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Elemental characteristics of mushroom species cultivated in China and Poland

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ABSTRACT

China is the first and Poland the fifth the greatest producers of cultivated mushrooms worldwide. Because new species are being domesticated and gaining popularity there is a need to study their biological activities and chemical composition. In this study, a multi-elemental analysis was conducted on 14 culinary and/or medicinal mushroom species cultivated in China and Poland, all of which were available in German and Polish oriental and internet shops (*Agaricus bisporus*, *Amauroderma rude*, *Auricularia auricula-judae*, *Auricularia nigricans, Ganoderma lucidum*, *Lentinula edodes, Lignosus rhinocerus, Ophiocordyceps sinensis*, *Pleurotus ostreatus*, *Sparassis crispa, Tremella fuciformis, Wolfiporia cocos* and *Volvariella volvacea*). Overall, the contents of 5 macroelements and 31 trace elements were quantified. The studied mushrooms varied widely in their content of both essential and toxic deleterious elements. *A. rude* was found to contain the highest content of toxic deleterious elements Al, As and Pt. Platinum content was of particular concern as it exceeded 7 mg kg^{ö1} dry matter. The studied mushrooms were generally found to contain higher amounts of Pt, Ni (particularly *W. cocos*), and rare-earth elements Er and Nd (particularly *V. volvacea*) than reported in many literature data. The study generally concludes that the levels of various elements in the analysed mushrooms are not toxic, although further attention should be paid to reducing Ni levels in commercial mushrooms available as culinary.

1. Introduction

Cultivated mushroom species attract considerable attention due to their nutritional value, biological activities and potential contamination. The mushrooms examined in this study can be divided into three groups. The first one consists of species commonly cultivated on a large scale, with quality control maintained at a high level, which nowadays are very rarely gathered from natural sites. In this group can be included such species as *Agaricus bisporus*, *Pleurotus ostreatus*, *Lentinula edodes* and *Ganoderma lucidum* (Cocchi et al., 2006; Wang and Hou 2011). *Agaricus bisporus* is world's most commonly cultivated species. Polish production of this species is the highest in Europe – 330 000 tons, in second place is the Netherlands 270 000 tons, third is Spain – 105 000 tons. After *Agaricus, Pleurotus* mushrooms are the second most cultivated and consumed mushroom in the world. From 1997 to 2010, *Pleurotus spp*. production increased from 876 t to 6288 t (618%) (Royse, 2014). Most of this increase was reported in China and accounted for over 85% of the world's total output in 2010. Both species are common in Polish shops and local markets for fresh consumption. In China different species of *Pleurotus* mushroom are more popular than *P. ostreatus* and *A. bisporus. Lentinula edodes* is the third most cultivated edible mushroom in the world (after *Agaricus* and *Pleurotus* mushrooms), particularly in the East Asian countries, where almost 90% of the world's production takes place (Li, 2012; Royse, 2014). In Poland it is less popular and purchased dried rather than fresh from shops which sell "Oriental herbs and seasoning", most likely by gourmet consumers. The same is true of *Gandorema lucidum* − which is widely cultivated in countries of East Asia (Chen, 2011), coming to Poland mostly dried or in the form of tablets, teas, powders etc. The values of chemical characteristics of this group are presented in Table 1.

The second group consists of mushroom species cultivated on smaller scale than those of the first group mostly in countries of East

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Table 1
The summary of literature data on elements content [mg kg^{-1}] reported for some cultivated mushroom species – group 1–big scale cultivated mushrooms.

GROUP 1				
Element	*Agaricus bisporus*	*Pleurotus ostreatus*	*Lentinula edodes*	*Ganoderma lucidum*
Ca	860–1400	190–1500	50–420	1370
K	38105–40371	21840–51000	26700–31600	457–84650
Mg	1099–1400	165–2300	1200–1622	1670
Na	545–957	250–1440	130–440	179
P	10430–12475	618–13390	5600–8700	3210
Al	19–548	17–85		
As	0.07–4.31			
B	3.7–19.4			
Ba	1.39–2.37			
Bi	0.53–5.65	1.9–9		
Cd	0.01–10.59*	0.28–5.39	0.2	< 0.15–1
Co	0.005–0.09			
Cr	0.7–22.6*	0.1–16.3	17.4	31.9
Cu	3–65	19–50	5.2–13.7	11–47
Ge				800–1000
Fe	44–190*	33–550	33–68	176–211
Hg	0.002–9.21	0.5–2.0	0.046	0.01–0.07
Li	0.169	0.044–0.208		
Mn	5.7–28.8*	5–31.4	39.6	8.7–70
Ni	0.35–9.02	1.5–31.5	1.82	
Pb	0.06–2.44	0.67–0.91	0.3	0.96–5.7
Se	1.88–4.21	0.11–0.55	0.039	0.09–0.38
Sr	4.13–6.7			7.37
Ti	0.91			
V	< 0.05			0.0025–0.0215
Zn	4–81*	25–265	61–126	18–120

Agaricus bisporus – (Vetter 2003a,b, 2004; Muñoz et al., 2005; Cocchi et al., 2006; Gyorfi et al., 2010; Zhu et al., 2011 (wild); Jain et al., 2013 (wild); Schlecht and Säumel 2015; Mleczek et al., 2016a).
Pleurotus ostreatus – (Muñoz et al., 2005; Vetter 2005; Bernaś et al., 2006; Alam et al., 2008; Maihara et al., 2008; Kalač 2010; Costa-Silva et al., 2011; Zhu et al., 2011).
Lentinula edodes – (Mattila et al., 2001; Vetter, 2005; Reguła and Siwulski 2007; Zhu et al., 2011; Falandysz and Borovička 2013; Jain et al., 2013).
Ganoderma lucidum – (Tong et al., 1994; Tham et al., 1999a, 1999b; Chiu et al., 2000; Zhao et al., 2004; Chen 2011; Wang and Hou 2011; Niedzielski et al., 2014).

Table 2
The summary of literature data on elements content [mg kg^{-1}) reported for mushroom species – group 2 – smaller scale cultivated mushrooms (both wild and cultivated samples).

GROUP 2						
Element	*Auricularia auricula-judae – wild*	*Auricularia auricula-judae – market*	*Auricularia polytricha – wild*	*Auricularia polytricha – market*	*Volvariella volvacea – wild*	*Volvariella volvacea – cultivated*
Ca	58.1–810	1600	590–6070	1224.5	3390–4460	6.64–328
K	3780	12000	12400–17666	1129	13240–61440	439–41600
Mg	1366–19.4	2000	593–1360	240	570–2240	0.43–1456
Na	93	8000	449–8584	310	150–4260	44.6–420
P	430		944–1115	532		5300–12200
Ag	1.94					
As	1.0	0.2				
Al						51
B						4.0
Cd	1.54–1.6	0.01	6.1–8.1	0.92		
Co	4.02					
Cr	1.81					0.24
Cu	6.2–8.0		3–6.2	2.24	155–164	0.11–101.8
Fe	21–58	200	110–163			0.19–322.5
Hg	1.8–29.8					
Li	0.096–0.226					14
Mn	5.1		6.2–13		35–59	2.11–78.6
Ni	5.47					
Pb	19.5–31.3	0.1	4.9–5.5	2.86		0.25–5.07
Se	0.055–36.3		0.02			
Zn	6.6–23.9	60	10–16	71.0	680–980	0.77–94.28

Wild – *samples for analysis collected from various sites (from literature).*
Local market– purchased on markets however without indication if the samples are from wild sites or cultivated; (from literature).
Cultivated – indicated that it was derived from mushroom production farm – cultivation.
Auricularia auricula-judae (wild) – (Stijve 1977; Michelot et al., 1999; Vetter 2003a,b; Cocchi et al., 2006; Eze et al., 2014).
Auricularia auricula-judae (local market) – (Kadnikova et al., 2015).
Auricularia polytricha (wild) – (Stijve 1977; Manjunathan et al., 2011; Anno et al., 2016).
Auricularia polytricha (local market) – (Okwulehie and Ogoke, 2013).
Volvariella volvacea (wild) – (Chang and Buswell, 1996; Mshandete and Cuff, 2007).
Volvariella volvacea (cultivated) – (Ramkumar et al., 2012; Kumhomkul and Panich-pat 2013; Ahlawat et al., 2016; Mohiuddin et al., 2016; Sharif et al., 2016).