THE MIGRATION OF Sr^{90} ALONG THE BIOLOGICAL CHAIN PLANT-TO-SHEEP-TO-FETUS

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On account of the contamination of the earth's surface with long-lived products of uranium fission (Sr^{90}, Cs^{137}, and Ce^{144}) as a result of the testing of nuclear and thermonuclear weapons, the problem of the migration of radioactive isotopes along various biological chains has taken on great importance [3, 5 – 8].

Radioactive isotopes that fall to the earth's surface are incorporated into the general cycle of materials and quickly enter living organisms [1 – 3, 5, 6, 8, 11 – 15]. An object of particular concern is Sr^{90}, which has marked biological activity [10]. Studies of the accumulation of Sr^{90} in living organisms under conditions of prolonged intake from the surrounding environment have been relatively few in number, the majority having been made on small laboratory animals. So, for example, Comar, Whitney, and Lengemann [12] showed in experiments on rats that calcium is absorbed from the gastrointestinal tract to a greater extent than Sr^{90} (3.6 times greater), and accumulates to a greater extent in the fetal skeleton (5.1 times).

We have conducted an investigation on domestic animals (ewes). In this article we present the results of a study of the migration of Sr^{90} along the biological chain plant-to-sheep-to-fetus.

METHODS

The experiments were performed on 12 adult (2 – 4 years old) pregnant ewes, from which 23 fetuses were obtained weighing 200 – 300 g apiece. Over a six-month period the ewes were fed hay containing Sr^{90}. The specific activity of the hay was about 0.04 μC / kg weight. Six months after the experiment began, the animals were sacrificed. The content of Sr^{90} and stable calcium was determined in the skeletons of both the ewes and the fetuses (fetal ages 3 – 4 months). Samples for the measurement of radioactivity with an end-type counter (mass of mica window 2-3 mg/cm^2) were prepared from the ash that remained after incineration of the bones in a muffle furnace (at 500°). Weighed aliquots of the bone ash were transferred to special aluminum disks 38 mm in diameter. The activity of the samples was measured after radioactive equilibrium was established between Sr^{90} and its radioactive daughter isotope Y^{90}, and generally not less than 21 days after the animal was killed.

RESULTS

The data are presented in the table. Examination of the data shows that six months after the start of the experiments the concentration of radioactivity in the bones of the ewes (0.263 μC/kg weight) was approximately five times as high as in the hay (0.05 μC/kg weight), and 14.6 times as high as in the fetuses (0.018 μC/kg weight). This observation is in complete agreement with the results of studies made by É. B. Kurlyandskaya, N. L. Beloborodova, and E. F. Baranova [4], and by A. A. Rubanovskaya and V. F. Ushakova [9], with small laboratory animals. According to these authors' data, the concentration of Sr^{90} in the skeletons of rabbits and rats borne by mothers that had been fed Sr^{89} and Sr^{90} for a long time during pregnancy was only one-tenth as high as that of the mothers.

If the radioactivity is calculated per gram of Ca rather than per unit weight of bone, the Sr^{90} concentration of the fetal skeleton differs less strikingly from that of the mother.

In this case, as the table shows, the relative concentration of Sr^{90} in the maternal skeleton (0.00131 μC/g Ca) is only 2.3 times as great as that for the fetus (0.000565 μC/gCa). These data indicate that the skeleton of the mother "protects" the fetus from excessive entry of Sr^{90} into it.

It is worth noting that as Sr^{90} migrates down the biological chain plant-to-ewe-to-fetus, the concentration of radioactive material (if we express the data in μC/g calcium) goes down. Thus, for example, the Sr^{90} concentration (in μC / g of calcium) in hay is 4.73 times as great as in the bones of the mother, and 10.9 times as great as in the bones of the fetus. These observations indicate that in the transport of Sr^{90} along the biological chain, discrimination occurs between Sr^{90} and calcium. The discrimination coefficient shows how far the concentration of Sr^{90} per g calcium is reduced in the transfer from one step in the food chain to another. It is important to know the discrimination coefficients in order

Characteristics of the Migration of Sr^{90} from Plants to the Skeletons of Animals and to Fetal Skeletons Via the Placenta

Material compared	Pregnant ewe	Fetus weighing 200—300 g
Radioactivity of food due to Sr^{90} (in μC/kg of hay)	0.05	—
Concentration of Sr^{90} (in μC/kg wet weight of organ) in bones six months after start of experiment	0.263± 0.03	0.018± 0.005
Concentration of calcium (in g/kg): in hay	8	—
in bones	200	31.8
Concentration of Sr^{90} (in μC/g Ca) in hay consumed by ewes	0.0062	—
Concentration of Sr^{90} (in μC/g Ca) in skeleton	0.00131	0.000565
Ratio of Sr^{90} concentration (in μC/g Ca) in hay to that in skeleton	4.73	10.9
Discrimination coefficient for the chain hay-to-bone	0.21	0.091

Note: The discrimination coefficient is the ratio of the Sr^{90} concentration(in μC/g Ca) in the skeleton to that in hay.

to calculate the possible content of Sr^{90} in foodstuffs and in human bones. The discrimination coefficient for the chain plant-to-maternal bone is roughly 0.21, and for the chain plant-to-fetal bone, about 0.091. These figures correspond rather well to the results of studies made by other authors on small laboratory animals [3, 11, 12]. These studies show that the discrimination coefficients for the transfer from food to bone are 0.57, 0.35, and 0.20 for rats, mice, and rabbits, respectively. From the data we have been considering here we may conclude that the discrimination coefficient is not very species-dependent.

The presence of a discrimination coefficient or protection coefficient (the inverse of the discrimination coefficient) different from unity indicates that the metabolism of Ca and Sr, two alkali-earth elements that are similar in their chemical properties, is not completely identical, despite their tendency to concentrate in bone tissue and their similar types of distribution. In this connection it should be remembered that during prolonged intake the accumulation factor (the ratio of the content of the element in the whole skeleton to the daily intake per os) is different for the three alkali-earth elements Ca, Sr^{90}, and Ra^{226}, which are selectively absorbed in the the skeleton; its value is 1000, 45, and 20, respectively, for these elements [7]. The problem for subsequent investigations will be not only to determine the magnitudes of discrimination coefficients and protection coefficients for various steps in biological chains, but also to discover the mechanisms underlying the differences in distribution of elements that are similar in chemical properties.

SUMMARY

When pregnant sheep are fed radioactive hay with a specific activity of 0.05 μC/kg body weight for a period of six months, the concentration of Sr^{90} in the skeleton reaches 0.263 μC/kg. This concentration is 14.6 times as high as the concentration in the skeleton of the fetus. During Sr^{90} migration within the biological chain, discrimination occurs between Sr^{90} and calcium. Discrimination coefficients for the chains plant-to-mother and plant-to-fetus are 0.21 and 0.091, respectively; the protection coefficients, which are the reciprocals of the discrimination coefficients, are 4.37 and 10.9, respectively.

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