SHORT COMMUNICATION

Journal of Radioanalytical and Nuclear Chemistry, Vol. 245, No. 3 (2000) 611–614

Determination of cesium and selenium in cultivated mushrooms using radionuclide X-ray fluorescence technique

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(Received October 14, 1999)

Cesium and selenium intake of cultivated mushrooms (*Agaricus bisporus*), with these elements previously added to the culture medium, has been examined from the viewpoint of health- and environmental protection. The process of measuring has been carried out by the radionuclide X-ray fluorescence technique. Treatments of the elementary substance with Se salt appears to influence the Se content of the mushrooms to a significant extent. Cs intake is of considerable importance, as this element is accumulated by mushrooms.

Introduction

The aim of the current study is to expound how Cs and Se, added to the culture media of *Agaricus bisporus,* might be observed to get into the champignons.

Champignons can be described as the variety of mushrooms produced in the largest quantities all over the world – 4 million $t.year^{-1}$ world-wide, 35 thousand $t.year^{-1}$ in Hungary, while in Slovakia it is 0.8 thousands t per year (1997). Besides champignons' outstanding future as a result of having a low carbohydrate content, it is also regarded as an important source of protein as well as a sort of food of great significance from the point of view of healthy nutrition due to its extraordinarily large mineral salt- and trace element content.

The investigation of trace elements is important from the point of view of nutrition and environmental analysis since the amount of trace elements necessary for normal vital functions might increase or decrease to considerable extent at certain steps of the chain of nourishment and it is also possible that toxic or even radioactive elements get into human organisms.

The intake of certain toxic and essential trace elements in cultivated mushrooms have already been given account of in previous studies.[1,2] The setting of the experiment has been carried out by applying the individual procedure worked out and used on previous occasions.

This study is particularly aimed at seeking the answer to two main questions. On the one hand, the concentration of Cs and Se has been investigated in the case of champignons grown on culture media containing cesium chloride in various concentrations as well as Na selenite. On the other hand, a comparison has been desired to be drawn-concerning Cs and Se content of mushrooms – between the cases of treating the culture media with Se and Cs salts separately.

Investigations regarding Cs have been motivated by the fact that the European Council decided to carry out a series of measurements with the aim of keeping radioactive mushrooms – imported from Eastern Europe (Poland, Lithuania, Romania, Russia, Ukraine) to the European Union – under increased surveillance. According to the council's law 737/90 passed after the of Chernobyl atomic power station catastrophe the licensed concentration of radioactive Cs is permitted to be max. 600 $Bq \cdot kg^{-1}$. The E.U. requires that its member states control mushrooms imported into the E.U. imposing exact measuring and a severe supervision on countries which are about to export this product to the E.U.

Measurements focused on Cs have been carried out carefully since mushrooms growing wild in permanently contaminated areas were observed to contain radioactive Cs in especially high concentration after the Chernobyl disaster.[3]

The research, of course, has been done with nonradioactive Cs – following the practice that had been worked out well and proved to be highly effective in the case of other elements on earlier occasions (Pb, Cd, Cs, Ni, Se, Mn). Regardless of the fact whether Cs is radioactive or not, the process of its migration into the fruit body is similar.

The psychological importance of selenium with a particular view to its curative effect is appreciated in a considerable number of scientific studies (>4000). Se is often described as a "favoured element". It is the indispensable element of enzymes responsible for significant psychological functions (e.g., glutation-peroxidease, tironim 5' deiodinase etc.). Se also has a protective effect in the case of poisonings caused by heavy metals as the metal selenide does not dissolve in water and therefore it will be evacuated with urine.

0236–5731/2000/USD 17.00
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It also hinders the harmful effect of free radicals deriving from oxygen. The lack of Se or its toxic effect could be observed if the daily intake is below 10 μg or is above 500 μg, respectively. The inadequate quality of Se might elicit certain biochemical and pathological changes of considerable danger.[4,5]

Examinations focusing on the question to what extent the Se supply to the human organism could be increased by mushroom consumption are very important. Another target of our investigations was to find out the extent to which cultivated mushrooms abort this element from the culture media. This is important because of the widely-known fact that Central Europe is regarded as an area lacking Se.

Experimental

Changes in the concentration of Se and Cs in each crop-cycle have been measured in mushrooms produced in a confined place by the addition of Cs and Se salt solutions at concentration of 10, 100 and 1000 $mg \cdot kg^{-1}$ to culture media of the same mass.

Mycelium having been made run on 150 cm^3 of wheat grain as well as salt solution of 11 solution (11 distilled water added to the control medium) have been added to production sacks each containing 20 kg of culture medium. The homogenisation of the substances has been carried out in a special mixing equipment.

Sampling and sample preparation

Representative samples from production sacks have been taken from the four cycles separately and there have been three parallel measurements in each sack. In the case of fruit bodies with closed caps measurements have been restricted to the caps which have been dried to weight constancy at 105 °C then powdered and sifted by a sieve of 60 μm. 250 mg of the total quantity has been then decomposed in a mixture of 5 cm^3 of cc. HNO_3 and 2 cm^3 of 30% H_2O_2 at 160 °C under high pressure in so-called non-stick bombs for three hours. The resulting clear solution has been filled up to 25 cm^3 by 0.1M HNO_3.

Instrumentation

The instrumentation was described in Reference 6. For excitation of characteristic X-ray ^{238}Pu and ^{241}Am radionuclides and for the measurement of X-ray Si(Li) semiconductor detector were used. The signal from the detector was evaluated with an Ortec multichannel spectrometer.

Results and discussion

The results of the measuring as well as the average values are shown in Table 2. Table 3 contains the calculation and values of the so-called factor of element mobilisation (EMF) which describes the extent to which migration (accumulation) increases:

$$\text{EMF} = \frac{\text{Element content of mushrooms taken from the culture medium of admixture}}{\text{Element content of mushrooms taken from the control culture medium}}$$

Table 1. CsCl and Na_2SeO_3 solutions added to the culture medium

Cs and Se ($mg \cdot kg^{-1}$) added to the culture medium	Measured quantities
10 Cs	0.25 g $CsCl/dm^3$
100 Cs	2.5 g $CsCl/dm^3$
1000 Cs	25 g $CsCl/dm^3$
rowd 10 Se	0.44 g Na_2SeO_3/dm^3
100 Se	4.4 g Na_2SeO_3/dm^3
1000 Se	44 g Na_2SeO_3/dm^3

Based on the data of Tables 2 and 3 champignon might be confidently declared to belong to those mushroom varieties which tend to infiltrate Cs into their organisms to a great extent (Fig. 1). The increase in Cs concentration – in the mushrooms taken from culture media treated with Cs chloride of gradually growing order of magnitude – appeared to be 12 and 12.6 times as great as the normal value. Thus champignons seem also to accumulate Cs. This also justifies the fact that mushrooms growing wild in a polluted area are not permitted to be sold. No need for Cs control in the case of cultivated mushrooms.

Treatments of the culture medium with Se salt significantly influence the Se content of the mushrooms (Fig. 2). Se concentration in the mushrooms growing in the first crop-cycle always turned out to be higher than on the following occasions (in the upcoming cycles). Se can get into mushrooms successfully in Na-selenite solution if this enters the culture medium in an aqueous solution. Se concentration at a beneficial level for the human organism in the chain of nourishment would also be possible to be improved in this way.

Table 2. Element concentration (mg·kg^{-1}) in each crop-cycle

Cs and Se (mg·kg^{-1}) added to the compost / Crop-cycles:	1st cycle	2nd cycle	3rd cycle	4th cycle	Average value
Cs ∅	3.2	2.2	4.1	2.8	3.6
Cs 10	14.1	11.3	13.3	18.2	14.2
Cs 100	158	135	140	195	157
Cs 1000	2010	1851	1884	2312	1958
Se ∅	153	140	136	81	128
Se 10	297	202	200	138	209
Se 100	1340	1153	769	832	1023

Cs∅, Se∅, = control.
In the case of Se 1000 concentration there has been no field due to the high toxicity.

Table 3. The relative increase in infiltration and the factor of element mobilisation of the mushrooms produced on a culture medium treated with Cs and Se salts

	Factor of element mobilisation*	Relative increase**
Cs 10	$\frac{14.2}{3.6} = 3.9$	–
Cs 100	$\frac{157}{3.6} = 43$	$\frac{43}{3.6} = 12$
Cs 1000	$\frac{1958}{3.6} = 544$	$\frac{544}{43} = 12.6$
Se 10	$\frac{209}{128} = 1.6$	–
Se 100	$\frac{1023}{128} = 8.0$	$\frac{8.0}{1.6} = 5.0$

* In comparison with the control.
** In relation to the previous toxic and trace element concentration.

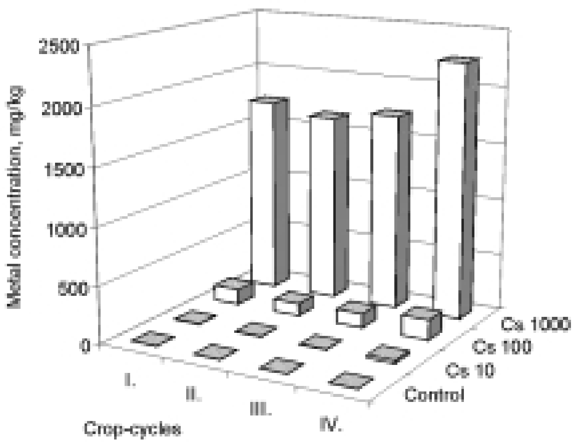

Fig. 1. Cesium content of champignons produced on a culture medium treated with cesium

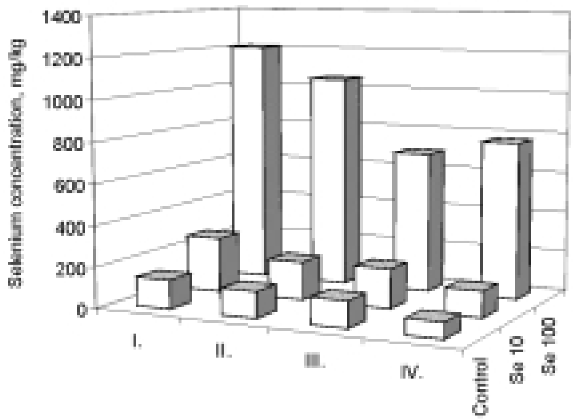

Fig. 2. Selenium content of champignons produced on a culture medium treated with selenium

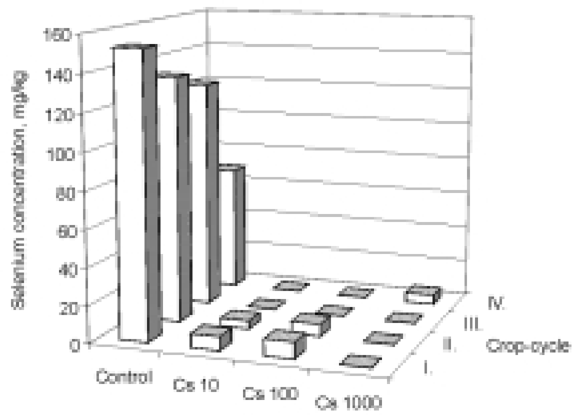

Fig. 3. Selenium contents of chamignons produced on a culture medium treated with cesium

No reliable conclusions could be drawn on the basis of the data obtained from the measurement of the change in the Cs content in the mushrooms taken from the culture medium treated with Se.

A surprising significant decrease in the Se concentration of the mushroom samples taken from the culture medium treated with Cs (Fig. 3) seems to indicate that Cs hindered Se from getting into the fruit body. This however, needs further investigations.

Conclusions

Champignons accumulate cesium. They belong to the variety of mushrooms which can contain radioactive Cs if growing in an area contaminated by radioactive Cs.

Mushrooms utilise selenium from the culture medium, in other words, its infiltration into the fruit body is in direct proportion to the amount of Se entering the culture medium. Increasing the amount of Se to a certain limit by the application of a solution of adequate concentration could be useful and desirable since it would render possible the increase in Se concentration for human organisms in the chain of nourishment.

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The paper was elaborated in the frame of grant projects 1/5201/98 VEGA MŠ SR, 2/6027 VEGA MŠ SR a INCO-COPERNICUS No. IC 15-CT 97-0703 (MŠ: PL 9464355).

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