, Giannaccini et al. 2012], *Macrolepiota procera* [Gucia et al. 2012 a, b], *Leccinum scabrum* [Falandysz et al. 2007], *Leccinum griseum* [Jarzyńska and Falandysz 2012] and *Suillus grevillei* [Falandysz et al. 2012]. The above mentioned authors analysed fruiting bodies harvested in different regions [Falandysz et al. 2008] or in the same place but at different dates [Zhang et al. 2010].

In Poland, *X. badius* is a mushroom species, which is picked very often and eaten willingly in different forms, especially during the period of its natural occurrence. Some investigations demonstrated high concentrations of minerals in *X. badius* fruiting bodies collected in different regions of Poland [Falandysz and Bielawski 2001, Malinowska et al. 2004]. The content of nutritional elements was found to be different in caps and stipes of this species. Concentrations of K, P and Mg were higher in caps than in stipes of *X. badius*, while stipes contained more Ca [Rudawska and Leski 2005]. Malinowska et al. [2004] reported variations both in the content of nutritional elements in caps and stipes of this species, and between fruiting bodies collected in different regions of Poland. In some regions consumption of wild-growing mushrooms, especially *X. badius* species, is high and their proportion in the diet can exert a significant influence on the human organism. For this reason the aim of this study was to determine the accumulation efficiency of selected nutritional elements (Ca, K, Mg, Na) and Al in *X. badius* mushrooms from 5 regions of Poland within the last 20 years.

MATERIAL AND METHODS

Mushroom sample collection

Fruiting bodies of *Xerocomus badius* (*X. b.*) were collected within the last 20 years (selected years when mushrooms were growing in the same places) from 5 regions of Poland comprising the following provinces (voivodeships): the Pomeranian Voivodeship (P_{2009} (n = 17), P_{2008} (n = 9), P_{2007} (n = 16), P_{2005} (n = 14), P_{1995} (n = 23) and P_{1991} (n = 6)), the Greater Poland Voivodeship (G_{2009} (n = 8), G_{2008} (n = 17), G_{2007} (n = 19), G_{2005} (n = 16), G_{2003} (n = 15), G_{2001} (n = 10), G_{1998} (n = 22) and G_{1995} (n = 14)), the Łódź Voivodeship (C_{2008} (n = 18), C_{2007} (n = 25), C_{2003} (n = 8) and C_{2001} (n = 11)), the Opole and Silesian Voivodeship (S_{2005} (n = 9), S_{2003} (n = 15), S_{2001} (n = 12), S_{1998} (n = 10), S_{1995} (n = 5) and S_{1991} (n = 14)) and the Lower Silesian Voivodeship (L_{2008} (n = 12), L_{2007} (n = 11), L_{2001} (n = 7), L_{1998} (n = 16), L_{1995} (n = 11) and L_{1991} (n = 7)). Locations of sample collection areas are presented in Figure 1.

The numbers presented in round brackets denote the number of mushroom samples (specimens) collected per year and place. Material was collected in each year from the same places, while no results for a particular year are due to the absence of *X. b.* growth.

Soil sample collection

Soil samples were taken from each location where mushrooms were collected from a depth of up from 5 cm below the ground surface. Everywhere where greenery (grass, moss) was found it was removed and soil was collected from the same depth. Soil samples

Fig. 1. General locations of areas (regions) of mushroom sample collection

were collected using a soil auger (5 cm outside diameter × 1.5 m tube length), by transferring about 0.5 kg soil samples to air-tight polypropylene containers so that the soil filled them to the brim (to prevent changes in the chemical composition). Afterwards the materials (mushroom and soil samples) were transported to the laboratory within 24 h.

Mushroom material preparation

Mushrooms after collection were carefully washed with distilled water (Milli-Q Advantage A10 Water Purification Systems, Merck Millipore) to remove soil particles, then dried in an electric drier at 105 ±2°C for 48 h (analysis of mushroom dry weight). Dry samples (whole mushrooms: caps and stipes jointly) were ground to a powder for 2 min in a laboratory Cutting Boll Mill 200 by RETSCH. The material as three representative samples (1 g each) was mineralized in a CEM Mars 5 Xpress microwave mineralization system (CEM Corp., Matthews, NC, USA) in a closed system (55 mL vessels) using 6 mL concentrated HNO_3 and 1 mL 30% H_2O_2. The mushroom material was digested according to a microwave program composed of three stages: the first stage – power 600 W, time 3 min, temperature 100°C; the second stage – power 600 W, time 3 min, temperature 120°C, and the third stage – power 1200 W, time 8 min, temperature 200°C. Materials after digestion were filtered through 45-mm filters (Sartorius Stedim Biotech. Grade 1288), and then whole contents were made up to a final volume of 50 mL with deionized water.

Soil analysis

The total Mg content was determined according to Schachtschabel's method and the analysis of the other elements was performed by atomic emission spectrometry (AES). Soil samples for the analysis of nutrients were prepared in the same way as mushroom samples (drying, grinding and mineralization). Characteristics of soils from the analyzed regions of Poland in terms of ranges of the lowest and highest values are presented in Table 1.

Table 1. Characteristics of soil samples from collection areas described by ranges of particular parameters or nutritional element concentrations on dry-weight basis within the last 20 years

Parameter/ element	Unit	Provinces (regions) of Poland				
		Pomeranian Voivodeship	Greater Poland Voivodeship	Łódź Voivodeship	Silesian Voivodeship	Lower Silesian Voivodeship
Al	%	0.28-0.68	0.17-0.43	0.38-1.22	0.73-1.59	0.58-0.94
Ca	%	0.02-0.08	0.01-0.06	0.04-0.08	0.04-0.09	0.04-0.13
K	%	0.01-0.04	0.02-0.06	0.03-0.15	0.02-0.09	0.04-0.19
Mg	%	0.03-0.05	0.04-0.09	0.06-0.17	0.04-0.15	0.05-0.09
Na	$mg \cdot kg^{-1}$	162-198	171-269	109-216	194-325	201-368

Table 2. Experimental conditions of applied methods and statistical parameters of calibration lines

Element		Al	Ca	K	Mg	Na
Technique		FAAS	AES	AES	AES	AES
Wavelength	nm	309.3	422.7	766.5	285.2	589.0
Slit width	nm	0.5	0.5	0.2	0.5	0.2
Lamp current	mA	9	–	–	–	–
Model	Quadratic – provides a second order least squares line forced through zero					
Sensitivity	B(x)	0.017	0.011	0.001	0.001	0.003
LOD	$mg \cdot kg^{-1}$	0.044	0.009	0.003	0.002	0.012
Minimum concentration	$C_{min}/mg \cdot kg^{-1}$	8.326	8.662	11 400	119.771	24.327
Maximum concentration	$C_{max}/mg \cdot kg^{-1}$	39.685	102.324	25 700	441.368	99.63
Correlation coefficient	r	0.9995	0.9989	0.9996	0.9995	0.9995

Analytical method and calculation

Concentrations of selected nutritional elements and Al in mushrooms were analysed by flame atomic absorption spectrometry (FAAS) and atomic emission spectrometry (AES), respectively, using an Agilent Technologies AA Duo – AA280FS/AA280Z spectrometer (Agilent Technologies, Mulgrave, Victoria, Australia) equipped with a Varian hollow-cathode lamp (HCL). Calibration curves were prepared before the analysis with four replicates per each element concentration. Experimental conditions of the applied analytical techniques and statistical parameters of the calibration lines are presented in Table 2.

Efficiency of element accumulation was characterised by the bioconcentration factor (BCF) values calculated according to Gast et al. [1988] as the ratio of element concentrations in mushrooms to the concentration of this element in soil.

Verification of obtained results

Results were validated on the basis of simultaneous analyses of randomly selected samples using an interlaboratory comparison (the other laboratory using atomic absorption spectrometry). The use of interlaboratory comparison was necessary because no certified reference material with a similar (mushroom) matrix and element concentration levels was available (Table 3).

Table 3. Comparison of element concentrations in the same selected mushroom samples, $mg \cdot kg^{-1}$ d.w.

Element	Interlaboratory comparison	
	authors' results	other laboratory result
Al	18.25 ±1.79	18.41 ±1.62
Ca	11.29 ±1.28	11.18 ±1.03
K*	2.22 ±0.18	2.14 ±0.12
Mg	219.90 ±11.48	227.44 ±16.75
Na	101.14 ±8.60	94.38 ±7.55

*Values presented in %.

Statistical methods

To determine similarities in the accumulation efficiency of 4 nutritional elements and Al absorbed by fruiting bodies of *X. b.* collected from five regions of Poland, an object clustering algorithm with cluster analysis (CA) by the Ward method was used to graphically present the results and determine the Euclidean distance. Moreover, a two-way joining analysis (Heatmap) was used to estimate the simultaneous effect of sample collection area (region of Poland) and the analysed trace element on similarities in trace element accumulation rates by mushrooms collected from a certain region.

Single-factor multivariate analysis of variance (MANOVA) [Morrison 1976] was used to examine differences in mean values of all tested trace elements between all years of sample collection from particular regions of Poland. Rejection of the general hypothesis of no differences between years of sample collection from all regions justified testing of particular hypotheses concerning individual comparisons (contrasts) of regions with respect to all trace elements using the appropriate F-statistic. The Mahalanobis distance [Mahalanobis 1936] was used as a measure of multivariate region similarity. On the basis of Mahalanobis distances, calculated for all pairs of regions, the shortest dendrite was drawn. Canonical variate analysis was performed for configuration of regions (years of sample collection) with regard to all eleven trace elements.

RESULTS

Accumulation efficiency of Al, Ca, K, Mg and Na in analysed *X. b.* fruiting bodies is presented in Table 4. Mean accumulation efficiency of tested elements was generally similar in mushrooms collected from particular regions of Poland, with some minor exceptions. The highest mean accumulation rates of Al, K and Mg were observed in mushrooms collected from the Lower Silesian Voivodeship they were highest for Ca and Na in mushrooms from the Łódź Voivodeship and the Pomeranian Voivodeship, respectively. Additionally, the range between the highest and the lowest concentrations of elements for analysed mushrooms collected from the investigated regions was significantly different in some cases (e.g. K and Na accumulation in mushrooms from the Pomeranian Voivodeship and the Greater Poland Voivodeship).

To provide precise information on element accumulation efficiency, the BCF values were calculated. Generally, BCF > 1 was found only for K accumulation, for mushrooms collected from all the 5 experimental areas (R 1.43-6.09). For the other elements BCF values were lower than 1, amounting to 0.01-0.02 for Al, 0.02-0.91 for Ca, 0.15-1.36 for Mg and 0.12-0.61 for Na, respectively.

In order to determine similarities in accumulation of particular elements in *X. b.* fruiting bodies collected from all regions of Poland, the trait agglomeration

Table 4. Mean long-term concentrations of nutritional elements and Al in mushrooms (mean ±SD) collected from different regions of Poland, mg·kg^{-1} d.w.

Element		Provinces (region) of Poland				
		Pomeranian Voivodeship	Greater Poland Voivodeship	Łódź Voivodeship	Silesian Voivodeship	Lower Silesian Voivodeship
Al	mean ±SD	24.44 ±4.51	23.95 ±5.68	22.20 ±4.57	24.90 ±2.71	28.08 ±5.81
	R	14.79^{ab}	18.04^{b}	12.86^{ab}	9.27^{a}	15.60^{ab}
Ca	mean ±SD	59.72 ±10.83	58.28 ±21.37	78.08 ±24.64	62.24 ±11.05	74.37 ±32.50
	R	33.18^{a}	68.43^{bc}	63.03^{bc}	34.47^{a}	95.32^{c}
K*	mean ±SD	2.03 ±0.25	2.24 ±0.37	2.24 ±0.27	2.24 ±0.36	2.39 ±0.21
	R	0.83^{a}	1.21^{b}	0.72^{a}	1.16^{b}	0.78^{a}
Mg	mean ±SD	319.11 ±53.65	339.71 ±65.67	362.30 ±79.46	321.34 ±63.54	372.31 ±90.55
	R	157.89^{a}	171.72^{ab}	190.18^{b}	206.90^{b}	261.72^{c}
Na	mean ±SD	77.03 ±20.16	57.20 ±14.70	64.22 ±4.88	63.70 ±9.51	69.30 ±21.00
	R	62.06^{d}	47.97^{c}	13.53^{a}	26.91^{b}	43.22^{c}

*Values presented in %.
Means within rows, with different letters, differ significantly at $P \leq 0.05$ (Tukey's test).

algorithm was applied. A graphic illustration of the results of agglomeration analysis by the Ward method made it possible to determine two clusters: one comprised Al and Ca, while the other consisted of K, Na and Mg. Similar values of Euclidean distances in the case of the above-mentioned groups of elements indicated that the accumulation of these elements in individual agglomerations followed a similar course (Fig. 2).

Employing the analysis of contrasts, the authors tested the hypothesis concerning no differences between regions with respect to the accumulation of all elements jointly (Al, Ca, K, Mg, Na) based on all years of mushroom sample collection. At P = 0.01 statistically significant values were found for a majority of contrasts, except for the following contrasts: the Pomeranian – the Silesian, the Greater Poland – the Łódź, the Greater Poland – the Silesian, and the Łódź – the Silesian provinces, respectively, as shown in Table 5.

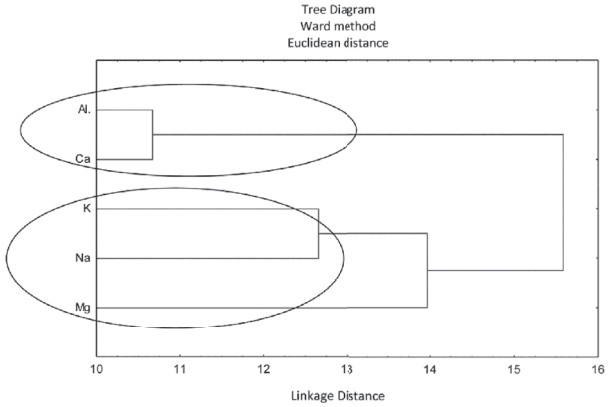

Fig. 2. Horizontal Hierarchical Tree Plot for studied elements

Since the experimental material was collected from different regions of Poland in selected years, the study verified the hypothesis on a lack of differences in element accumulation rates by mushrooms collected in particular years. Based on the general hypothesis tested at $F_{0.01}$, statistically significant differences were found in the accumulation efficiency of all the examined elements from different years and from different places of sample collection. Figure 3 presents an analysis of canonical variables with respect to interdependencies between individual Voivodeships (A – the Pomeranian, B – the Łódź, C – the Lower Silesian, D – the Greater Poland and E – the Silesian provinces). Individual observations represented averaged values from all observations (individual years of mushroom collection) for individual regions of Poland.

The interdependencies presented in the figure above indicate significant differences with respect to the accumulation efficiency of nutritional elements and Al between individual years as well as fruiting bodies collected from different regions of Poland.

Table 5. Testing significance of contrasts between regions of Poland

Contrast	F
Pomeranian Voivodeship – Greater Poland Voivodeship	5.33
Pomeranian Voivodeship – Łódź Voivodeship	7.13
Pomeranian Voivodeship – Silesian Voivodeship	2.86
Pomeranian Voivodeship – Lower Silesian Voivodeship	5.77
Greater Poland Voivodeship – Łódź Voivodeship	3.09
Greater Poland Voivodeship – Silesian Voivodeship	0.74
Greater Poland Voivodeship – Lower Silesian Voivodeship	6.42
Łódź Voivodeship – Silesian Voivodeship	2.99
Łódź Voivodeship – Lower Silesian Voivodeship	4.13
Silesian Voivodeship – Lower Silesian Voivodeship	3.80
Critical	$F_{0.01} = 3.25$
	$F_{0.05} = 2.33$

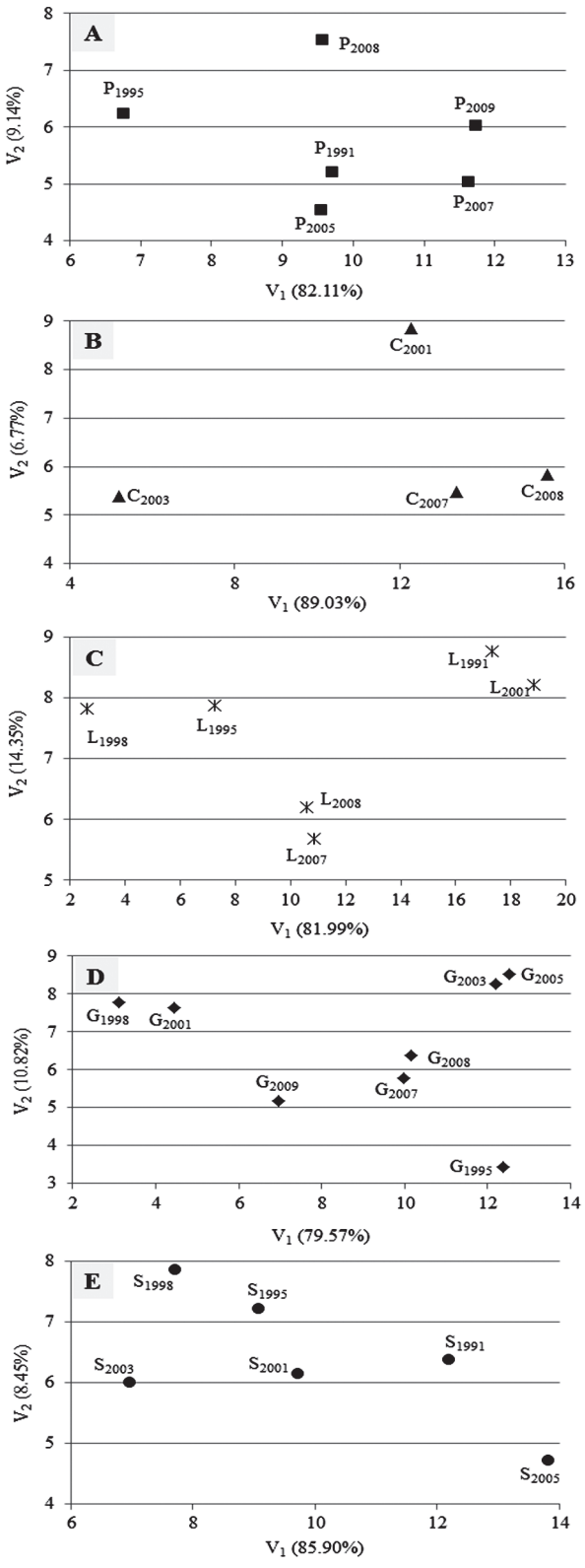

Fig. 3. Configuration of observations in the system of the first two canonical variables (V_1 and V_2) as regards all tested elements' accumulation efficiency jointly with consideration of all years of mushroom sample collection

DISCUSSION

Both nutritional elements and microelements play a significant role in the natural metabolic pathways of human organisms [Kabata-Pendias and Pendias 1999, Howard et al. 2006]. The nutritional elements investigated in this study were analysed with reference to their accumulation in the fruiting bodies of one of the most commonly consumed mushroom species in order to determine quantities of the elements supplied to the human organism during the consumption of these mushrooms. According to the recommendations of the National Academy of Science, Food and Nutrition Board, USA, the suggested Dietary Reference Intakes (DRIs) for individual groups in the general population are as follows: 700-1300 (Ca), 3000-5100 (K), 80-420 (Mg) and 1-1.5 (Na) mg·kg^{-1} body mass·day^{-1} [Dietary... 1997]. Assuming a single consumption of mushrooms at 300 g (fresh mass weight), which corresponds to approximately 30 g d.w. of mushrooms, the quantities of elements supplied to the human organism (60 kg) amount to only 0.04 (Ca), 0.19 (Mg), 1.20 (K) and 0.04 (Na) mg·day^{-1}. The values presented above were calculated for the highest concentrations of the examined elements in the *X. b.* mushroom fruiting bodies, and thus/ it may be concluded that both sporadic and long-term consumption of this species during the last 20 years in the examined regions of Poland did not to cover their daily allowances and did not pose a health hazard for humans. Moreover, in view of the data reported by Kalac [2010], who determined the typical contents of major mineral elements in wild growing mushrooms at 100-500 (Ca), 20,000-40,000 (K), 800-1800 (Mg) and 100-400 (Na) mg·kg^{-1} d.w., respectively, it may be assumed that amounts of these elements in the examined mushroom fruiting bodies were relatively small.

Additionally, the performed experiments comprised analyses of Al concentrations. Although this element is removed from a healthy organism rapidly, nevertheless when present in excessive amounts it can lead to disturbances in metabolic processes associated with Ca-,

Mg- and Fe-dependent enzymes (calcification of soft tissues, anaemia or loss of cell membrane elasticity) [Crisponi et al. 2012] as well as many other diseases [Alvarez et al. 2007]. The Minimal Risk Levels (MRLs) calculated by the Agency for Toxic Substances and Disease Registry (ATSDR) for Al were determined at 1 mg·kg^{-1} body mass·day^{-1} (values for oral route, both (a) intermediate – 15 to 364 days, and (b) chronic – 1 year or longer) [ATSDR 2010]. Bearing in mind the earlier criterion of the amount of mushroom consumption (30 mg·day^{-1} d.w.), as well as the highest Al concentration determined in the fruiting bodies collected from the Lower Silesia Voivodeship (28.08 ±5.81 mg·kg^{-1} d.w.), the amount of consumed Al was 0.014 mg·kg^{-1} body mass·day^{-1}. This quantity was lower than that recommended by the ATSDR, but it should be remembered that Al, as well as the other trace elements, is also taken up from other food products [Melø et al. 2008, Uluozlu et al. 2009]. Therefore, it should be concluded that only sporadic consumption of *X. b.* fruiting bodies by people from the examined regions of Poland did not exert a negative influence on their health. Similar conclusions were presented by Gucia et al. [2012 b], who investigated accumulation efficiency of 20 elements in the *Macrolepiota procera* fruiting bodies collected from 11 spatially distant areas in northern Poland, differing in land use character. Gucia et al. [2011] indicated that a 300- and 500-g daily intake of caps of this mushroom species was safe when eaten frequently by fanciers during the mushroom growth season.

Falandysz et al. [2001] determined contents of 36 elements in 18 mushroom species collected in 1994 in the Pomeranian Voivodeship. They found that in *X. b.* fruiting bodies mean Ca, K, Mg and Na concentrations were 30 ±13 mg·kg^{-1} d.w., 43 ±2 mg·g^{-1} d.w., 1.1 ±0.1 mg·g^{-1} d.w. and 470 ±70 mg·kg^{-1} d.w., respectively. In comparison with the data from our experiments, fruiting bodies collected from that region contained nearly two times more Ca, 50% less K, three times less Mg and six times less Na. Also Malinowska et al. [2004] examined the contents of 14 elements, including Ca, K, Mg and Na, in *X. b.* collected in northern and north-eastern Poland. Comparing a similar area of analysis, we found in our experimental materials significantly lower concentrations of Na and K as well as similar contents of Ca and Mg. One probable cause of the differences in Na and K contents may be attributed to the fact that the mushrooms were collected in different years (1993-1998 – Malinowska et al. [2004] vs. 1990-2010 – our study) together with the impact of the location of mushroom collection site ed as evidenced by significant differences in BCF values, especially for Ca, Mg and Na.

Significant differences in Al, Ca, K and Mg accumulation rates by *X. b.* fruiting bodies in comparison with our experiments were also observed in the case of the results reported by Rudawska and Leski [2005], who investigated the accumulation of 12 elements by 8 mushroom species, including *X. b.*, from the Notecka Primeval Forest. In general, our results were lower in comparison with those reported by Rudawska and Leski [2004] in the case of fruiting bodies and similar for the soil, with the exception of Al content. Our samples were not collected from the same area, therefore BCF values were significantly lower.

The important role of the substrate (geological origin and soil substrate pollution) for mushroom growth was emphasised by Falandysz et al. [2007], who investigated accumulation of 26 elements in caps and stipes of *Leccinum scabrum* collected from lowland and mountain areas of Poland in 2000. They reported significant differences in the accumulation efficiency of selected elements depending on the place of growth of mushroom fruiting bodies. Differences in the efficiency of element accumulation depended on both the place of picking and on mushroom species [Vetter 2003]. In the experiments presented by Vetter [2003], 4 *Xerocomus* species were examined, i.e. *X. armeniacus*, *X. chrysentheron*, *X. porosporus* and *X. subtomentosus*. Those results showed that mean Na concentration for all mushroom fruiting bodies was 233 ±147 mg·kg^{-1} d.w., with significant differences found in the accumulation of this element (C_{min} = 84.1 ±7 and C_{min} = 475 ±14.2 mg·kg^{-1} d.w.).

CONCLUSION

Considering the achieved results we conclude that during last 20 years, the studied mushroom material (fruiting bodies) collected in different regions of Poland did not contain significant amounts of nutritional elements, however they contain also trace toxic elements such as Al. We believe that occasional consumption of the mushroom is not hazardous.

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REFERENCES

Abrefah R.G., Mensimah E., Ampomah-Amoako E., Opata N.S., Gyamfi K., 2011. Determination of the concentration of essential elements in *Pleurotus ostreatus* cultivated on *Valisneria arthiopica* as a supplementary substrate to sawdust using instrumental neuron activation analyses. Res. J. Appl. Sci. Eng. Technol. 3 (11), 1290-1295.

Alvarez L., Rebollido M., Fernandez-Lorenzo J.R., Cocho J.A., Fraga J.M., 2007. Electrothermal atomic absorption spectrometry determination of aluminium in parenteral nutrition and its components. J. Trace Elem. Med. Biol. 21 (1), 29-30.

Akyuz M., Kirbag S., 2010. Element contents of *Pleurotus eryngii* (DC. ex. Fr.) Quel. var. *eryngii* grown on some various agro-wastes. Ekoloji 19 (74), 10-14.

ATSDR. 2010. Minimal Risk Levels (MRLs) for Hazardous Substances. Agency for Toxic Substances and Disease Registry.

Bernaś E., Jaworska G., Lisiewska Z., 2006. Edible mushrooms as a source of valuable nutritive constituents. Acta Sci. Pol., Technol. Aliment. 5 (1), 5-20.

Carlile M.J., Watkinson S.C., Gooday G.W., 2001. The Fungi. Elsevier.

Crisponi G., Nurchi V.M., Bertolasi V., Remelli M., Faa G., 2012. Chelating agents for human diseases related to aluminium overload. Coordin. Chem. Rev. 256 (1-2), 89-104.

Demirbas A., 2001. Concentration of 21 metals in 18 species of mushrooms growing in the East Black Sea region. Food Chem. 75 (4), 453-457.

Dietary reference intakes for calcium, phosphorus, magnesium, vitamin D, and fluoride. 1997. Inst. Med. Food Nutr. Board. National Acad. Press Washington, D.C.

Falandysz J., Bielawski L., 2001. Mercury content of wild edible mushrooms collected near the town of Augustow. Pol. J. Environ. Stud. 10 (1), 67-71.

Falandysz J., Chudzyński K., Kojta A.K., Jarzyńska G., Drewnowska M., 2012. Comparison of two acid extraction methods for determination of minerals in soils beneath to Larch Bolete (*Suillus grevillei*) and aimed to estimate minerals sequestration potential in fruiting bodies. J. Environ. Sci. Heal. A, 47 (11), 1607-1613.

Falandysz J., Kunito T., Kubota R., Bielawski L., Frankowska A., Falandysz J., Tanabe S., 2008. Multivariate characterization of elements accumulated in King Bolete *Boletus edulis* mushroom at lowland and high mountains regions. J. Environ. Sci. Heal. A, 43 (14), 1692-1699.

Falandysz J., Kunito T., Kubota R., Bielawski L., Mazur A., Falandysz J., Tanabe S., 2007. Selected elements in Brown Birch Scaber Stalk *Leccinum scabrum*. J. Environ. Sci. Heal. A, 42 (14), 2081-2088.

Falandysz J., Szymczyk K., Ichihashi H., Bielawski L., Gucia M., Frankowska A., Yamasaki S-I., 2001. ICP/MS and ICP/AES element al analysis (38 elements) of edible wild mushrooms growing in Poland. Food Addit. Contam. 18 (6), 503-513.

Frankowska A., Ziółkowska J., Bielawski L., Falandysz L., 2010. Profile and bioconcentration of minerals by King Bolete (*Boletus edulis*) from Płocka Dale in Poland. Food Addit. Contam. B, 3 (1), 1-6.

Gast C.H., Jansen E., Bierling J., Haanstra L., 1988. Heavy metals in mushrooms and their relationship with soil characteristics. Chemosphere 17 (4), 789-799.

Genccelep H., Uzun Y., Tunctürk Y., Demirel K., 2009. Determination of mineral contents of wild-grown edible mushrooms. Food Chem. 113 (4), 1033-1036.

Giannaccini G., Betti L., Palego L., Mascia G., Schmid L., Lanza M., Mela A., Fabbrini L., Biondi L., Lucacchini A., 2012. The trace element content of top-soil and wild edible mushroom samples collected in Tuscany, Italy. Environ. Monit. Assess. 184 (12), 1-17.

Gucia M., Jarzyńska G., Kojta A.K., Falandysz J., 2012 a. Temporal variability in 20 chemical elements content of Parasol Mushroom (*Macrolepiota procera*) collected from two sites over a few years. J. Environ. Sci. Heal. B, 47 (2), 81-88.

Gucia M., Jarzyńska G., Rafał E., Roszak M., Kojta A.K., Osiej I., Falandysz J., 2012 b. Multivariate analysis of mineral constituents of edible Parasol Mushroom (*Macrolepiota procera*) and soil beneath fruiting bodies collected from Northern Poland. Environ. Sci. Pollut. Res. 19 (2), 416-431.

Howard P., Jonkers-Schuitema C., Furniss U., Kyle L., Muehlebach S., Ödlund-Olin A., Page C., Wheatley M., 2006. Managing the patient journey through enteral nutritional care. Clin. Nutr. 25 (2), 187-195.

Jarzyńska G., Falandysz J., 2012. Metallic elements profile of Hazel (Hard) Bolete (*Leccinum griseum*) mushroom and associated upper soil horizon. Afr. J. Biotechnol. 11 (20), 4588-4594.

Kabata-Pendias A., Pendias H., 1999. Biogeochemia pierwiastków śladowych [Biogeochemistry of trace elements]. PWN Warszawa [in Polish]

Kalac P., 2010. Trace element contents in European species of wild growing edible mushrooms: A review for the period 2000-2009. Food Chem. 122 (1), 2-15.

Kalyoncu F., Ergonul B., Yildiz H., Kalamis E., Solak M.H., 2010. Chemical composition of four wild edible mushroom species collected from southwest Anatolia. GU. J. Sci. 23 (4), 375-379.

Mahalanobis P.C., 1936. On the generalized distance in statistics. Proc. Nat. Inst. Sci. India 2, 49-55.

Malinowska E., Szefer P., Falandysz J., 2004. Metals bioaccumulation by bay bolete, *Xerocomus badius*, from selected sites in Poland. Food Chem. 84 (3), 405-416.

Mattila P., Könkö K., Eurola M., Pihlava J.A., Astola J., Vahteisto L., Hieraniemi V., Kumpulainen J., Valtonen M., Pironen V., 2001. Contents of vitamins, mineral elements, and some phenolic compounds in cultivated mushrooms. J. Agric. Food Chem. 49 (5), 2343-2348.

Melø R., Gellein K., Evje L., Syversen T., 2008. Minerals and trace elements in commercial infant food. Food Chem. Toxicol. 46 (10), 3339-3342.

Morrison D.F., 1976. Multivariate statistical methods. McGraw-Hill Kogakusha Tokyo.

Rudawska M., Leski T., 2005. Macro- and microelement contents in fruiting bodies of wild mushrooms from the Notecka forest in west-central Poland. Food Chem. 92 (3), 499-506.

Sanmee R., Dell B., Lumyong P., Izumori K., Lumyong S., 2003. Nutritive value of popular wild edible mushrooms from northern Thailand. Food Chem. 82 (4), 527-532.

Uzun Y., Genccelep H., Kaya A., Akcay M.E., 2011. The mineral contents of some wild edible mushrooms. Ekoloji 20 (80), 6-12.

Uluozlu O.D., Tuzen M., Mendil D., Soylak M., 2009. Assessment of trace element contents of chicken products from Turkey. J. Hazard. Mater. 163 (2-3), 982-987.

Vetter J., 2003. Data on sodium content of common edible mushrooms. Food Chem. 81 (4), 589-593.

Zhang D., Frankowska A., Jarzyńska G., Kojta A.K., Drewnowska M., Wydmańska D., Bielawski L., Wang J., Falandysz L., 2010. Metals of King Bolete (*Boletus edulis*) Bull.: Fr. collected at the same site over two years. Afr. J. Agric. Res. 5 (22), 3050-3055.

POBIERANIE MAKROELEMENTÓW ORAZ GLINU PRZEZ OWOCNIKI PODGRZYBKA BRUNATNEGO

STRESZCZENIE

Wstęp. Praca jest uzupełnieniem badań prowadzonych w połączeniu z oceną efektywności akumulacji wybranych pierwiastków śladowych przez owocniki podgrzybka brunatnego, pobieranych z kilku regionów Polski w wybranych latach.

Materiał i metody. Wykorzystując atomową spektrometrię absorpcyjną i emisyjną (FAAS i AES), oznaczano w owocnikach podgrzybka brunatnego całkowitą zawartość Ca, K, Mg oraz Na, jak również Al jako metalu zdolnego do łatwego wchodzenia w interakcje z makroelementami oraz hamowania ich właściwego działania w organizmie ludzkim.

Wyniki. Największe stężenia Al, K i Mg – wynoszące odpowiednio: 28,08 ±5,81 mg·kg^{-1} s.m., 2,39 ±0,21 g·kg^{-1} s.m. i 372,31 ±90,55 mg·kg^{-1} s.m. – oznaczono w owocnikach podgrzybka pobieranych z województwa śląskiego. Jednocześnie największe stężenie Ca (78,08 ±24,64 mg·kg^{-1} s.m.) i Na (77,03 ±20,46 mg·kg^{-1} s.m.) stwierdzono w owocnikach pobieranych z województw pomorskiego oraz centralnej Polski. Obliczone wartości współczynnika biokoncentracji były 1< wyłącznie dla K.

Wnioski. Stężenia makroelementów oznaczone w badaniach świadczą, że spożywanie owocników podgrzybka brunatnego dostarczało jedynie niewielkich ilości tych składników w porównaniu z ilościami pobieranymi z innymi produktami. Oznaczone w tym gatunku grzyba stężenia Al pokazały, że jego spożywanie w Polsce w ciągu ostatnich 20 lat nie mogło przyczyniać się do problemów zdrowotnych wywołanych obecnością tego metalu.

Słowa kluczowe: akumulacja, glin, makroelementy, grzyby, podgrzybek brunatny

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