Z Lebensm Unters Forsch (1995): 201: 311–316

Zeitschrift für
Lebensmittel-
Untersuchung
und -Forschung

Original paper

Levels of some trace elements in edible fungi

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Received: 27 December 1994

Abstract. A number of common edible fungi were analysed for their contents of Pb, Cd, Cr, Ni, Co, Zn, Cu, Mn and Se. The results indicate that the Cd level in the species *Rozites caperata* can be as high as several mg/kg fresh weight. In *Lycoperdon perlatum* and *Macrolepiota procera* the Pb level was found to be up to 2.5 mg/kg. The Ni level was at or below 0.1 mg/kg in all species, with the exception of *Albatrellus ovinus*, which had a mean concentration of 0.72 mg/kg. The level of Cr was highest in *M. procera* with a mean of 0.091 mg/kg. In a single sample of the species *Agaricus augustus*, the concentration of Co was found to be exceptionally high at 0.28 mg/kg. Zn and Cu levels were highest in *L. perlatum* and *M. procera.* Mn levels were fairly similar in the different species. The results of several surveys show that there can be large differences in the concentrations of the same metal (e.g. Pb) in the same species. The Se level was found to be very high in the species *Boletus edulis*, as has been shown by others. In the other species analysed the level of Se was low.

Introduction

In Sweden, as in many other countries, fungi collection is very popular, particularly during the autumn. For most people, the amount collected is quite insignificant as a food. Some people, however, collect fungi in such quantities that they can make a substantial contribution to food intake. It is therefore of interest to know the levels of both toxic and essential metals in some of the most commonly collected fungi.

The fact that fungi can accumulate metals has been shown primarily by the high Cd levels found in the *flavescentes* species of the *Agaricus* genus (e.g. [1–4]). Cd levels exceeding 10 mg/kg are quite common, and this has led to recommendations in Sweden to restrict consumption of these species. The high level of Se in *Boletus edulis* is also well known and seems to have no parallel in other species. An important factor is the absorption of these elements in the body after ingestion. It has been suggested that little or none of the Cd present in fungi is absorbed during passage through the intestinal tract [5]. However, other studies indicate that Cd uptake may be fairly high [6].

To what extent other metals accumulate in fungi, and in which species, are not very well documented. There are, however, several indications in the literature that a number of species can contain fairly high levels of different metals [4, 7, 8]. Tyler [9], has shown that many species can act as "bioaccumulators" or "bioexcluders" of metals.

This study contains the results of two surveys; one of metals in fungi collected between 1985 and 1993, and the other of Se in samples collected in 1983, mainly from the Boletaceae family.

The fungi nomenclature used is taken from the book "Svampar i naturen" [10].

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Materials and methods

Sampling. The selection of the species to be analysed for metals was based on two criteria. Firstly they should represent some of the most commonly known edible fungi. Secondly they should be easily recognised, with a minimum risk of confusion with fungi of a similar appearance. Several common groups of fungi, e.g. Russulaceae and Tricholomataceae, did not meet both criteria and, therefore, were not included. Samples of each species were collected from different sites in order to cover possible geographical variations. Most of the samples came from the county of Uppland, and some from the county of Dalarna. The samples of *A. bisporus* were purchased fresh in shops and were of Swedish (from different producers) and Dutch origin. The samples for Se determination were all collected in the county of Uppland. When the samples arrived at the laboratory they were freed from foreign matter. Damaged or soiled parts were trimmed off with a knife and smaller particles were removed with a fine brush. Large fungi, ≥ 15 g, were finely chopped and mixed so that the sample analysed would represent the whole fungus. Smaller fungi were analysed whole.

Analysis. All samples for metal determination were analysed in duplicate by a method collaboratively tested and approved by the Nordic Committee of Food Analysis (NMKL) [11]. The sample, of mass 5–15 g, was weighed and placed into a platinum crucible and

Table 1. Levels of elements in certified reference materials analysed together with the samples. Results in mg/kg dry wt. Means ± std. deviation, n = number of samples

Metal	Material	
	Cantharellus tubaeformis ($n = 6$)	Potato powder ($n = 2$)
Pb found	1.42 ± 0.27	<0.027
Certified	1.43 ± 0.10	0.026 ± 0.0028
Cd found	0.500 ± 0.073	0.038 ± 0.0007
Certified	0.437 ± 0.031	0.035 ± 0.0016
Ni found	0.371 ± 0.063	0.186 ± 0.020
Certified	0.381 ± 0.024	0.193 ± 0.043
Cr found	0.199 ± 0.039	0.137 ± 0.002
Certified	0.223 ± 0.068	0.098 ± 0.018
Co found	0.083 ± 0.019	0.052 ± 0.00
Certified	0.073 ± 0.013	—
Zn found	58.6 ± 7.9	8.9 ± 0.14
Certified	55.0 ± 2.0	9.0 ± 0.32
Cu found	38.0 ± 1.7	3.60 ± 0.02
Certified	34.4 ± 3.5	3.87 ± 0.18
Mn found	49.4 ± 1.4	8.7 ± 0.04
Certified	50.0 ± 5.1	8.1 ± 0.32

dry ashed at 450 °C, after which the ash was dissolved in 0.1 M HNO_3. The metals were determined by atomic absorption spectrophotometry (AAS). Pb, Cd, Ni, Cr and Co were analysed by graphite furnace AAS, using a Perkin Elmer 5100 PC/HGA-600 with Zeeman background correction and autosampler AS-60. Zn, Cu and Mn were determined by flame AAS, using a Varian SpectrAA 300 with deuterium background correction. The wavelengths used were: Pb 283.3 nm, Cd 228.8 nm, Ni 232.0 nm, Cr 357.9 nm, Co 240.7 nm, Zn 213.9 nm, Cu 324.7 nm and Mn 279.5 nm.

The water content of the fungi was determined by drying 5–10 g of sample to a constant weight at 102 °C.

The samples for Se determination were freeze-dried and pulverised. Approximately 0.5 g was dry ashed together with a mixture of magnesium nitrate/magnesium oxide and Se was determined by AAS at 196.0 nm after generation of its hydride. The method has been described in detail elsewhere [12].

Analytical quality assurance. A certified reference material (CRM) consisting of *Cantharellus tubaeformis* was developed for the survey and analysed together with the samples. The characterisation of the CRM is described elsewhere [13]. A potato CRM [14] was also analysed as an extra control for the lower concentrations. The CRMs in which Se was determined (bovine liver no. 1577 and wheat flour no. 1567 from the National Institute of Standards and Technology, Washington, USA) were analysed before and after the fungi. The results of the analysis of these CRMs are shown in Tables 1 and 2. Detection limits were calculated as 3 times the standard deviation of a large number of blanks that were taken through the entire analytical procedure.

Results

Water content

The water content of the individual samples ranged between 86% and 96%, with the lowest mean level in *Macrolepiota procera* (87%) and the highest mean levels in *C. cibarius* and *Suillus luteus* (both 93%). All results are expressed on a fresh weight basis.

Table 2. Levels of Se in certified reference materials analysed before and after the samples. Results in mg/kg dry wt. Means ± std. deviation, n = number of samples

Metal	Material	
	Bovine liver 1577 ($n = 6$)	Wheat flour 1567 ($n = 4$)
Se found	1.0 ± 0.1	0.87 ± 0.2
Certified	1.1 ± 0.1	1.1 ± 0.2

Fungal analysis

The results of the analysis of the CRMs (Tables 1 and 2) show good agreement with the certified levels. The mushroom CRM also comply, with a few exceptions, with the tolerance criteria as described in the guide for use [13].

Each sample consisted of fungi collected from a single location. For most of the species analysed, samples were collected from, on average, five different locations, but the number varied between three and six. The results of the analysis of the fungi are presented in Table 3. In some instances only one sample of a species was analysed, which makes it difficult to draw any firm conclusions from the results. However, they were considered to have an information value and therefore are included as Table 4.

Lead. The highest mean levels were found in *Lycoperdon perlatum.* Tyler [9] has indicated that several species of Lycoperdaceae have a capacity for bioaccumulation of Pb. As shown in Table 5, results from Denmark [4] also indicate high levels in this family. Atmospheric deposition can probably be excluded as the primary source of Pb, since the regions where *L. perlatum* is found for example, are usually outside urban areas. Seeger et al. [15] have also reported high Pb levels in Lycoperdaceae, as well as in many other species. However, it is possible that the latter authors have overestimated the levels, since they used the AAS flame technique and did not report that background correction was used. *Coprinus comatus*, which is frequently found on lawns in urban areas, could be expected to show high Pb levels due to deposition or uptake of Pb emitted from car exhaust. However, the level in that species was very low. The lowest mean level was found in the commercially cultivated *A. bisporus.*

The possible influence of road traffic on the Pb level was investigated in two samples of *A. arvensis* that grew 25 m and 250 m from a major road near Stockholm (≈50 000 vehicles/day). The samples were analysed both before and after rinsing with water. The Pb levels in the unrinsed samples were 0.44 mg/kg and 0.19 mg/kg at 25 m and 250 m, respectively. After rinsing, the levels were 0.36 mg/kg and 0.19 mg/kg, respectively. The fact that rinsing had little effect on the Pb level indicates that the Pb is derived mainly from the contaminated roadside soil, rather than atmospheric deposition. The exposure time for many fungi is very short, which makes deposition of

Table 3. Metal levels in edible mushrooms in mg/kg fresh weight. Number of samples in parentheses:

Species	Value	Element Pb	Cd	Ni	Cr	Co	Zn	Cu	Mn
Agaricus bisporus (4)	Mean	0.011	0.011	0.020	0.014	<0.002	5.5	3.8	0.60
	SD	0.008	0.006	0.010	0.017	0.001	1.4	2.4	0.12
	Min–max	<0.006–0.019	0.003–0.018	0.014–0.032	<0.001–0.039	<0.002–0.002	4.6–7.6	1.7–7.2	0.50–0.77
Albatrellus ovinus (6)	Mean	0.025	0.074	0.72	0.013	0.040	4.2	0.60	1.1
	SD	0.012	0.055	0.45	0.011	0.035	2.2	0.34	0.67
	Min–max	0.010–0.044	0.014–0.15	0.35–1.3	0.003–0.032	0.008–0.10	2.4–8.4	0.30–1.1	0.47—2.4
Boletus edulis (5)	Mean	0.027	0.21	0.12	0.016	0.007	7.4	1.8	0.76
	SD	0.033	0.12	0.021	0.008	0.009	1.6	0.44	0.38
	Min–max	0.005–0.086	0.11–0.41	0.090–0.15	0.010–0.030	<0.001–0.023	5.7–9.5	1.4–2.3	0.38–1.3
Cantharellus cibarius (6)	Mean	0.084	0.063	0.14	0.023	0.045	8.0	4.6	4.3
	SD	0.12	0.058	0.13	0.016	0.024	3.3	1.7	4.5
	Min-max	0.014–0.33	0.028–0.18	0.056–0.40	0.007–0.050	0.026–0.090	4.4–14	3.1–7.8	0.83–13
C. tubaeformis (5)	Mean	0.090	0.15	0.044	0.014	0.006	5.1	3.2	2.4
	SD	0.032	0.12	0.016	0.005	0.003	0.91	0.29	0.86
	Min–max	0.057–0.14	0.054–0.31	0.026–0.064	0.007–0.020	0.002–0.010	4.2–6.5	2.8–3.5	1.4–3.5
Coprinus comatus (6)	Mean	0.042	0.21	0.014	0.035	0.003	5.8	5.3	0.57
	SD	0.014	0.084	0.012	0.048	0.002	1.8	1.6	0.11
	Min–max	0.020–0.057	0.10–0.31	<0.006–0.030	0.009–0.12	<0.001–0.006	4.5–9.0	4.2–8.0	0.49–0.77
Craterellus cornucopioides (4)	Mean	0.38	0.22	0.061	0.014	0.025	13	4.5	2.2
	SD	0.34	0.18	0.017	0.010	0.041	1.9	1.1	0.83
	Min–max	0.11–0.88	0.050–0.43	0.038–0.075	0.005–0.028	<0.002–0.086	10–14	3.1–5.8	1.4–3.1
Hydnum repandum (5)	Mean	0.050	0.044	0.053	0.021	0.004	5.7	2.9	2.6
	SD	0.016	0.034	0.060	0.013	0.003	0.93	0.69	2.7
	Min–max	0.030–0.066	0.008–0.086	0.022–0.16	0.008–0.040	0.001–0.008	4.1–6.3	2.1–4.0	0.88–7.4
Lactarius deterrimus (5)	Mean	0.033	0.073	0.062	0.024	0.013	12	1.2	1.0
	SD	0.018	0.066	0.022	0.029	0.013	3.5	0.62	0.43
	Min–max	0.018–0.060	0.018–0.18	0.028–0.080	0.002–0.072	0.002–0.034	9.4–18	0.74–2.1	0.33–1.5
Lycoperdon perlatum (5)	Mean	1.5	0.13	0.056	0.009	0.016	23	19	4.7
	SD	0.94	0.073	0.036	0.007	0.013	7.0	5.1	0.72
	Min–max	0.73–2.5	0.050–0.24	0.015–0.11	0.004–0.020	0.004–0.037	14–32	11–25	3.5–5.4
Macrolepiota procera (3)	Mean	0.74	0.19	0.026	0.091	0.008	14	20	1.6
	SD	0.41	0.053	0.003	0.13	0.005	4.9	11	0.40
	Min–max	0.29–1.1	0.15–0.25	0.024–0.030	0.012–0.24	0.002–0.011	9.3–19	8.9–31	1.2–2.0
Rozites caperata (5)	Mean	0.031	1.3	0.030	0.019	0.009	5.5	3.8	1.4
	SD	0.026	1.1	0.018	0.018	0.004	2.2	2.0	0.77
	Min–max	0.007–0.076	0.27–2.6	0.013–0.054	0.008–0.050	0.004–0.014	2.2–7.8	1.2–5.3	0.67–2.6
Suillus luteus (5)	Mean	0.024	0.013	0.026	0.008	0.014	5.7	0.79	0.83
	SD	0.019	0.012	0.018	0.006	0.011	4.5	0.74	0.52
	Min–max	0.007–0.055	0.004–0.034	<0.009–0.052	0.002–0.017	0.002–0.030	1.8–13	0.16–2.0	0.36–1.6

Table 4. Metal content of single samples of certain fungi. Levels in mg/kg fresh weight

Species	Element Pb	Cd	Ni	Cr	Co	Zn	Cu	Mn
Agaricus arvensis[a]	0.15	0.044	0.038	0.015	0.007	19	9.5	0.97
A. augustus	0.38	14	0.060	0.005	0.28	15	24	1.5
Boletus badius	0.14	0.29	0.091	0.006	<0.002	7.5	0.79	0.68
Lentinus edodes	0.009	0.17	0.025	0.014	0.011	9.1	2.9	1.9
Pleurotus ostreatus	0.007	0.076	0.016	0.002	<0.002	7.2	0.72	0.56
Russula decolorans	0.099	0.043	0.017	0.008	<0.002	11	6.9	2.2
Sparassis crispa	0.012	0.13	0.012	0.006	<0.002	3.2	0.31	0.37

[a] Mean of two samples from the same area

Pb from vehicle exhaust a small problem that is continuing to decrease as the use of leaded petrol is phased out in Sweden.

Cadmium. The lowest mean levels were found in *A. bisporus* and *S. luteus*. By far the highest mean level was found in *Rozites caperata*, 1.3 mg/kg. A similar level was found in this species by Seeger [1]. Studies by Tyler [9] indicate that this species can bioaccumulate Cd. Several other species, e.g. *C. comatus* and *B. edulis*, had fairly high levels of Cd, which is consistent with the findings of other studies, as seen in Table 5. It is conceivable that the high

Table 5. Comparison of metal levels between different studies. Mean levels in mg/kg fresh weight

	Metal							
Species and reference	Pb	Cd	Ni	Cr	Co	Zn	Cu	Mn
Cantharellus Cibarius								
Present study	0.084	0.063	0.14			8.0	4.6	4.3
[1] (Germany)		0.06						
[3] (Finland)	0.12	0.075						
[7] (Yugoslavia)		0.062				6.50	3.55	2.57
[8] (Hungary)		0.028	0.072			5.98	3.68	2.03
[21] (Germany)		0.23						
Craterellus cornucopioides								
Present study	0.38	0.22	0.061			13	4.5	
[1] (Germany)		0.02						
[4] (Denmark)	1.04	0.042	0.50			21	8.0	
[21] (Germany)		0.03						
Lycoperdon perlatum								
Present study	1.5	0.13	0.057			23	18	4.7
[1] (Germany)		0.25						
[4] (Denmark)[a]	1.5	0.28	0.056			25	10	
[7] (Yugoslavia)		0.46				22.7	9.47	2.07
Boletus edulis								
Present study	0.027	0.21	0.12			7.4	1.8	0.76
[1] (Germany)		0.30						
[3] (Finland)	0.09	0.21						
[4] (Denmark)[a]	0.11	0.62	0.26			15.0	5.1	
[7] (Yugoslavia)		0.23				6.71	1.65	4.35
[8] (Hungary)		0.31	0.39			11.9	1.72	1.39
[21] (Germany)		0.25						
Coprinus comatus								
Present study	0.042	0.21	0.014			5.8	5.3	0.57
[1] (Germany)		0.06						
[3] (Finland)	0.26	0.35						
[4] (Denmark)	0.09	0.10	0.052			3.9	5.4	
[7] (Yugoslavia)		1.40				7.52	7.62	2.17
[23] (Croatia)	0.12	0.17						
Macrolepiota procera								
Present study	0.74	0.19	0.026	0.091		14	20	1.6
[1] (Germany)		0.21						
[3] (Finland)	0.07	0.12						
[7] (Yugoslavia)		0.80				19	12	1.08
[8] (Hungary)		0.12	0.12	0.017		8.2	16	2.1
Agaricus augustus								
Present study	0.38	14	0.060		0.28	15	24	1.5
[1] (Germany)		4.8						
[4] (Denmark)	0.75	2.0	1.08			18	31	
[8] (Hungary)		1.5	0.43		0.36	7.1	6.1	0.91
Pleurotus ostreatus								
Present study	0.007	0.076	0.016	0.002	<0.002	7.2	0.72	0.56
[4] (Denmark)	0.13	0.26	0.16			5.6	1.8	
[8] (Hungary)		0.16	0.17	0.06	0.002	8.2	0.79	1.5
[24] (Czechoslovakia)	0.002	0.079		0.066		6.8	1.5	0.74

[a] Average of several species within the family
The results have in most cases been recalculated from dry matter. The water content was in the calculations set to 90% if the actual water content was not reported

Cd level in *C. comatus*, which is frequently found on lawns, originate from the phosphate fertilizer often used there.

Nickel. The highest level by far was found in *Albatrellus ovinus*, with a mean of 0.72 mg/kg. The next highest level was found in *B. edulis*, with a mean of 0.12 mg/kg. The lowest level, 0.014 mg/kg, was found in *C. comatus*. Thus the lowest and highest levels differ by a factor of about 50. As can be seen in Table 5, the Ni levels reported in different studies vary widely.

Table 6. Se concentrations of certain fungi in mg/kg fresh weight

Species	Parameter		
	Mean	Range	*n*
Boletus edulis	1.0	0.56–1.5	7
B. piperatus	0.17	—	1
B. subtomentosus	0.004	—	1
Suillus granulatus	0.10	0.085–0.12	2
S. grevillei	0.037	0.028–0.046	2
S. luteus	0.071	0.058–0.092	3
S. variegatus	0.036	—	1
Leccinium aurantiacum	0.044	0.034–0.054	2
L. scabrum	0.032	—	1
Macrolepiota procera	0.13	0.054–0.21	2
Agaricus arvensis	0.033	0.004–0.062	2
A campestris	0.066	—	1

Chromium. The levels were very consistent at around 0.01–0.04 mg/kg, with the exception of *M. procera*, which had a mean level of 0.091 mg/kg. Only three samples of this species were found during the survey. In two of these the Cr level was 0.01–0.02 mg/kg and in the third it was 0.24 mg/kg, which indicates that there can be a great difference between samples.

Cobalt. The levels were generally very low. In *A. bisporus*, the mean Co level was < 0.002 mg/kg. Relatively high levels were found in *A. ovinus* and *C. cibarius* – 0.040 mg/kg, and 0.045 mg/kg, respectively. A very high level was found in the analysis of a single sample of *A. augustus* (*Table* 4). Vetter [8] had also reported a high level (0.36 mg/kg) in *A. augustus.*

Zinc. The lowest mean level was found in *A. ovinus* and the highest in *L. perlatum.* The difference between the various species was fairly low, only a factor of about 5. The variation within species was also low. The results agree reasonably well with those from other studies, as shown in Table 5.

Copper. The mean levels in the different species varied from 0.60 mg/kg in *A. ovinus* to 20 mg/kg in *M. procera.* The mean level for most species was in the range of between 1 and 5 mg/kg. The results from other studies shown in Table 5 show a reasonably good agreement.

Manganese. The highest mean levels were found in *C. cibarius* (4.3 mg/kg) and *L. perlatum* (4.7 mg/kg) and the lowest in *C. comatus* (0.57 mg/kg) and *A. bisporus* (0.60 mg/kg). Mn was the only element that showed any correlation with the place of origin. The average level in seven species from one site in the county of Dalarna was markedly, but not significantly (at $P = 0.05$), higher than in the same species from one site in the county of Uppland. This could possibly be due to geological differences, but this has not been confirmed. As shown in Table 5, there was good agreement between the results of different surveys, with the exception of *B. edulis.*

Selenium. By far the highest level was found in *B. edulis* (Table 6), which is known to accumulate Se (e.g. 4, 7, 8, 16, 17). Of eight other Boletaceae investigated in this survey, none had Se levels of the same order of magnitude. Due to this high Se level, *B. edulis* was regarded to be a good source of Se in the diet. However, it was shown in 1986 in a study by Mutanen [18] that the bioavailability of Se from *B. edulis* is fairly low.

Discussion

In several species of fungi, the levels of the toxic metals Pb and Cd were rather high. For Pb the mean level in all species in Table 3 was 0.23 mg/kg. If the two species with the highest levels, *L. perlatum* and *M. procera*, are omitted the mean level of Pb decreases to 0.072 mg/kg. In Sweden the average daily intake of Pb by women is estimated to be about 0.026 mg [19]. Thus, an intake of 250 g of fresh fungi with a mean level of 0.23 mg/kg would more than triple the daily intake to 0.083 mg, or if the two species with the highest levels are eliminated, the daily intake would equate to 0.044 mg, when calculated as above.

Consumption of fungi once a week or less has little effect on the weekly Pb intake. The provisional tolerable weekly intake (PTWI) of Pb proposed by the Joint FAO/WHO Expert Committee on Food Additives [20] is 0.025 mg/kg body weight, which is equivalent to 1.5 mg for a person weighing 60 kg. The weekly intake would increase from 0.182 mg to 0.240 mg if one fungi meal as described above was included; excluding the two species with the highest concentrations would increase the intake to 0.200 mg.

The mean level of Cd for all the species in Table 3 was 0.21 mg/kg, which would give an intake of 0.055 mg from 250 g. This is similar to the Cd intake estimated by Dötsch et al. [21] from 250 g of fresh fungi – about 0.035 mg. A meal of 250 g excluding *R. caperata*, would contain 0.032 mg. The average daily intake of Cd by women in Sweden is estimated to be about 0.008 mg [19]. A meal of 250 g of the fungi in Table 3 thus would increase the total daily intake to 0.064 mg, or excluding the species *R. caperata* to 0.041 mg. The PTWI for Cd [22], i.e. 0.007 mg/kg bw(= 0.420 mg/week for a person weighing 60 kg) is, however, only slightly increased by a single meal of fungi per week. The weekly intake would increase from 0.056 mg to 0.120 mg if one fungi meal as described above was included; excluding the two species with the highest concentrations would increase the intake to 0.097 mg.

As shown above, consumption of 250 g of several species of fungi can markedly increase the daily intake of the Pb and Cd. However, for most species, consumption of 250 g will have little effect on the intake over the period of a week. For people who frequently consume large quantities of wild fungi it would seem prudent to restrict consumption of *L. perlatum*, *M. procera* and *R. caperata* in order to keep the intakes of Pb and Cd low.

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