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Iron-55 in Humans and Their Foods

Abstract. *Measurable quantities of iron-55 are present in people, animals, and food. The amount in Eskimos and caribou at Anaktuvuk, Alaska, is about eight times that in residents and cattle near Richland, Washington. Meat and grains are the foods that contribute most to the body burdens of iron-55 in human beings.*

Iron-55 is one of several activation products produced in relatively high abundance by the nuclear detonations of the U.S.S.R. and the United States in 1961–62. Periodic measurements of this radionuclide in fallout have been made at several locations in the United States (*1*). We recently found Fe^{55} in the blood of Alaskan caribou, and have since measured the content of this isotope in Eskimos, in residents of Richland, Washington, and in the food of both.

Iron-55 is a nuclide which decays by electron capture. The only easily detectable radiation it emits is a 5.9-kev x-ray in 28 percent of the disintegrations. To detect this low-energy x-ray, we used an argon-methane gas-flow proportional counter with a thin [0.00015-inch (0.0038-mm) aluminized Mylar] entrance window. The 5.9-kev photopeak counts were determined with a multichannel analyzer. To reduce the background count rate, the counter was placed between two 4- by 9⅝-inch (10- by 24.4-cm) NaI(Tl) scintillation crystals which act as anticoincidence shields, and this system was surrounded by 4 inches of lead shielding. The minimum amount of Fe^{55} detectable with this system is 0.008 nc at 99-percent confidence in a 1-hour count.

The samples for counting were ashed and dissolved in 6*M* HCl; the iron was extracted with 20 percent Alamine-336 in xylene. The iron was then stripped into 1*M* $HClO_4$, precipitated as the hydroxide, redissolved in a 6*M* H_2SO_4 solution saturated with $(NH_4)_2C_2O_4$, and electrodeposited onto 3.85-cm copper planchets by the method of Maletskos and Irvine (*2*).

Table 1 gives our measurements of the concentration of Fe^{55} in the blood of humans, caribou, and cattle; each figure represents analyses of duplicate 20-ml samples. Estimates of the total blood volumes came from the literature; we then assumed that 60 percent [values up to 73 percent have been reported (*3*)] of the iron in the body was in the blood and so estimated the total body burden.

Eskimos contain about eight times as much Fe^{55} as Richlanders. Similarly, the concentration in caribou, which the Eskimos eat, is about eight times that in cattle slaughtered near Richland. Since a steer weighs about five times as much as a caribou, the total body burdens of the animals differ by less than a factor of two. We assume that the high burdens of Fe^{55} in Eskimos and caribou result, like those of cesium-137 (*4*), from accumulation of the radionuclide on lichens.

Analysis of a sample of lichen collected at Anaktuvuk, Alaska, in September 1964 showed the Fe^{55} content to be 14 nc per kilogram of dry lichen. Eskimo body burdens range from 32 to 89 nc; those of Richland residents, from 4 to 16 nc. The average Eskimo burden of 61 nc should be compared with the maximum permissible body burden of 100,000 nc for members of the general population who are not exposed in the course of their occupations (*5*).

It seems likely that the main source of Fe^{55} for the Anaktuvuk Eskimos is caribou meat, which constitutes about 40 percent of their total diet (*6*). However, we found that Eskimos with the highest body burdens of cesium-137 did not necessarily have the highest burden of Fe^{55}; in fact two Eskimos with the highest cesium-137 burden had the lowest Fe^{55} burden. This fact corroborates the finding of other investigators, that uptake and retention of these isotopes is not the same for each individual. To determine the main sources

Table 1. Content of Fe^{55} in humans, cattle, and caribou.

Date sampled	No. of subjects/total blood vol.*	Fe^{55} Blood (nc/liter)†	Fe^{55} Total body content (nc)†
	Anaktuvuk Eskimos		
Jan. 1965	7/5	7.3	61
	Richland residents		
Nov. 1964	4/5	0.96	8
	Alaskan caribou		
Jan. 1965	11/5	87.4	728
	Washington cattle		
Jan. 1965	8/27	9.9	440

* Total blood volume (in liters) per subject is estimated. † Average.

Table 2. Content of Fe^{55} in various foods purchased in December 1964. Sample numbers are in parentheses; stable Fe and Fe^{55} are expressed per kilogram of sample.

Food	Content: Stable Fe (mg)	Content: Fe^{55} (nc)
Alaskan caribou		
Round steak (1)	53	3.6
Round steak (2)	43	2.9
Liver	208.8	28.7
Washington State meats		
Beef, round steak (1)	22	0.86
Beef, round steak (2)	25	.92
Beef, round steak (3)	22	.30
Beef liver (1)	95	.95
Beef liver (2)	45	1.2
Elk, lean (1)	30	1.7
Elk, lean (2)	37	1.8
Bologna	9.1	.34
Pork and ham loaf	16	.06
Pork chops	6.7	.013
Hamburger	27	.25
Weiners	12	.21
Pacific seafoods		
Smelt	8.1	7.47
Salmon	5.0	3.42
Tuna (1)	6.9	6.42
Tuna (2)	2.3	5.19
Cod	3.1	0.24
Clams	17.7	.045
Oysters	170	.087
Oysters (Atlantic)	98	.057
General		
Whole-wheat flour (1)	29	0.31
Whole-wheat flour (2)	46	.27
Bleached white flour (1)	30	.065
Bleached white flour (2)	31	.036
Bleached white flour (3)	33	.049
Bleached white flour (4)	31	.026
Wheat flakes	56	.25
40% Bran flakes	48	.37
Quaker oats	41	.15
Eggs (1)	25	.54
Eggs (2)	20	.055
Eggs (3)	23	.16
Lettuce*	4.5	.011
Carrots*	4.1	.028

*Average, 3 samples.

of Fe^{55} for Richland residents, we analyzed some of their common foods (Table 2). Meat, grain products, and some eggs are probably the main sources. Cooling water from the nuclear reactors upstream from Richland empties into the Columbia River from which the inhabitants derive their drinking water, but analysis of this water showed only 0.0005 nc of Fe^{55} per liter —an insignificant contribution to the total body burden.

Since whole-wheat flour from various sources contains ten times as much Fe^{55} as does bleached white flour, the Fe^{55} is probably associated with the outer shell of the wheat. We have found similar differences with cesium-137 and manganese-54 in whole-wheat and white flour. This difference, plus the fact that vegetables contain very little Fe^{55}, indicates that the radionuclides probably reach the grain directly from the air rather than through the root system. Menzel *et al.* (*7*) and Rivera (*8*) found that most of the strontium-90 in wheat came from deposition on above-ground parts of the plants.

Relatively high amounts of Fe^{55} were found in smelt, salmon, and tuna caught in the Pacific Ocean. The content in tuna is about ten times the content reported by Seymour (*9*) in tuna from the Japanese fish markets in 1962. We do not know the exact location at which the fish we examined were caught; it is possible that some of the Fe^{55} in them may have derived from the Columbia River. Oysters, which tend to concentrate zinc-65 from ocean water (*10*), have low concentrations of Fe^{55} even though they have a higher iron content than any other food measured, except for caribou liver.

Caribou meat and liver samples have a higher content of Fe^{55} than do beef meat and liver from near Richland, as would be expected from the blood measurements. It is interesting that the content of stable iron in the meat and liver of Alaskan caribou and elk from Washington is also much higher than that in beef meat and liver.

Since the rate of fallout is now decreasing (*11*), the difference between amounts of Fe^{55} in Eskimos and residents of Richland will probably become greater. Because of the long retention of fallout nuclides by the lichens, the amounts in the caribou and Eskimos will increase until the rate of fallout is less than the rate of decay of the already deposited Fe^{55}, whose half-life is 2.7 years. Because of the short period of availability of the isotope on vegetation near Richland, we expect its concentrations in cattle, humans, and foods to decrease much sooner and more rapidly than in Eskimos and caribou.

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Adult Thymectomy: Effect on Recovery from Immunologic Depression in Mice

Abstract. *A/Jax mice treated for 1 week with rabbit antiserum to A/Jax lymphocytes showed peripheral lymphopenia and tissue lymphocyte depletion which persisted for 4 weeks after initiation of serum treatment. During this time, such animals showed depression of the humoral antibody response and inability to reject skin allografts. After 4 weeks, mice recovered from effects of serum treatment. Normal blood and tissue lymphocyte levels returned, and immunologic competence was restored. Thymectomy of A/Jax mice (8 to 10 weeks old) prior to serum treatment resulted in peripheral and tissue lymphopenia and depression of antibody formation, which persisted twice as long as that shown by animals given serum alone. Similarly, skin allografts survive two to four times longer in serum-treated thymectomized mice, and, in some cases, persisted over 100 days in perfect condition.*

Thymectomy in mice performed within 24 hours of birth usually results in a syndrome characterized by progressive weight loss, cachexia, lethargy, ruffled fur, diarrhea, and, in a large proportion of the animals, subsequent death (*1*). Characteristically in such thymectomized animals there is a depletion of small lymphocytes in the blood and lymphoid tissues (*2*). These mice show immunological incompetence as determined by (i) impaired ability to reject skin allografts and xenografts (*3*) as well as grafts of normal and neoplastic allogeneic cells (*4*), and (ii) by decreased ability to form antibody to a number of antigens (*5*). In contrast, mice thymectomized at 8 weeks of age also show decreased numbers of small lymphocytes in the peripheral blood and lymphoid tissues, but immunological competence is unimpaired (*6*). Similarly, thymectomy of adult rabbits (*7*), rats (*8*), and guinea pigs (*9*) has no effect on immunological competence as determined by humoral antibody formation or skin allograft rejection. Under special circumstances, however, the adult thymus is important to the restoration of immunological competence. Thus, Claman and Talmadge (*10*) rendered mice tolerant of bovine γ-globulin by injections of this antigen from birth to adulthood and found that thymectomy of such mice as adults impaired, but did not abolish, their recovery from the tolerant state. Similar results with this antigen and also with bovine serum albumin have been reported by Taylor (*11*). Normal adult mice given a potentially lethal dose of ionizing irradiation followed by infusion of isogeneic bone marrow recover normal immune responses 4 to 10 weeks after irradiation and bone-marrow therapy. However, adult mice thymectomized prior to irradiation and bone-marrow therapy failed to respond to skin allografts and sheep erythrocytes 2 months after irradiation (*6, 12*). The recovery of