NUKLEONIKA 2003;48(3):155–157

LETTER TO THE EDITOR

Discrimination between ^{137}Cs and ^{40}K in the fruiting body of wild edible mushrooms

Grażyna Bystrzejewska-Piotrowska, Paweł Ł. Urban, Romuald Stęborowski

Abstract Samples of five species of wild edible mushrooms, growing in the vicinity of Warsaw, were analyzed in order to determine discrimination factors (DF) for ^{137}Cs and ^{40}K in their caps and stipes. The obtained DF values range from 0.80 to 2.87, and seem to be characteristic of each species. A brief discussion of the observed phenomenon is presented.

Key words ^{137}Cs/^{40}K discrimination factor • fruiting body • mushrooms

Introduction

The artificial ^{137}Cs and natural ^{40}K radionuclides are known to be accumulated by mushrooms to an enormous extent [6, 7, 9]. This can be concluded as a result of high cesium fate in the analyzed real samples. Also potassium levels in many fungal species are considerably higher than those in food of plant origin [5]. The ability of mushrooms to accumulate ^{137}Cs from the fallout was first reported by Grüter [3], but after the Chernobyl NPP accident (in 1986) this subject was taken up by other researchers [6, 7]. ^{137}Cs levels in mushrooms are significantly higher than those observed in common agricultural plants.

In contrast to plants [10], there are poor data on the distribution of cesium and potassium within the individual parts of mushrooms [4, 12]. It is only known that ^{137}Cs concentrations are usually higher in the fruiting bodies when compared with mycelium [13] and that cesium shows better accumulation in the cap than in the stipe [12].

For better understanding of the ^{137}Cs and ^{40}K translocation processes in the fruiting body of wild edible mushrooms, the ratios of both radionuclides in the cap and stipe have to be determined. The Cs/K discrimination factor (see below) seems to be an effective tool for examining the specificity of cesium concentration in higher fungi.

Materials and methods

The fruiting bodies of four mushroom species (*Cantharellus cibarius* Fr., *Tricholoma equestre* (L.) Kummer, *Tricholoma terreum* (Schff.: Fr.) Kummer, *Xerocomus badius* (Fr.) Kühn. Ex. Gilb.) were sampled in the vicinity of Warsaw (λ = 20–22° E, φ = 51.5–52.5° N) in October 2001. The other one, *Morchella esculenta* (L.) Pers., was sampled in April 2002. The analyzed samples were prepared from a mixture of 70 mushrooms. They were all divided in two

G. Bystrzejewska-Piotrowska✉, P. Ł. Urban, R. Stęborowski
Isotope Laboratory,
Faculty of Biology,
Warsaw University,
1 Miecznikowa Str., 02-096 Warsaw, Poland,
Tel.: +48 22/ 554 23 00, Fax: +48 22/ 554 11 06,
e-mail: byst@biol.uw.edu.pl

Received: 20 May 2003, Accepted: 24 July 2003

parts: caps and stipes, dried at 105°C for 24 h until total dehydration (an air flow dryer; Memmert GmbH+Co. KG, Äußere Rittersbacher Str. 38, D-91126 Schwabach), homogenized in a mill (M 20 Universal Mill; IKA-Werke GmbH & Co. KG, Janke & Kunkel-Str. 10, D-79219 Staufen) and portioned (ca. 10 g) into polypropylene cups (120 ml, cat. BI-M; DHN Sp. z o.o., 83 Filtrowa Str., 02-032 Warsaw). The levels of radionuclides (^{137}Cs and ^{40}K) were determined by means of an NaI gamma-spectrometer (detector mod. 802; Canberra Packard Central Europe GmbH, Wienersiedlung 6, A-2432 Schwadorf). Data collection and analysis were performed by using the Genie 2000 Gamma Acquisition and Analysis software (V 1.3, May 15, 1999; Canberra Industries). The duration of each measurement was set for 86,400 s. The samples of *M. esculenta* were measured with an HPGe spectrometer (Heavy Ion Laboratory, Warsaw University; configuration on request).

The ^{137}Cs/^{40}K discrimination factor (DF), characterizing each species, was defined as follows:

$$\mathrm{DF} = \frac{\dfrac{A(^{137}\mathrm{Cs})_{\mathrm{cap}}}{A(^{40}\mathrm{K})_{\mathrm{cap}}}}{\dfrac{A(^{137}\mathrm{Cs})_{\mathrm{stipe}}}{A(^{40}\mathrm{K})_{\mathrm{stipe}}}} . \tag{1}$$

In fact, this is a modification of general formula presented by Zhu and Smolders [15], which referred to plant/substrate DF. The letter A symbolizes (respective) cesium and potassium activities in the samples of caps and stipes.

Results and discussion

The ^{137}Cs/^{40}K discrimination factors in the examined species varied from 0.80 up to 2.87 (Table 1) and can be represented as follows:

C. cibarius < *X. badius* < *M. esculenta* < *T. terreum* < *T. equestre*

The values of DF exceeding one unit, observed in three species, indicate that ^{137}Cs in mushrooms is more efficiently translocated from stipe to caps than potassium (measured as ^{40}K). These results point to a different ability of cesium accumulation, even though its concentrations in soil are many orders of magnitude lower than for potassium. This suggests that the behavior of ^{137}Cs in mushrooms is different from that of ^{40}K. Moreover, it is different from that in plants.

Table 1. Discrimination factor for cesium-137 and potassium-40 in the fruiting body of wild edible mushrooms (total uncertainty in brackets).

Sample	DF
Tricholoma equestre	2.87 (± 0.53)
Tricholoma terreum	2.81 (± 0.33)
Morchella esculenta	1.66 (± 0.15)
Xerocomus badius	1.24 (± 0.18)
Cantharellus cibarius	0.80 (± 0.09)

The obtained values differ markedly from those acquired for plants, e.g. potassium in rice plants was much better transported than cesium and its translocation rates were different [10]. In previous studies [2], it was shown that an enormous disproportioning of Cs and K may occur within layers of one organ, i.e. onion storage leaves, where the ^{137}Cs/^{40}K ratio ranged from 0.75 to 2.54. Since the DF values are relative, the observed differences cannot be explained by irregularities in the total Cs and K concentration in soil.

The observed phenomenon could be explained by referring to data on the habitats preferred by various species. For example, *T. terreum* occurs mainly in coniferous forests with a soil of lower pH, while *T. equestre* also grows in deciduous forests with clay-like soils characterized by different decomposition of organic matter and more rich with complexing particles. Although *X. badius* also prefers sandy habitats in the Scots pine forests, Cs translocation in this species is not so high (Table 1). Therefore, the specific translocation of cesium may be characteristic rather of common genus than for habitat. Cesium level in *M. esculenta* was still higher than in *X. badius* and DF was 1.66. This species belongs to *Ascomycota* group and may have different physiological constitution.

DF is not related to the rate or season time period of *Fungi* development. This is supported by the data obtained for *M. esculenta,* which, in contrast with other, rather autumnal *Fungi*, develops in spring and immediately produces fruiting bodies. Minimal differences in DF for *T. equestre* and *T. terreum*, which grow in different habitats (deciduous and coniferous forests, respectively) indicate a dependence on genus rather than habitat. As far as cesium availability is concerned, considering that its ions migrate into soil, the depth of mycelium may be of importance. Nevertheless, *X. badius* which has the deepest-reaching mycelium among the examinated species, exhibits a DF value lower than that of *T. equestre* and *T. terreum*.

The reasons for disproportioning of cesium and potassium in plant cells and tissues have been recognized to some extent [1, 2, 8, 11, 14, 15]. This mainly occurs due to unequal affinity of membrane transporters to Cs^+ and K^+. Despite simple anatomy, fungal fruiting body seems to show a high selectivity in the ionic transport as well. Some molecular studies showed huge similarities between potassium transporters in primitive fungi and plants [8].

The problem of cesium/potassium discrimination in *Fungi*, with respect to the group phylogenesis, seems to be unsolved and requires further studies on the greater number of species. A practical goal of such studies is to consider the possibility of application of mushrooms in bioremediation.

Acknowledgments Thanks are due to Professor J. Jastrzębski and Ms. A. Trzcińska from HIL for collaboration in the field of gamma spectrometry.

References

1. Broadley MR, Escobar-Gutiérrez AJ, Bowen HC, Willey NJ, White PJ (2001) Influx and accumulation of Cs^+ by the *akt*1 mutant of *Arabidopsis thaliana* (L.) Heynh. lacking a dominant K^+ transport system. J Exp Bot 52:839–844

2. Bystrzejewska-Piotrowska G, Urban PL (2003) Accumulation and translocation of cesium-137 in onion plants (*Allium cepa*) (submitted to Environ Exp Bot)
3. Grüter H (1964) Eine selektive Anreichung des Spaltproduktes ^{137}Cs in Pilzen. Naturwissenschaften 51:161–162
4. Heinrich G (1993) Distribution of radiocesium in the different parts of mushrooms. J Environ Radioact 18:229–245
5. Kalač P (2001) A review of edible mushroom radioactivity. Food Chem 75:29–35
6. Mietelski JW, Jasińska M, Kubica B, Kozak K, Macharski P (1992) The map of radioactive contamination of fungi in Poland. Report No. 1590/D. Institute of Nuclear Physics, Cracow (in Polish)
7. Mietelski JW, Jasińska M, Kubica B, Kozak K, Macharski P (1994) Radioactive contamination of Polish mushrooms. Sci Total Environ 157:217–226
8. Rodríguez-Navarro A (2000) Potassium transport in fungi and plants. Biochim Biophys Acta 1469:1–30
9. Seeger R (1978) Kaliumgehalt höherer Pilze. Zeitschrift für Lebensmittel-Untersuchung und Forschung 167:23–31
10. Tsukada H, Hasegawa H, Hisamatsu S, Yamasaki S (2002) Rice uptake and distributions of radioactive ^{137}Cs, stable ^{133}Cs and K from soil. Environ Pollut 117:403–409
11. Urban PL, Bystrzejewska-Piotrowska G (2003) Comparative analysis of cesium and potassium uptake in onion *Allium cepa* L. Czech J Phys A 53:91–96
12. van Elteren JT, Woroniecka UD, Kroon KJ (1998) Accumulation and distribution of selenium and cesium in the cultivated mushroom *Agaricus bisporus* – a radiotracer-aided study. Chemosphere 36:1787–1798
13. Vinichuk MM, Johanson KJ (2003) Accumulation of ^{137}Cs by fungal mycelium in forests ecosystems of Ukraine. J Environ Radioact 64:27–43
14. White PJ, Broadley MR (2000) Mechanisms of caesium uptake by plants. New Phytol 147:241–256
15. Zhu YG, Smolders E (2000) Plant uptake of radiocaesium: a review of mechanisms, regulation and application. J Exp Bot 51:1635–1645