EXTRACTION OF RADIOCESIUM FROM CONTAMINATED MUSHROOMS

EXTRACTION DU RADIOCESIUM DES CHAMPIGNONS

(Tjakko STIJVE)

Ex OBSERVATIONS MYCOLOGIQUES,
Bulletin de l'Observatoire Mycologique, n° 6, 1994.

Version abrégée en français en fin d'article.

English abstract:

To decontaminate wild-growing mushrooms containing high amounts of radiocesium as a consequence of the Chernobyl nuclear accident, the extraction of the radionuclides with water and salt solution was studied.

The mushroom species included in the investigation were all bioaccumulators of cesium e.g. Cantharellus tubaeformis, Hydnum repandum, Hygrophorus camarophyllus and Albatrellus ovinus. Simple processing operations as soaking or parboiling removed radiocesium to a large extent, especially from deep frozen and dried mushrooms. A disruption of the cell tissue is necessary for complete extraction.

Our findings were amply confirmed by an independent investigation reporting effective removal of radiocesium from Xerocomus badius, a choice edible mushroom in Germany and Switzerland.

1. INTRODUCTION

The risk of contamination of foods by radionuclides was emphasized by the reactor accident at Chernobyl in April, 1986 (1).

It has repeatedly been observed that many macrofungi, including various edible mushrooms have the ability to accumulate radiocesium isotopes (2,3).

In fact, the concentrations measured in these organisms are generally 100 times higher than that of green vegetation. Clearly, many fungi have the ability to mobilise radiocesium from soils, and to transfer the isotopes into the human food chain. Knut Hove et al. (4) observed that in grazing dairy goats as little as 20-100 g of fungal dry matter per day noticeably increased the radioactivity of the milk. In addition, consumption of fungi and lichens by animals during late Summer and Autumn will heavily contribute to the radiocesium content of meat from sheep and reindeer (4,5).

Furthermore, it should be borne in mind that very high Cs concentrations were measured in popular wild-growing edible mushrooms, which are increasingly offered for sale either fresh, dried or as preserves on the European markets.

This has been a cause of some concern, because in countries such as Sweden, that have received appreciable amounts of Chernobyl fallout, the mushrooms gathered in some regions have a radiocesium content that often exceeds 10-100 times the European general limit for foods of 600 Bq/kg (2). Consequently, we undertook a study of the possibilities to decrease the radiocesium content of contaminated mushrooms.

Limited literature data indicate that even simple processing should have a beneficial effect in this respect, since Grueter (6) observed already in 1971 that canned wild mushrooms of commerce had a lower radiocesium content than fresh ones. It was estimated that blanching reduced the radioactivity with about 50 percent. In a test with the accumulating species *Paxillus involutus* which was boiled in water, only 36 % of the radioactivity remained in the mushroom.

To study the effect of water extraction, parboiling and cooking on the Cs-activity content of edible mushrooms we purchased several species from the Gåvle area in Sweden, where radiocesium contents were in the range of 3000 - 10'000 Bq/kg fresh weight.

2. EXPERIMENTAL

Sampling

Mushroom species studied

- *Cantharellus tubaeformis* fresh, several collections of varying activity.
- *Cantharellus tubaeformis*, dried.
- *Hydnum repandum*, fresh.
- *Hygrophorus camarophyllus*, fresh.
- *Albatrellus ovinus*, fresh.

Radiocesium measurement

All gammaspectrometric analyses were carried out as described in ref. 1.

Accuracy of measurement

Total error is in the range of 15-20 %, because sample inhomogeneity may exceed 10 percent, whereas calibration and measurement errors may also attain 5 percent each. depending on the activity measured.

Procedure

Mushrooms were carefully cleaned and large specimens were cut in four parts. After measuring activity of the cesium radionuclides, the cooking and parboiling experiments were carried out on 100-200 g portions in large glass beakers with suitable volumes of water, either at room or at boiling temperature. In case of dried mushrooms, about 10 times smaller portions were taken. After varying extraction times the contents of the beaker were passed over a 2 mm sieve. Subsequently, the activities of the extracted mushrooms and sometimes also of the aqueous extracts (to check the activity balance) were measured.

4. RESULTS AND DISCUSSION

Initially, 200 g portions of *Cantharellus tubaeformis* having an appreciable radiocesium content were dipped in 2 l boiling water for a length of time varying from a few seconds to 10 min, and the loss of radioactivity monitored. The results are listed in Table 1.

Even after 1 min immersion in boiling water there was already a 74 percent loss, and what's more, the texture and taste of the mushrooms were still pleasant. However, after 5 min the consistency became flabby and unattractive. Upon lowering the water volume to 0,7 and 1,5 l and maintaining the 1 min dipping time, it was observed that the loss of radioactivity remained virtually the same, but the texture and taste improved somewhat.

Table I : Loss of radiocesium from fresh *Canth. tubaeformis* upon plunging in boiling water. Initial activity 16500 Bq/kg

Time	Remaining activity in Bq/kg	Loss (in %)
5 sec	6900	58
10 sec	6300	62
1 min	4300	74
5 min	2770	83
10 min	1820	89

This treatment was applied to other mushrooms, albeit with some modification. Since a smaller volume of water yielded mushrooms with a better flavour and consistency, 100 g portions were parboiled 2 min in 0,5 l water.

Table II : Loss of radiocesium from different fresh mushrooms upon parboiling 100 g in 0,5 l water.

Mushroom	Initial radiocesium content in Bq/kg	After parboiling	Loss (%)	After twice parboiling
Hydnum repandum	2980	530	82	---
Cantharellus tubaeformis	8000	3950	51	---
Hygrophorus camarophyllus	46000	5180	88	97
Albatrellus ovinus	230	125	46	---

It is interesting to note that, in spite of twice boiling, the excellent edible *H. camarophyllus* retained a firm consistency and good flavour. Somewhat surprisingly, the collection of *Canth. tubaeformis* proved more resistent to leaching than that from Table I. Other experiments with this particular mushroom collection gave the following results :

Table III : *Canth. tubaeformis* 8000 Bq/kg - loss upon soaking 200 g in 3 l fresh or salted water during 12h

	Remaining activity in Bq/kg	Loss in %
Soaking in water	4800	40
in 1 percent salt solution	4010	50
in 5 percent salt solution	3140	61
after twice rinsing and parboiling	400	95

Addition of salt noticeably increases radiocesium loss. Soaking for 12 h did not affect the organoleptic properties very much, although the combination with rinsing and parboiling resulted in a slimy consistency.

Parboiling undoubtedly causes loss of nutrients, such as mineral salts, soluble carbohydrates, amino acids, and, perhaps even more important, flavour. On the other hand, in certain mushrooms, e.g. *Lactarius* spp. which are popular in Finland, the treatment also removes the pungency which can be quite outspoken.

Loss of radiocesium from *Canth. tubaeformis* seems to be directly proportional with the removal of water as shown in Table IV.

Table IV : *Canth. tubaeformis* 8000 Bq/kg - 200 g in 3 l water

Treatment	Remaining activity in Bq/kg	Loss in %
1 min parboiling	6400	20
+rinsing	4900	38
+rinsing and squeezing	3900	51

A third batch of *Canth. tubaeformis* was available in dried state, and had an activity of 140'000 Bq/kg.

Sixteen grams of the whole dried mushrooms were soaked in 0,5 l water. After 30 min soaking time, the fully reconstituted specimens were found to have an activity of 8'400 Bq/kg, corresponding to about 84'000 on dry weight. The remaining activity was $\frac{84'000}{140'000} \times 100 = 60$ percent.

The loss incurred during only half an hour soaking of the dried mushrooms is more important than that observed upon subjecting fresh specimens during 12h to the same treatment (table III).

When soaking the dried specimens overnight in water, virtually all radioactivity was lost, but the consistency of the reconstituted mushrooms was rather unattractive. Increased removal of radiocesium from dried mushrooms during soaking can be explained by disruption of the cells during drying and reconstitution.

Upon further experiments it was found that soaking 16 g dried mushrooms during 15 min in 0,5 l, followed by parboiling during 3 min. effectively removed 99 percent of the radiocesium. Moreover, the thus reconstituted and decontaminated mushrooms were found to have a good texture and a pleasant taste.

5. COMPARISON WITH LITERATURE DATA

When this study was going on, a paper was published by Neukom and Gisler (7) about decontamination experiments with the Bay boletus, *Xerocomus badius*, a popular edible mushroom that is notorious for its radiocesium enrichment. The authors studied decrease in Cs-activity in fresh, deepfrozen and dried mushrooms, mainly by soaking and boiling. see Tables A, B and C.

Table A : Decrease of Cs-activity in fresh mushrooms by extraction with water and 0,5 percent salt solution

Sample weight (g)	Conditions	Temperature (°C)	Remaining radiocesium activity (%)
300	2h soaking in 1,5 l water	20	71
300	2h soaking in 1,5 l NaCl solution	20	85
300	5 min boiling in 1,5 l water	100	66
300	5 min boiling in 1,5 l NaCl solution	100	67

Table B : Decrease of Cs-activity in deepfrozen mushrooms by extraction with water and 0,5 % NaCl solution

Sample weight (g)	Conditions	Temperature (°C)	Remaining radiocesium activity (%)
140	3h soaking in 0,5 l water	20	32
140	3h soaking in 0,5 l NaCl solution	20	29
140	1 min boiling in 0,5 l water	100	71
140	1 min boiling in 0,5 l NaCl solution	100	59
140	5 min boiling in 0,5 l NaCl solution	100	44
140	15 min boiling in 0,5 l NaCl solution	100	28

Table C : Decrease of Cs-activity in dried *X. badius* imported from Poland by single and repeated extraction with water and 0,5 % NaCl solution

Sample weight (g)	Conditions	Temperature (°C)	Remaining radiocesium activity (%)
50	3h soaking in 0,5 l water	20	35
50	3h soaking in 0,5 l NaCl solution	20	35
50	1 min boiling in 0,5 l NaCl solution	100	51
50	5 min boiling in 0,5 l NaCl solution	100	42
50	15 min boiling in 0,5 l NaCl solution	100	41
50	4 x 0,5h soaking in 0,5 l water	20	38, 15, 5, 2
50	4 x 1h soaking in 0,5 l water	20	34, 11, 4, 1
40	3 x 0,5h soaking in 2 l water	20	31, 7, 2
50	3 x 1h soaking in 2 l water	20	22, 5, 1
40	3 x 2h soaking in 2 l water	20	11, 2, <1

For a better appreciation of these tables it should be noted that the fresh and deepfrozen *X. badius* had a total radiocesium ($Cs^{134} + Cs^{137}$) activity of about 600 Bq/kg. In the dried mushrooms from Poland 10'000 Bq/kg was measured.

Obviously, removal of radiocesium from this particular mushroom in the fresh state is somewhat difficult, probably due to its hydrophobic surface layer. However, if the cell structure is partially or completely destroyed, as is the case in frozen and dried mushrooms, more radiocesium is extracted under all conditions as is shown in tables B and C.

Once again, when increasing the water volume, or using repeated extractions, virtually complete removal of activity could be achieved. These observations largely confirm ours, although the authors found no significant difference between water and salt solutions.

6. CONCLUSION

The experiments reported in this note demonstrate that radiocesium can be removed to a large extent from mushrooms when the cell tissue has been disrupted prior to water extraction. Deep freezing and drying mushrooms effectively causes disruption of the cell tissue. Indeed, in many cases sufficient decontamination can be achieved by moderately soaking and boiling, thus preserving the culinary appeal and organoleptic qualities of the mushrooms.

Even heavily contaminated mushrooms may still be fit for consumption if they are preserved in the dried state, and parboiled before eating.

7. ACKNOWLEDGEMENT

Anna Stina-Edholm (Göteborg, Sweden) is thanked for providing information and technical assistance.

8. REFERENCES

1) Zimmerli, B. and E. Bosshard, Strahlenexposition durch Radionuklide in Lebensmittel. Mitt. Gebiete Lebensm. Unters. u. Hyg. 80, 387-404 (1989).

2) Stijve, T. and M. Poretti, Radiocesium levels in wild-growing mushrooms from various origin, Laboratory News no 60, January-June 1989, topic 9.

3) Stijve, T. and D. Tornare, Uptake of radiocesium by wild-growing mushrooms. Research Note no QS-RN930002 of 22.01.'93.

4) Hove, Knut et al., Fungi : a major source of radiocesium contamination of grazing ruminants in Norway, Health Physics 59, 2, 189-192 (1990).

5) Rissanen, K. and T. Rahola, Cs-137 concentration in reindeer and its fodder plants. The Science of the Total Environment, 85, 199-206 (1989).

6) Grueter, H., Radioactive Fission Product 137Cs in Mushrooms in W. Germany during 1963-1970. Health Physics, Pergamon Press 1971. Vol. 20 (June) pp. 655-656.

7) Neukom, H.P. and Gisler, E., Extraction of Radioactive Caesium from Mushrooms with *Xerocomus badius* as an Example. Lebensm. Wiss. u. Technol., 24, 442-444 (1991).

Version abrégée en Français:

La capacité des champignons d'accumuler du césium radioactif est bien connue et a été soulignée par l'acident de Tchernobyl. Knut Hove & al. ont observé que chez les chèvres, 20 à 100 grammes d'incorporation de champignons (matière sèche) par jour augmentait de façon significative la radioactivité du lait.

Ajoutons que dans certaines régions (en Suède notamment) les champignons récoltés dépassent souvent de 10 à 100 fois la limite européenne de 600 Bq/kg.

Cela nous a amené à étudier les possibilités de diminuer la teneur des champignons en césium radioactif.

Dès 1971 Grueter (6) remarquait que les champignons sauvages en conserve contenaient moins de césium que les frais, estimant son élimination à 50%.

Notre étude a porté sur des champignons de la région de Gàvle en Suède présentant une contamination de 3000 à 10000 Bq/kg sur la matière fraîche.

METHODES:

Les espèces analysées étaient Cantharellus tubaeformis (chanterelle en tube), Hydnum repandum (pied de mouton), Hygrophorus camarophyllus et Albatrellus ovinus.

RESULTATS ET DISCUSSION:

TABLEAU I: Elimination de césium radioactif de C. tubarformis après immersion dans l'eau bouillante (activité de départ: 16500 Bq/kg).

TABLEAU II: Elimination de césium de différents champignons frais après avoir blanchi 100 g dans 0,5 l d'eau pendant 2 minutes.