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RESEARCH NOTE

Toxic elements in certain higher fungi

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Certain species and genera of higher fungi possess the ability of bioaccumulation of certain elements. The high (in few cases extremely high) concentrations of cadmium, mercury, selenium, lead, vanadium, copper and arsenic in different taxons are demonstrated and possible mechanisms are noted and discussed.

It is already generally known that some living organisms possess the ability to take up and accumulate, in their structure, certain elements (both metallic and nonmetallic) at high concentrations. Within the plant kingdom, such species are called indicator plants, because their presence indicates the occurrence of some elements in large quantities in the environment. Other living organisms (such as lichens) came into prominence in environmental protection, because their presence or even extermination could be a good bioindicator of the occurrence of a toxin.

Recently, both international and Hungarian studies have drawn attention to the occurrence of certain toxic elements found in the fruit body of some macrofungi (*Basidiomycetes* and some *Ascomycetes*).

Cadmium is known as a principal toxic element, since it inhibits many life processes. In Table 1 the cadmium content of several species of both edible and poisonous toadstools in Hungary has been documented (Vetter, 1987, 1989). It was documented that the cadmium content in other species, originating from the same habitats as the macrofungi with high cadmium concentrations, was, by an order of magnitude, lower. There are two important questions: does the high cadmium concentration in certain species of *Agaricus* reflect abnormally high levels of cadmium in the environment or is the element preferentially accumulated by these species, perhaps because of a specific biochemical function of the metal? With what kind of compounds is cadmium bound in these organisms? Following Schmitt & Meisch (1985) the presence of a specific cadmium transport system may be postulated for certain toadstools, mainly for *Agaricus* species. From the fruit bodies of *Agaricus macrosporus* a cadmium-binding phosphoglycoprotein, cadmium mycophosphatin, was isolated (Schmitt & Meisch, 1985). This protein has a molecular weight of 12 000 daltons, containing phosphorus, but not sulphur, and contains glucose and galactose. The ability to accumulate cadmium is closely correlated with the presence of the binding compound, which is a genetically coded feature.

The mean mercury level in macrofungi surpasses, by two orders of magnitude, those in the green plants (green plants: 0·015 ppm; macrofungi, 1–1·5 ppm) and varies according to the type of fungi, since litter-decomposing species (*Agaricus, Marasmius*) have higher mercury concentrations (0·1–72 ppm) than the wood-destroying species and genera (1·5–2·0 ppm) (Laaksovirta & Lodenius, 1979). Taking into account the standard of FAO–WHO and the actual mercury concentration in mushroom in Finland, consumption of 40 to 370 g fresh mushroom per week for adult is the maximum recommended.

According to the investigations of Stijve (1977), of Quinche (1983) and of the author (Vetter, 1987, 1989, 1990) the selenium content of macrofungi ranged from 0·01 to 43 ppm (that means about 0·001 to 4·3 ppm by wet weight) and is regarded as a chemotaxonomic character. The selenium content appears to be species-dependent, with the highest values registered in *Boletus* species (Stijve, 1977).

Lead contamination varies and manifests itself in other ways than in the green plants. Lead accumulating species of fungi are not known; the lead concentration of the analyzed mushroom species and the samples was 0·1 to 40 ppm (on dry weight basis) (Seeger *et al.*, 1976; Laaksovirta & Alakuijala, 1978). Important lead contaminants were registered in some urban fungi samples from England (Thomas, 1992). Beside busy streets the concentrations were so high that the fungi could not be recommended for food use (Laaksovirta & Alakuijala, 1978).

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Table 1. Cadmium content of some higher mushrooms from Hungary

Species	Cadmium content	
	ppm (dry wt)	μg/g (wet wt)
Agaricus augustus	15·1	1·48
A. arvensis	17·3	1·65
A. abruptibulbus	45·0	4·50
A. purpurellus	86·3	8·51
A. silvestris	49·4	4·80
Russula foetens	16·5	1·55
R. vesca	12·4	1·20
Amanita muscaria	22·2	2·18

The quantity of vanadium, detectable in macrofungi, generally amounts to 0·1 to 0·3 ppm (Table 2). Only the fly agaric (*Amanita muscaria*) has been reported as possessing a high vanadium content. Strikingly high values were measured in the cap and stipe of this species by Koch *et al.* (1987), who isolated a water- and alcohol-soluble compound, amavadine, which explains the striking vanadium content.

The copper content in macrofungi is significantly higher than that of the green plants (the average of Hungarian fungi samples amounts to 44–48 ppm: Vetter, 1987). This toxic element is accumulated by the genera *Macrolepiota* and *Agaricus* (Table 3).

The average arsenic content was 1·6 ppm (Vetter, 1987) on the basis of 80 mushroom samples, but in certain taxonomic groups (e.g. the genus *Agaricus* and the family *Tricholomataceae*), a significant bioaccumulation was shown (*Agaricus augustus*: 11·9 ppm; *Macrolepiota rhacodes*: 26·6 ppm; Vetter, 1990). The extremely high arsenic concentrations of *Laccaria* species (mainly *L. amethystina* and *L. fraterna*) has been measured as 260 ppm (Stijve *et al.*, 1990). An extreme arsenic level (360–2130 ppm) was reported in *Sarcosphaera coronaria* (Ascomycetes), but nothing is known of the mode of action for accumulation.

Metal accumulating ability of mushroom can have two origins:

Table 2. Vanadium content of some Amanita species from Hungary

Species	Vanadium content	
	ppm (dry wt)	μg/g (wet wt)
Amanita phalloides (cap)	0·16	0·012
A. phalloides (stipe)	0·10	0·008
A. verna	0·19	0·017
A. vaginata	0·36	0·034
A. rubescens	0·55	0·034
A. muscaria	56·8	5·65

Table 3. Copper content of Agaricus and Macrolepiota species from Hungary

Species	Copper content	
	ppm (dry wt)	μg/g (wet wt)
Macrolepiota rhacodes	117	11·0
M. procera (cap)	226	22·1
M. procera (stipe)	121	12·1
Agaricus xanthoderma	147	14·5
A. arvensis	153	15·1
A. silvaticus	260	25·8

(a) bioaccumulation, supposing the presence of certain metal binding compounds (for cadmium, vanadium, etc.);
(b) a higher element content in consequence of higher metal content in the environment.

Bioaccumulating ability can be coupled with supernormal concentrations occurring in the environment. On the other hand, levels as measured in Hungarian macrofungi call attention to the accumulation ability of certain genera and species, which could cause human toxicological problems. The metal-accumulating ability is a characteristic and differentiating biological feature.

REFERENCES

Koch, E., Kneifel, H. & Bayer, E. (1987). Das Vorkommen von Amavadin in Pilzen der Gattung Amanita. *Z. Naturforsch.*, **42**, 873–8.

Laaksovirta, K. & Alakuijala, P. (1978). Lead, cadmium and zinc content on fungi in the parks of Helsinki. *Ann. Bot. Fenn.*, **15**, 253–7.

Laaksovirta, K. & Lodenius, M. (1979). Mercury content of fungi in Helsinki. *Ann. Bot. Fenn.*, **16**, 208–12.

Quinche, J. P. (1983). Les teneurs es selenium de 95 especes de champignon superieurs et de quelques terres. *Rech. Agron. en Suisse*, **22**, 137–44.

Schmitt, J. A. & Meisch, H. U. (1985). Cadmium in mushrooms, distribution growth effects and binding. *Trace Elements in Medicine*, **2**, 163–6.

Seeger, R., Meyer, E. & Schönut, S. (1976). Blei in Pilzen. *Z. Lebensm. Unters.-Forschung*, **162**, 7–10.

Stijve, T. (1977). Selenium content of mushrooms. *Z. Lebensm. Unters.-Forschung*, **164**, 201–3.

Stijve, T., Velliga, E. C. & Herrman, A. (1990). Arsenic accumulation in higher fungi. *Persoonia*, **14**, 161–9.

Thomas, K. (1992). Heavy metals in urban fungi. *The Mycologist*, **6**, 195–6.

Vetter, J. (1987). Mineral elements in higher fungi. *Mikológiai Közlemények*, **26**, 125–50.

Vetter, J. (1989). Prüfung des Mineralstoffgehaltes von höheren Pilzen. *Int. J. Mycol. Lichenol.*, **4**, 107–35.

Vetter, J. (1990). Mineral element content of edible and poisonous macrofungi. *Acta Aliment.*, **19**, 27–40.