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^{137}Cs content in mushrooms from localities in eastern Slovakia

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Abstract The amount of radiocaesium in chosen species of mushrooms from localities in eastern Slovakia was studied. From the obtained results it was found that *Macrolepiota procera* and *Armillariella mellea* are defined by low ability to accumulate caesium. Higher values of ^{137}Cs were measured in *Russula aeruginea* and *Xerocomus subtomentosus* and achieved 869.6 and 322.9 Bg kg^{-1} dry weight, respectively. Soaking and washing can be used to decrease radioactivity in mushrooms. Using water and solution of table salt in studied species of mushrooms decreased the amount of radiocaesium by 33–88%.

Key words radiocaesium • mushrooms • soil contamination • sequential extraction

Introduction

Monitoring of environmental radioactivity is necessary because of development of nuclear energy and exploitation of radioactive materials in various parts of popular activity. Its aim is to determine the influence of radioactivity on health of today's and future population. Our laboratory is one of the permanent component of radioactivity monitoring network, that carries out regular measurements of soils, hydrosphere, individual parts of food chains as well as aerosols, fallout etc.

The amount of artificial radionuclides in the individual compartments of food chains is at present at a very low level, generally at the limit of detection. Values of radiocaesium in individual samples of fruits, vegetables and cereals are within 0.06–0.1 Bq kg^{-1}.

Mushrooms are characterised by high ability to accumulate radiocaesium [1, 3, 7]. The reason why mushrooms work as such good indicators of radioactivity in general is connected with their structure. Their bodies consist of gentle fibres, hyphae. Fungal metabolism differs from that of green plants. Mushrooms are heterotrophic organisms and depend on supply of organic compounds. Water constitutes about 90–95% of mushroom fresh weight.

Consumption of wild mushrooms as a delicacy has been high in many countries, mainly in central and eastern Europe and collecting mushrooms has become a national hobby in many countries. A possible risk of radioactivity for human health is expressed by the effective dose [3, 4].

The activity of ^{137}Cs concentrations depends on several factors, e.g. mushroom species, contamination of soil, moisture, etc.

The aim of this study was to determine the amount of radiocaesium in the selected mushroom species from localities in the East of Slovakia. The process of soaking of

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Table 1. Individual extraction agents and corresponding caesium fractions isolated from soil components.

Step	Reagent composition	Action time (h)	Isolated fraction
1	redistilled water (pH = 5.5)	1	water-soluble
2	1 M $MgCl_2$ (pH = 7)	1	exchangeable
3	0.025 M $Na_4P_2O_7$	1	bound to humic acids
4	1 M NaOAc + HOAc (pH = 5)	24	bound to carbonates
5	0.04 M $NH_2OH{\cdot}HCl$	24	bound to Fe/Mn
6	30% H_2O_2 + HNO_3 (pH = 2)	24	organically bound and bound to sulfates
7	2 M HNO_3	24	residue, soluble in mineral acid
8	1 M NaOH	24	residue, soluble in hydroxide
9			insoluble rest

HOAc=CH_3COH

mushrooms in water and table salt solution in order to decrease their radioactivity was studied.

Materials and methods

Fruit bodies of the selected mushroom species (*Armillarella mellea, Leccinum scabrum, Amanita rubescens, Amanita muscaria, Macrolepiota procera, Russula aeruginea, Lactarius piperatus, Xerocomus subtomentosus, Lepista saeva, Cortinarius brunneus, Sarcodon imbricatum*) were sampled in the localities from eastern part of Slovakia between 2001 and 2003. The samples were dried at 105°C until total dehydration, homogenised and put into Marinelli pots. The specific activity of ^{137}Cs in the studied samples was measured gamma-spectrometrically by using a multichannel analyser (Canberra Series 35 Plus) with Ge(Li) detector. The data acquisition and analysis were performed using Gamat software.

In 2001 several species of mushrooms were collected (*Macrolepiota procera, Lepista saeva, Lactarius delicious, Lycoperdon perlatum* and *Agaricus campestris*) in the town of Jasov. Soil samples from the same ecosystems were collected as well. The amount of radiocaesium in samples was determined by the use of gamma spectrometry. For determination of individual fractions of radiocaesium in soils the modified Tessier sequential extraction method [6] was used, where two steps were added to the original method [8]: extraction with redistilled water (step 1), and extraction with 2 M HNO_3 (step 8). Individual extraction agents and corresponding caesium fractions isolated from soil components are shown in Table 1. This experiment involved 10 g of dry soil and 40 ml of extraction agent placed into a 100-ml bottle and shaken using end-over end shaker.

In the washing phase of the experiments two steps were used. At first, mushrooms were soaked in water and then in 0.2 M NaCl. The treatment duration was 30 minutes.

Results and discussion

Mushrooms radioactivity in the studied localities

Data on radiocaesium levels are given in Table 2. Low values of ^{137}Cs were detected in *Macrolepiota procera*. Concentrations of ^{137}Cs in this species are between 0.39–57.98 Bq kg^{-1} d.w. A little higher values were observed in *Armillariella mellea*. The obtained results are in a good agreement with literature [3]. These species are characterised by a low ability to accumulate radiocaesium. In the samples of *Russula aeruginea* and *Xerocomus subtomentosus* a high ^{137}Cs activity was detected and its values achieved 869.6 and 322.9 Bq kg^{-1} d.w., respectively. These species belong to the group with high ability to absorb radioactivity. The highest values, 2.34, 4.17 and 6.24 kBq kg^{-1} d.w. were obtained in the samples of *Lepista saeva*, *Cortinarius brunneus* and *Sarcodon imbricatum*, respectively. These species were from the town of Stará L'ubovňa, sampled in 2002. From the obtained values we can see that there is a great deviation between individual samples from various localities and collected in different years.

The activity of ^{137}Cs concentrations are affected by soil contamination, soil horizon from which the species take up nutrients, as well as the moisture.

The knowledge of the total content of radionuclides in soils provides a limited information only concerning their transfer to plants. Therefore, the measurement of availability and mobility is required, if reliable evaluations of the pollution hazards are to be made. Sequential extraction procedures have been commonly used to determine the forms of radionuclides in soils [2, 6].

Radiocaesium levels in the species from the town of Jasov are presented in Table 3. Individual forms of ^{137}Cs determined by using Tessier sequential extraction procedure are presented in Fig. 1. Easily available share of caesium, as a sum of the fractions isolated in steps 1–4 (water-soluble, exchangeable, bound to humic acids, bound to carbonates fractions) was only 4.4% in studied soil. It was found that prevailing part of radiocaesium appears in the form which is not available (89.61%), nevertheless radiocaesium is highly available for mushrooms. This effect can be pronounced for organic horizons of forest soil [5].

Decrease in of mushroom radioactivity by soaking in water and salt solution

In washing and soaking experiments water and 0.2 M solution of NaCl were used. The collected results are presented in Figs. 2 and 3. The amount of radiocaesium

Table 2. The amount of ^{137}Cs and ^{40}K in the selected mushrooms from eastern Slovakia.

Family	Species	Locality	Bq kg^{-1} dry weight		Year of sampling
			^{137}Cs	^{40}K	
Tricholometaceae	*Armillariella mellea*	Dargov	6.33	1755.96	2003
	Armillariella mellea	Dargov	14.14	1561.46	2003
	Armillariella mellea	Humenné	25.13	1725.46	2002
	Armillariella mellea	Košice	68.76	2443.95	2002
	Armillariella mellea	Michalovce	3.26	1807.90	2003
	Armillariella mellea	Trebišov	102.28	3234.97	2001
	Lepista personata	Stará L'ubovňa	2343.31	2727.84	2002
Amanitaceae	*Amanita muscaria*	Dargov	18.41	2006.88	2003
	Amanita muscaria	Záhura	90.25	1539.73	2003
	Amanita pantherina	Stará L'ubovňa	91.39	2988.33	2002
	Amanita rubenscens	Dargov	9.58	2063.51	2003
	Amanita rubenscens	Stará L'ubovňa	73.03	1285.54	2002
Agaricaceae	*Lepiota cristata*	Dargov	89.08	2715.91	2003
	Lepiota cristata	Michalovce	1406.06	10,281.60	2002
	Macrolepiota procera	Humenné	10.49	1911.91	2001
	Macrolepiota procera	Humenné	11.71	1159.20	2002
	Macrolepiota procera	Michalovce	13.14	1100.32	2002
	Macrolepiota procera	Plešivec	0.39	1230.39	2001
	Macrolepiota procera	Slanec	11.16	1935.76	2003
	Macrolepiota procera	Ťahanovce	57.98	4047.56	2003
	Macrolepiota procera	Trebišov	49.39	1468.97	2001
	Macrolepiota procera	Trebišov	4.90	2379.68	2002
	Macrolepiota procera-caps	Dreveník	0.99	633.28	2003
	Macrolepiota procera-caps	Jasov	3.02	1947.31	2001
	Macrolepiota procera-stipes	Dreveník	4.21	1473.67	2003
	Macrolepiota procera-stipes	Jasov	4.86	1279.56	2001
Boletaceae	*Leccinum aurantiacum*	Humenné	6.41	969.19	2003
	Leccinum aurantiacum	Jasov	25.80	629.17	2001
	Leccinum griseum	Svidník	5.97	1379.55	2003
	Leccinum scabrum	Humenné	4.13	1872.81	2001
	Leccinum scabrum	Humenné	0.88	743.40	2002
	Leccinum scabrum	Humenné	8.30	1066.07	2003
	Leccinum scabrum	Kojšova hoľa	40.20	1172.33	2003
	Leccinum scabrum	Michalovce	177.26	3101.55	2002
	Leccinum scabrum	Plešivec	13.98	1273.12	2001
	Leccinum scabrum	Svidník	5.38	1364.79	2003
Xerocomaceae	*Xerocomus subtomentosus*	Humenné	322.93	1730.42	2001
	Xerocomus subtomentosus	Humenné	16.19	837.74	2002
	Xerocomus subtomentosus	Michalovce	28.25	593.60	2002
	Xerocomus subtomentosus	Plešivec	12.99	771.07	2001
	Xerocomus subtomentosus	Stará L'ubovňa	80.92	1347.55	2002
Russulaeae	*Lactarius delicious*	Michalovce	14.71	1337.65	2002
	Lactarius delicious	Stará L'ubovňa	22.24	623.86	2002
	Lactarius delicious	Stará L'ubovňa	29.61	674.74	2002
	Lactarius piperatus	Dargov	439.15	1588.56	2001
	Lactarius piperatus	Jasov	4.46	1483.49	2001
	Lactarius piperatus	Zlatá Idka	65.49	282.03	2001
	Lactarius rufus	Dargov	21.12	1537.84	2003
	Russula aeruginea	Humenné	13.20	1323.93	2003
	Russula aeruginea	Michalovce	140.48	1160.80	2002
	Russula aeruginea	Slanec	6.80	1224.99	2003
	Russula aeruginea	Stará L'ubovňa	869.63	10,801.60	2002
	Russula aeruginea	Záhura	34.91	1241.53	2003
	Russula foetens	Michalovce	77.43	1254.91	2002
Cortinariaceae	*Cortinarius brunneus*	Stará L'ubovňa	4166.66	1953.72	2002
Hydnaceae	*Sarcodon imbricatum*	Stará L'ubovňa	6236.86	11,234.10	2002

Table 3. Comparison of radiocaesium levels in the species from the town of Jasov.

Species	^{137}Cs	
	Bq kg^{-1} DM	Bq kg^{-1} FM
Macrolepiota procera-caps	3.02	0.23
Macrolepiota procera-stipes	4.86	0.37
Lepista personata	19.56	1.31
Lycoperdon perlatum	14.79	1.91
Lactarius piperatus	4.46	0.50
Clitocybe geotropa	9.03	0.92
Agaricus silvaticus	6.93	0.52

rinsed with water was within 17.46–63.81% with maximal value for *Lepiota clypeolaria*. The minimal value was in the sample of *Hypholoma fasciculare*. Using table salt solution ^{137}Cs concentration in *Lycoperdon perlatum* decreased by

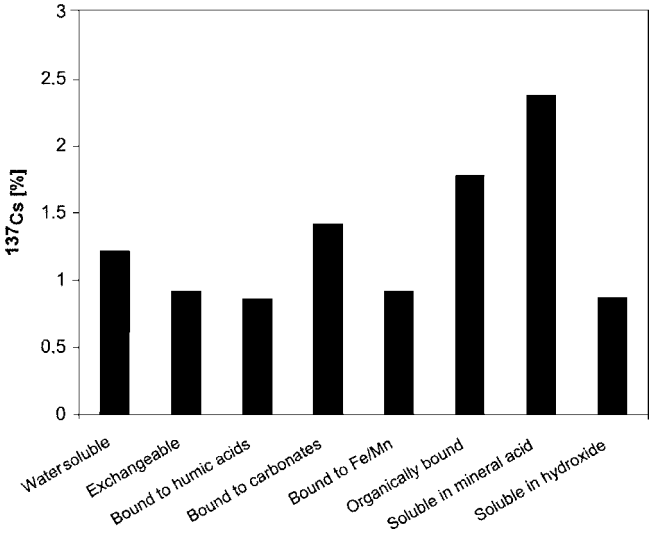

Fig. 1. The ^{137}Cs individual fractions shares in the soil sample from the town of Jasov.

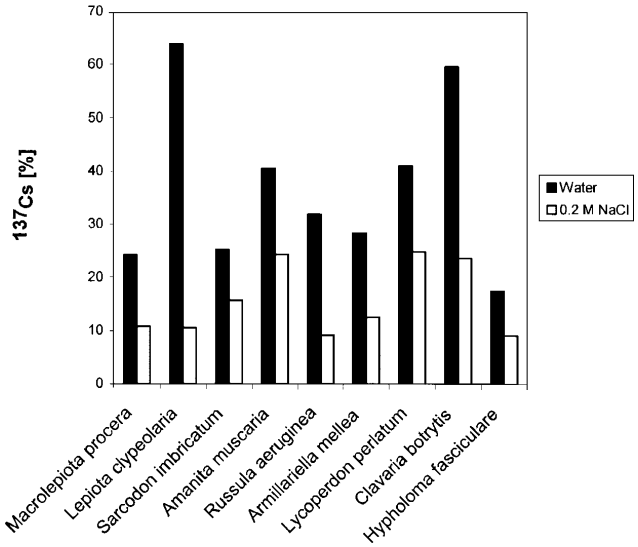

Fig. 2. The ^{137}Cs content in water and table salt solutions used for radioactivity decrease in chosen mushrooms.

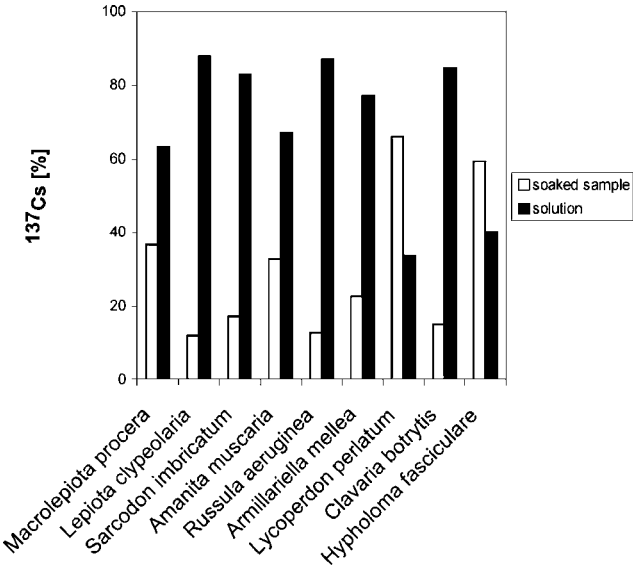

Fig. 3. The ^{137}Cs content in soaked mushrooms and solutions used for radioactivity decrease in chosen mushrooms.

24.95%. It was found that washing and soaking of mushrooms resulted in decreasing of radiocaesium content in mushroom samples. This procedure was very effective in the case of *Lepiota clypeolaria* and *Russula aeruginea*. Radiocaesium decreased by 88% and 87%, respectively.

Conclusions

Mushrooms are characterised by high ability to accumulate radiocaesium. Low values of ^{137}Cs were determined in *Macrolepiota procera* and in *Armillariella mellea*. The highest value 6.24 kBq kg^{-1} d.w. was obtained in the sample of *Sarcodon imbricatum*, from the town of Stará L'ubovňa. On the basis of the obtained results, we can say that washing and soaking of mushrooms result in decrease of radiocaesium in mushroom samples.

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