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

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 $^{137}\text{Cs}$ and $^{40}\text{K}$ 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 $^{137}\text{Cs}$/${}^{40}\text{K}$ discrimination factor • fruiting body • mushrooms

Introduction

The artificial $^{137}\text{Cs}$ and natural $^{40}\text{K}$ 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 $^{137}\text{Cs}$ 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]. $^{137}\text{Cs}$ 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 $^{137}\text{Cs}$ 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 $^{137}\text{Cs}$ and $^{40}\text{K}$ 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 ($\text{Cantharellus cibarius}$ Fr., $\text{Tricholoma equestre}$ (L.) Kummer, $\text{Tricholoma terreum}$ (Schff.: Fr.) Kummer, $\text{Xerocomus badius}$ (Fr.) Kühn. Ex. Gilb.) were sampled in the vicinity of Warsaw ($\lambda = 20–22^\circ$ E, $\varphi = 51.5–52.5^\circ$ N) in October 2001. The other one, $\text{Morchella esculenta}$ (L.) Pers., was sampled in April 2002. The analyzed samples were prepared from a mixture of 70 mushrooms. They were all divided in two
parts: caps and stipes, dried at 105°C for 24 h until total dehydration (an air flow dryer; Memmert GmbH + Co. KG, Außere 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 Filutowa Str., 02-032 Warsaw). The levels of radionuclides (137Cs and 40K) 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 (High Ion Laboratory, Warsaw University; configuration on request).

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

\[
DF = \frac{\frac{A(137 \text{Cs})}{A(40 \text{K})}_{\text{cap}}}{\frac{A(137 \text{Cs})}{A(40 \text{K})}_{\text{stipe}}}.
\]

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

\[
C. \text{ cibarius} < X. \text{ badius} < M. \text{ esculenta} < T. \text{ terreum} < T. \text{ equestre}
\]

The values of DF exceeding one unit, observed in three species, indicate that 137Cs in mushrooms is more efficiently translocated from stipe to caps than potassium (measured as 40K). 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 137Cs in mushrooms is different from that of 40K. 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).

<table>
<thead>
<tr>
<th>Sample</th>
<th>DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tricholoma equestre</td>
<td>2.87 (± 0.53)</td>
</tr>
<tr>
<td>Tricholoma terreum</td>
<td>2.81 (± 0.33)</td>
</tr>
<tr>
<td>Morchella esculenta</td>
<td>1.66 (± 0.15)</td>
</tr>
<tr>
<td>Xerocomus badius</td>
<td>1.24 (± 0.18)</td>
</tr>
<tr>
<td>Cantharellus cibarius</td>
<td>0.80 (± 0.09)</td>
</tr>
</tbody>
</table>

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 disproportional of Cs and K may occur within layers of one organ, i.e. onion storage leaves, where the 137Cs/40K 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 examined species, exhibits a DF value lower than that of T. equestre and T. terreum.

The reasons for disproportional 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 bio-remediation.

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

References


