Radioactive Cesium in Edible Mushrooms

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The purpose of this study was to ascertain whether field-collected, edible mushrooms showed levels of radioactive contamination, particularly ^{137}Cs, above the background level. Samples were analyzed by a γ-ray spectrometer. The study showed that the γ-ray intensity of ^{137}Cs from the Polish sample was 7.2 times greater than the background. It also revealed the clear presence of ^{137}Cs in the North American samples, in which the intensity was 4.3 times greater than the background. Thus, the enhancement of ^{137}Cs in field-collected samples is probably due to an inherent metabolic factor, making field mushrooms suitable indicator organisms for analysis of radioactive contamination.

This study was begun out of curiosity when one of the authors received a gift of dried mushrooms collected in 1987 near Gdansk, Poland. These mushrooms were collected about 17 months after the famous nuclear accident at Chernobyl, 800 + km away. Would radioactive traces from that accident be detectable? We decided to use a γ-ray spectrometer and focus on ^{137}Cs, an easily identifiable fission product, whose half-life is 30 years.

Intuitively, since mushrooms grow as absorptive heterotrophs at the air–soil interface, we suspected they might be suitable indicators for assay of radioactive fallout in the soil. These contaminants would be expected from the recent accident in Chernobyl, from older accidents, such as at the Windscale Facility, England, and from atmospheric nuclear bomb tests conducted globally in the 1960s. The release of 3 million Ci of ^{137}Cs at Chernobyl has been estimated by the Lawrence Livermore National Laboratory (Marshall, 1986). Cesium is of great long-term concern because it is biologically active and was released in enomorous quantities. Investigators estimate the Chernobyl incident released one-tenth to one-sixth as much ^{137}Cs as was emitted into the environment from all nuclear weapons tests to date (Flavin, 1987).

Some minimum amount of ^{137}Cs was detected by the very sensitive spectrometer in our local background, as indicated by curve B in Figure 1. The γ-ray intensity under the ^{137}Cs peak from the Polish sample (curve P) was found to be significantly greater than from the background. Two samples of north American mushrooms were also analyzed, and their nearly identical spectra are shown as curve N on the same figure. There is cause for concern since numerous studies have shown radioactive contaminants move through the food chain to human consumers and often exceed acceptable health standards (Davis, 1986; Revelle and Revelle, 1988). Caribou flesh in northern Finland, sheep flesh in northern Ireland, and powdered milk exported from Ireland to Mexico have shown radioactive residues restricting their consumption. Additionally, radiolytic products, caused by disruption of molecular bonds in the cells of food products, are only beginning to be investigated by the Food and Drug Administration and the World Health Organization for their possible carcinogenic, teratogenic, and mutagenic properties in animals and humans (Miller, 1988).

MATERIALS AND METHODS

Samples and Localities. Four mushroom samples were analyzed. Terminology and taxonomy follow Lincoff and Knopf (1984) and Alexopoulos (1966).

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(*1*) *Poland.* A dried sample of the choice pore mushroom *Boletus edulis* Bull. ex Fr. was collected near Gdansk in 1987, with a dry weight of 75.3 g.

(*2*) *New Jersey.* A dry sample of *B. edulis* was obtained that had been collected in 1981 near Montclair. It also weighed 75.3 g. *B. edulis* is a highly prized, edible species associated with moist conditions in frondose woods. It is commonly known as Steinpilz or cepe and sold dried in long strings.

(*3*) *New York.* A dry sample of *Boletus affinis* var. *maculosus* Pk. was collected near Riverhead in 1987. It weighed 68.3 g. Known as the spotted bolete, it is like *B. edulis*, a member of the cosmopolitan family Boletaceae.

(*4*) *Pennsylvania.* A fresh, 70-g sample of the gilled, common, cultivated mushroom, *Agaricus campestris bisporus*, family Agaricaceae, was obtained for comparative purposes.

No special preparations for the analytical studies of samples were performed. The first three samples were obtained from the people who gathered the mushrooms and dried them in the air on strings in their homes. No additional dehydration was necessary as the amount of any water remaining was so low as to have no negative effect on the specific activity per gram of sample. The last sample consisted of fresh mushrooms purchased in New Jersey in April 1988. The volumes occupied by the samples in all cases were approximately equal to 5 × 5 × 8 cm^3. The distances from the centers of the samples to the surface of the γ-ray detector were equal to 4 ± 0.5 cm.

Apparatus and Procedures. A γ-ray spectrometer, utilizing a 3 × 3 in. NaI crystal, was used to detect radioactive contaminants. A broad range of γ-ray energies from 0.1 to 3.5 meV was covered. The spectra were studied with a standard multichannel analyzer, Northern Econ II series, Model NS-710. Our study centers on the specific peak associated with ^{137}Cs, although other peaks indicate other contaminants are also present, in significantly smaller amounts. The counting rates below the 660-keV peak of ^{137}Cs for the studied samples were compared with the rates produced by a set of three sealed sources of ^{137}Cs, whose combined absolute activity at the time of calibration was 19.2 mCi. The distance from the calibrated sources to the surface of the detector was 133 cm. No special safety precautions for our exposure to the radioactive sources were necessary, owing to their weak nature and brief duration of exposure.

RESULTS AND DISCUSSION

Figure 1 shows three spectra that were generated in 23-h cumulative scanning periods. It indicates that the counting rates were very low in all cases, so that no dead-time corrections were necessary. The traces of ^{137}Cs can be seen in all three spectra, even in spectrum B, which refers to

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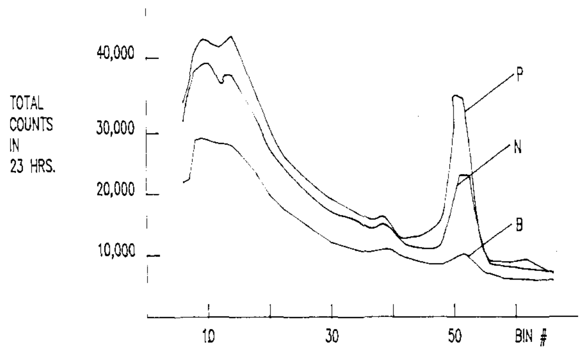

Figure 1. Cummulative γ-ray spectra from three sources in 23 h. Bins refer to scanning channels. Key: (P) Polish mushrooms; (N) North American mushrooms; (B) background, empty container.

an empty container. This background is due to previously mentioned sources of contamination, e.g. bomb tests. Spectrum P, the Polish sample, shows an intensity 7.2 times greater than the background. This was determined by graphic analysis of the areas under the peaks. This activity was calculated to be 10 ± 3 pCi/g of sample. This was calculated by comparison of the ^{137}Cs peak of the Polish sample with that of our calibrated sources of ^{137}Cs whose absolute activity has been previously mentioned. In other words, there was 17×10^{-15} g of ^{137}Cs/g of dry sample. The total increased γ-count from this sample not only under the ^{137}Cs peak but integrated overall was found to be equal to approximately 40% of the background, making the Polish sample overall 40% more radioactive than the background.

The most surprising result was the amount of ^{137}Cs contamination in dry, field-collected, mushrooms in the United States. Spectrum N shows the virtually identical signature obtained for both the New Jersey and New York samples. It shows, by graphic area analysis, that the γ-ray intensity due to ^{137}Cs is 4.3 times greater than the background. Outside of this cesium peak, on the other hand, the γ-ray intensity of the North American samples was found to be nearly the same as that from the Polish sample. Thus, only the excess of the ^{137}Cs in the Polish sample can be attributed to the proximity to Chernobyl.

A sample of fresh commercial mushrooms was also tested. Its intensity was essentially the same as the background. A soil sample from where the New Jersey mushrooms were gathered was analyzed for ^{137}Cs. No enhancement above the background peak was detected.

This suggests that the metabolism of wild boletacean mushrooms is associated with an approximately 4.3-fold concentration of ^{137}Cs compared to the soil level. This is due to the fact mushrooms metabolize ^{137}Cs as if it were potassium (von Naegeli, 1969). Therefore, these species may be used as sensitive detectors of radioactive contamination with ^{137}Cs.

It is our opinion that the overall γ-ray dose that a consumer of Polish mushrooms would receive is totally negligible in comparison to what is considered to be dangerous; the maximum permissible whole-body burden for ^{137}Cs, 30 mCi (Brodsky, 1969), would correspond to 3000 kg of dry mushrooms! However, as reported in the *New York Times*, 17 April 1988, consumer groups and some governments have warned Europeans not to overindulge in the 1987 crop of wild mushrooms. These collectibles are still concentrating ^{137}Cs from Chernobyl that is present in decaying leaves. Furthermore, the Institute for Energy and Environmental Research is cautioning pregnant women not to eat any European mushrooms. Although *B. edulis* has been shown to contain natural tumor inhibitors (Lucas, 1957) and the FDA spot checks all imported foods, the caution to pregnant women is probably warranted.

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