Table I. Results Secured with Male Weanling Rats in a 51-Day Liver Vitamin A Storage Study with Two Diets and Two Dispersion Materials

Lot No.	Test Ration	I.U. Vit. A Daily	Carrier of Vit. A	Av. Daily Gain, Grams	Av. Wt. Livers, Grams	Av. I.U. Vit. A. per Gram Liver	I.U. Vit. A per Liver	I.U. Vit. A Increase per Liver	I.U. Vit. A Stored per Day	% of Daily Dose Stored
					(Five rats started)					
Control	None	...	...	...	2.3	115.2	265	...	...	...
1	USP XIV	1.2	CS Oil[a]	3.7	9.6	0	0	(−265)	...	...
2	USP XIV	40	CS Oil	3.8	10.2	52.7	538	273	5.4	13.2
3[b]	NFDM	1.2	CS Oil	1.2	3.9	17.3	68	(−197)	...	...
4	NFDM	40	CS Oil	1.5	4.7	157.4	740	475	9.3	23.2
5[c]	NFDM	1.2	DCA[d]	1.2	3.5	30.1	105	(−160)	...	...
6[b]	NFDM	40	DCA	1.6	5.0	154.7	774	509	10.0	25.0
7	NFDM[e] + 5% Fat	40	Oil	2.3	5.7	135.1	770	505	9.9	24.8
8	NFDM[e] + 5% Fat	40	DCA	2.3	4.5	176.1	792	527	10.3	25.8

[a] Cottonseed oil. [b] 1 Rat died. [c] 2 Rats died. [d] Desoxycholic acid. [e] 5% Cottonseed oil added.

influence on the utilization of vitamin A from NFDM. Further evidence that fat does not influence utilization of vitamin A from NFDM is apparent from lots 7 and 8, wherein inclusion of 5% cottonseed oil did not increase liver vitamin A storage from vitamin A in oil or vitamin A desoxycholate over that secured without additional fat (lot 6). Therefore, vitamin A utilization from NFDM is unrelated to added fat content and appears, like vitamin D (*4–6*), to be absorbed in association with milk proteins. If fat is needed for effective utilization of vitamin A in NFDM by the rat, the 1.2% fat in NFDM is adequate. Absorption of vitamin A from the NFDM ration is superior to absorption from the stock diet containing 5% fat.

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CATTLE AS FALLOUT MONITORS

Iodine-131 in Bovine Thyroid Glands from 1957 through 1961

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Iodine-131 accumulation by cattle thyroids has been studied under a variety of circumstances. Van Middlesworth (*16, 17, 19, 20*), Wolff (*22*), and Blincoe and Bohman (*2*) reported on I^{131} concentrations subsequent to nuclear weapons tests. Iodine-131 accumulation by the thyroid glands of domestic ruminants was also reported after a nuclear reactor accident by Van Middlesworth (*18*) and Robertson and Falconer (*13*). Because of the short half-life of I^{131} (8.08 days), its presence indicates recent releases of fission products and is uncomplicated by older fallout.

This paper reports on thyroid I^{131} concentrations of cattle maintained in desert environments under a variety of fallout conditions.

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Methods

Two general categories of cattle were used for these studies: cattle maintained on desert range areas in Nevada, and cattle slaughtered by a packing plant in Reno, Nev.

Figure 1 indicates the locations of the three test herds of range cattle used in this study. All animals were grade or purebred Herefords. Cattle at the two southern locations (DV and NTS) sub-

The thyroid I^{131} concentrations in Nevada range cattle at three locations and in Reno slaughter cattle were studied from late 1957 to the resumption of nuclear weapons tests in September 1961. Local and distant nuclear weapons tests of low and high yield and reactor tests were detected. A constant, small (1 pc. per gram) concentration of I^{131} was observed in bovine thyroid glands in the absence of reported releases of I^{131} to the atmosphere. Range cattle are efficient monitors of the iodine^{131} in the biosphere.

sisted on desert range alone except for occasional concentrate feedings during the winter if the range was insufficient for their maintenance. The KC herd was on the range during the summer and was fed locally produced native grass hay during the winter. Considerable differences exist between the environments of the grazing areas. The KC location is representative of the sagebrush-grass range of the northern great basin. The DV and NTS locations were both salt desert shrub ranges typical of southern great basin and southwestern United States range conditions. The KC cattle were at 5400 feet elevation (datum mean sea level), whereas the NTS and DV herds were at about 3500 feet elevation. At all three locations the cattle ranged in and out of mountain areas depending on the condition of the range, availability of water, etc. The NTS and DV cattle were approximately 300 miles south of the KC herd. The NTS herd grazed areas of the Nevada Test Site of the U. S. Atomic Energy Commission usually east of those areas used for nuclear research. The DV herd was approximately 30 miles east of the Nevada Test Site boundary. Air movement in this part of Nevada when atmospheric nuclear weapons tests are conducted is generally from southwest to northeast.

Twice yearly, from the fall of 1957 through the spring of 1961, representative cattle were slaughtered from the three herds. At each sampling period after the first few, a calf, a yearling, a 2-year-old, a 3-year old, and an older adult animal were sacrificed from each herd and their thyroid glands removed. The detailed slaughter program is given in Table I and the slaughter dates in Table II. Concomitant with the fall 1960 and spring 1961 samplings of the NTS herd, three mature cows from near St. George, Utah, were also slaughtered. Table III lists the known releases of I^{131} relative to these samplings.

From 1959 through 1961, thyroid samples were collected from cattle slaughtered in a Reno, Nev., packing plant. The only selection practiced was that glands were not taken from very young animals. The greater rate of iodine metabolism (*1*) and the different diet of calves would have negated comparison of such data with those from older animals. Individual histories were not available on most animals. It is estimated that at least 90% of the animals slaughtered spent the 60 days prior to slaughter within 100 miles of Reno and within the rain shadow of the Sierra Nevada Mountain range.

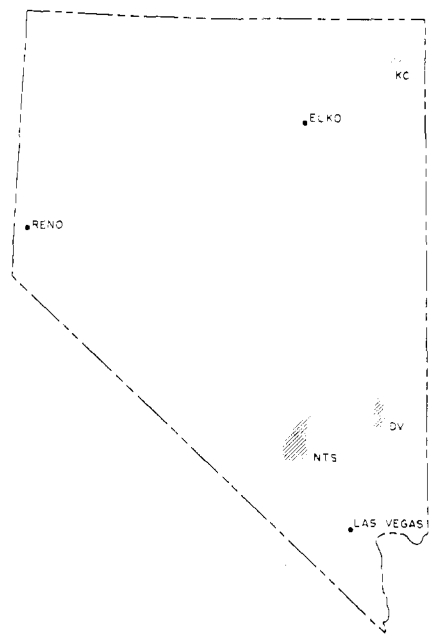

Figure 1. Locations of test herds of range cattle

In all cases, the thyroid glands were removed immediately following slaughter of the animals. With the exception of the Reno packing plant samples, the thyroid glands were placed in plastic bags containing paraformaldehyde and were transported to Reno for radiation measurements. The glands removed in

Table I. Experiment Design—Sampling Procedures for Each Herd

Period	Calves	Yearlings	2 Yr.	3 Yr.	Older Adult	Total per Sample Period
Fall 1957[a]	2	2			1(2)[b]	11
Spring 1958	1	1	1[c]		1	10
Fall 1958	1	1	1		1	12
Spring 1959	1	1	1		1	12
Fall 1959	1	1	1	1	1	15
Spring 1960	1	1	1	1	1	15
Fall 1960	1	1	1	1	1	15
Spring 1961	1	1	1	1	1	15

[a] NTS and DV herds only. [b] Two adults slaughtered from DV herd only. [c] Two-year-old from NTS herd only.

Table II. Experiment Design—Slaughter Dates

Period	NTS	DV	KC
Fall 1957	11/27–12/12/57	12/5–9/57	...
Spring 1958	6/2–3/58	5/27/58	5/27/58
Fall 1958	11/21/58	11/14/58	11/6/58
Spring 1959	4/24/59	4/30/59	5/8/59
Fall 1959	11/12/59	11/5/59	11/19/59
Spring 1960	4/29/60	4/22/60	5/7/60
Fall 1960	11/8/60	10/19/60	11/16/60
Spring 1961	5/23/61	5/31/61	5/17/61

Table III. Known Releases of I^{131} in Relation to Thyroid Sampling Dates in Nevada

Time Sampled	I^{131} Releases
Fall 1957	Plumbob series (5/21 to 10/7/57) Nevada Test Site British series (to 12/57), Pacific ocean. U.S.S.R. series (to 12/57). Safety tests (12/57) Nevada Test Site NTS herd assembled 12/57
Spring 1958	No local nuclear tests. Hardtack, Phase I (4/58 to 8/58) Pacific. British series (4/58 to 9/58), Pacific
Fall 1958	Hardtack, Phase II (9/12 to 10/30/58), Nevada Test Site Sampling immediate post testing
Spring 1959	Testing moratorium
Fall 1959	Testing moratorium
Spring 1960	Testing moratorium. French tests (2/60 to 4/60). Sahara desert
Fall 1960	Testing moratorium. "Kiwi" reactor tests (7/8/60, 10/19/60), Nevada Test Site
Spring 1961	Testing moratorium. French tests (12/60), Sahara desert

the commercial meat packing plant were measured immediately after removal without preservation.

Iodine-131 was determined on 4.0 ± 0.1 gram (fresh weight) samples of thyroid tissue by the method of Van Middlesworth (*17*). Insofar as possible, both lobes of a gland were sampled from at least two locations. Tissue from the isthmus was not used. The gland tissue was dissected free of extraneous tissues. Samples were placed in new plastic test tubes, and the I-131 content was measured using a well-type scintillation counter, pulse-height analyzer, and scaler. The 0.364-m.e.v. gamma ray of I-131 was counted with the pulse-height analyzer set to accept only gamma ray energies between 0.359 and 0.369-m.e.v. (10-kv. band width). All samples were counted on two measurement systems of different manufacture (Table IV) and the results averaged. Samples were counted for 1 hour. Thirty-minute background counts were made between samples and all background data collected on a given day were averaged. Standardization was accomplished by counting capsules containing known activities of purified I^{131}. All data were decay corrected to 10:00 AM PST on the day of slaughter.

Data for calculation of the precision of measurement were compiled by random selection of no more than two values collected on any one day. Only data collected during the period without nuclear weapons testing and only data from Reno samples were used for these calculations.

Thyroid I^{131} metabolism has been studied in various species in considerable detail (*8*). Because many of the kinetic rate constants for thyroid I^{131} metabolism are known, it is possible to extrapolate from a single measurement and predict with reasonable accuracy the concentrations at prior and later times (*5, 11*). Thyroid I^{131} of cattle has been observed by this group (*2*) and others (*17*) to decrease with an apparent half-life of 6.6 days following fallout contamination. This value of 6.6 days for the combined physical and biological half-lives (effective half-life) was used in all extrapolations of thyroid I^{131} concentration.

In the event that I^{131} contamination of feed is sudden, it will take some time for the thyroid gland to acquire its maximum concentration of I^{131}. Robertson and Falconer (*13*) developed a relationship for the thyroid I^{131} concentration as a function of time after contamination of feed with I^{131}. This relation assumes the contamination was essentially instantaneous and that nothing other than physical decay removes I^{131} from the feed. This latter assumption appears to be valid in arid regions such as Nevada. This equation and the rate constants for thyroid function of cattle (*3*) show that the maximum thyroid concentration should occur 12 days after contamination of the feed. This was used in calculating the maximum I^{131} concentration after sudden contamination of feed either by a single release of I^{131} or by moving animals to a region of high feed contamination. If the animals were on the same range throughout a test series, it was assumed that their thyroid I^{131} concentrations were at equilibrium with their dietary I^{131} at all times. In these cases, the thyroid I^{131} at the conclusion of a test series was estimated by extrapolating the values measured after conclusion of the test series to the last day of the series.

Table V. Analysis of Variance Summary—Influence of Age and Location on Thyroid I^{131} Concentrations

Source of Variance	Degrees of Freedom	Mean Square
Age	4	0.595
Location	1	2.31[a]
Age × location	4	1.20
Error	19	0.31
Replications	1	1.80

[a] Significant (P = 0.025).

Results and Discussion

Pertinent characteristics of the two measurement systems used are given in Table IV. The two counting systems were quite comparable in signal-to-noise ratio. For samples collected in the absence of atmospheric nuclear weapons testing, the standard deviation of measurement (precision), as determined by comparing measurements on the same sample from both measurement systems, was 0.67 pc. (picocuries or micromicrocuries) I^{131} per gram. The precision of either counting assembly alone was 0.48 pc. per gram as determined by replicated counts (*23*). The standard deviation of samples collected during the periods of atmospheric testing, as determined by the total number of counts collected, ranged between 1 and 3% of the reported values.

Since a portion of the data presented in this study concerns very low concentrations of I^{131} in thyroid glands in the absence of known releases of I^{131} to the atmosphere, it is necessary to present evidence that the radioactivity measured was I^{131}. For these purposes, data collected on Reno slaughter cattle during periods without known releases of I^{131} were used. The radioactivity was measured counting only a narrow (0.010 m.e.v.) band of gamma ray energies centered around the energy of the I^{131} gamma ray (0.364 m.e.v.). Counts made on 4-gram samples of muscle tissue from each animal sacrificed indicated no detectable activity; therefore, the radioactivity measured is peculiar to the thyroid gland as is the presence of iodine. Several samples were counted at two or more times after slaughter. The radioactivity was observed to decrease with a half-life of 4 to 12 days. More precise half-life measurements were not possible due to the high measurement error with these small amounts of radioactivity. Since the radioactivity measured was peculiar to the thyroid gland of the same gamma ray energy as I^{131}, and decayed with a half-life comparable to that of I^{131}, it was concluded that the activity measured was probably I^{131}.

Range Cattle. Analysis of variance on data collected at two locations (NTS and KC) in the absence of known releases of I^{131} (fall 1959 and spring 1961) revealed no significant effect of age on the thyroid I^{131} content but did indicate a slightly significant (P = 0.025) influence of location on thyroid I^{131} concentration (Table V). No interaction was found between age and location. With age of no influence, the

Table IV. Comparison of Counting Systems

System	N	T	Units
Av. background	2.80	2.07	Counts per min.
Av. total background counts collected per day	496	384	Counts
Std. dev. of counting the av. background	0.13	0.10	Counts per min.
Counter efficiency	5.0	2.8	Per cent

Table VI. Mean Thyroid I^{131} Concentrations in Range Cattle

Slaughter Dates	Pc. I^{131} per Gram[a]				
	NTS	DV	KC	Reno[b]	Saint George[c]
11/29–12/12/57	286	534	...	...	...
5/20–6/3/58	4,640	244	75	...	...
11/6–11/21/58	129,000	7640	5590	48	...
4/24–5/28/59	15	19	18	1.1	...
11/5–11/19/59	1.7	4.4	1.6	0.90	...
4/22–5/7/60	13.9	14.1	2.8	1.2	...
10/19–11/16/60	425	0.25	1.7	0.53	29.3
5/17–5/31/61	1.7[d]	1.6	0.59	1.2	0.26

[a] Corrected to 10 A.M. PST on the day of slaughter. [b] Reno data are the mean of several sets of samples taken from 7 days before to 7 days after the slaughter dates. [c] St. George, Utah. [d] Three cattle slaughtered 5/2/61 averaged 1.1 pc. I^{131} per gram.

data from each sampling at each location were averaged and are tabulated in Table VI. Age is known to influence both the uptake and turnover of I^{131} by cattle (*7*). Most of the change, however, occurs in young calves. Animals at 9 months of age are very similar to adults. Since the "calf" group included animals ranging in age from a few weeks to almost a year, it is not surprising that no difference was observed between this heterogeneous group and the older animals.

The thyroids collected in the fall of 1957 (Table VI) were taken 2 months after the conclusion of the Plumbob nuclear weapons test series at the Nevada Test Site of the U. S. Atomic Energy Commission. A simultaneous test series by the Soviet Union was reported to have ended a few days after the termination of the Plumbob series. Knowing these dates, and assuming a total (biological and physical) half-life of I^{131} in cattle of 6.6 days (*2*, *17*), one can compute the probable concentration of I^{131} in the thyroid glands of these cattle at the conclusion of the Plumbob test series. For the NTS group, this concentration is estimated to be 156,000 pc. per gram (0.16 μc. per gram) and for the DV group 32,000 pc. per gram (0.03 μc. per gram). Since samples were not taken frequently during the test series, one cannot calculate the total radiological dose to the thyroids of these animals resulting from these test series.

The spring 1958 thyroid samples (Table VI) were taken during the U. S. Hardtack I and a Soviet Union test series. Both test series were conducted at considerable distances from the experimental cattle. Hardtack I was conducted at the Pacific Proving Grounds of the U. S. Atomic Energy Commission and the U.S.S.R. tests in Siberia. These data thus represent "distant" fallout from these tests. The concentrations found (75 to 4640 pc. per gram) were of the same order of magnitude as those reported by Van Middlesworth (*17*, *19*) at locations remote from 1954, 1955, 1956, and 1957 nuclear weapons tests. The reasons for the greater concentration of I^{131} in cattle thyroids from the NTS location (mean, 4640 pc. per gram; range, 2460 to 5710 pc. per gram) than from the DV location (mean, 244 pc. per gram; range, 77 to 395 pc. per gram) at this time is obscure. An atmospheric test took place in December 1957, on the Nevada Test Site (Table III), but it is improbable that this test could affect the thyroid I^{131} concentrations over 20 half-lives later. No release of fission products from the Nevada Test Site was reported during the Spring of 1958. No unusual weather conditions were reported (*21*) prior to this sampling in southern Nevada.

The Fall 1958 samples (Table VI) were taken shortly after the conclusion of a nuclear weapons test series on the Nevada Test Site (Hardtack II) and near the conclusion of a weapons test series in Siberia. The day following the last tests on the Nevada Test Site, the NTS herd was moved to graze the area on which the above-ground tests had been conducted on and prior to October 31, 1958. They were allowed to range and graze that area at will. The maximum I^{131} concentration in these cattle should have occurred 12 days after the cattle started grazing this highly contaminated area. The extrapolated I^{131} concentration at this time would have been 280,000 pc. per gram (0.28 μc. per gram). This is considerably higher than any previously or presently reported bovine thyroid I^{131} concentrations. Wolff (*22*) observed higher values in sheep from southwestern Utah in 1953. The authors' cattle were managed to obtain the maximum possible degree of contamination from the weapons tests. In effect, they grazed "ground zero." The DV herd thyroid I^{131} concentrations represent a composite of decaying local fallout from the Nevada Test Site and fallout from the U.S.S.R. tests. The KC herd probably reflects great basin conditions remote from both Nevada Test Site and Soviet Union nuclear weapons tests. The values at KC are substantially greater (mean: 5590 pc. per gram; range: 4430 to 7560 pc. per gram) than northern hemisphere levels reported for previous weapons tests (*17*), reflecting the more frequent releases of I^{131} during this period of accelerated testing. Reno area slaughter cattle were markedly lower than KC cattle. This probably reflects the special dietary and management conditions of feed lot cattle prior to slaughter which will be discussed later.

From late 1958 until late 1960, only four small nuclear detonations were reported. The samples taken in the fall of 1960 reflect release of I^{131} from an experimental reactor and will be discussed separately. The samples collected in April and May of 1959 (Table VI) at the KC, DV, and NTS locations gave essentially identical concentrations of I^{131}. This level, about 10 times that observed in Reno slaughter animals in the absence of nuclear weapons tests, is felt to be residual from the fall 1958 Soviet test series, which appears to have ended in December. The fall 1959 and spring 1961 samples (Table VI) illustrate levels associated with the absence of known releases of I^{131}, and are comparable to, though higher than, Reno area slaughter samples.

The spring 1960 samples from NTS and DV animals are significantly higher than either the KC samples or any Reno slaughter animals (Table VI) sampled during the period without nuclear weapons tests. Fallout from the French nuclear detonation of February 13, 1960, was observed in Reno area slaughter cattle 38 days later (March 22) on its second trip around the world. The French test of April 1, 1960, was of lower fission yield than the test of February 13, 1960. Increased thyroid I^{131} concentrations were not observed in Reno area slaughter cattle. The NTS and DV samples on April 29 and 30, 1960, were taken 29 and 30 days after this second test and indicate possible contamination from this test. If the NTS and DV cattle do reflect the French weapons test of April 1, then the data from KC and Reno indicate that this fallout did not extend that far north.

Kiwi Reactor Tests. During the summer and fall of 1960, two tests of the "Kiwi" reactor (*14*) were conducted on the Nevada Test Site of the U. S. Atomic Energy Commission. The test of October 19, 1960, took place immediately prior to the fall herd sampling. The DV herd (100 miles east of the reactor) was sampled 8 hours prior to the reactor test. Five animals from the NTS herd and three adult dairy cows from St. George, Utah, were slaughtered 3 weeks after the reactor test. These

Table VII. The Effect of "Kiwi" Reactor Test of October 19, 1960, on Bovine Thyroid I^{131}

Location	Date	Distance and Location from Reactor	Thyroid I^{131}, Pc. Per Gram: Mean	Range
NTS	11/8/60	45 mi. northeast	425	265–605
St. George, Utah	11/8/60	140 mi. east	29	18–47
DV	10/19/60	100 mi. east	0.2	0.05–0.45
Reno	10/24/60	270 mi.	0.2	0.1–0.5
	11/22/60	Northwest	0.5	0.1–1.0

Table VIII. Calculated Values from Kiwi Reactor Test Data

Location	Maximum I^{131} Concentration, Pc. per Gram	Body Burden of I^{131} μc.	Thyroid Dose, Rep
NTS	983	0.15	0.18
St. George, Utah	68	0.01	0.013

data, and data on Reno area slaughter animals, are summarized in Table VII. These data make it possible to extrapolate to the maximum thyroid I^{131} concentration in these cattle resulting from this release of I^{131}. The estimated maximum thyroid I^{131} concentrations in the NTS and St. George cattle resulting from the "Kiwi" test are given in Table VIII. The estimated maximum I^{131} concentration was about 1000 pc. per gram in the NTS cattle 45 miles east of the reactor and 70 pc. per gram in St. George cattle 140 miles east of the reactor.

Table VIII also gives an estimate of the maximum body burden of I^{131} resulting from this test calculated on an assumed thyroid weight of 34 grams (*4, 10*) and assuming that 30% of the total body iodine is in the thyroid gland (*15*). The total radiation dose received by the average animal was computed by the method of Dunning (*6*). These calculations are based on the assumption of a continuous ingestion of feed contaminated at one time. In these calculations, the contribution of tellurium isotopes which later disintegrate to form radioisotopes of iodine was omitted since it was felt that a high vapor pressure would have been necessary for radioisotopes to escape from the reactor fuel elements. The authors assumed that only preformed I^{131} escaped the reactor. It was found (Table VIII) that the NTS cattle received a total of 0.18 rep from this reactor test and the St. George cattle a total of 0.01 rep. These figures represent an easily measured uptake of I^{131} from a "distant" (i.e., 45 to 140 miles) propulsion reactor test. They do not indicate that at these distances the levels of I^{131} were sufficient to damage the animals or to present a hazard to those consuming them after slaughter.

Reno Area Cattle—1959–61. During 1959 and 1960, and through August of 1961, only four small nuclear weapons tests were conducted in the atmosphere. This period without testing afforded the opportunity to study bovine thyroid I^{131} concentrations in the absence of known releases of I^{131} and to study the response of bovine thyroid I^{131} concentrations to small, distant nuclear weapons tests.

During 1959 and 1961, the concentration of I^{131} in bovine thyroids was very constant at an average value of about 1 pc. per gram of fresh tissue (Figure 2, Table IX). The early 1959 data are of the same order of magnitude as reported for other locations in the northern hemisphere (*20*). In 1960, the concentration was erratic. The mean concentration for the year was 1.9 pc. per gram and the average concentrations for a single day ranged from 0.2 to 4.9 pc. per gram.

During late December 1959 and the first 47 days of 1960, an increase in bovine thyroid I^{131} concentration was observed (Figure 2). During this period, snow fell in Reno almost daily. After the precipitation stopped, the thyroid I^{131} concentration decreased with a half-period of 6 days to its previous level. The rate of return to normal was the same as that observed subsequent to nuclear weapons tests (*2, 13*). This increase was felt to be due to washing out of I^{131} from the atmosphere by precipitation. It has been demonstrated in several mammalian species that iodine-131 is absorbed primarily through the gastro-intestinal tract (*7, 13*), although calculations have been made assuming pulmonary absorption (*9*). Bovine thyroid I^{131} should thus reflect deposited, rather than air-borne fallout, and should parallel precipitation when I^{131} is present in the troposphere.

Table IX. Yearly Mean Values of Bovine Thyroid I^{131} in Reno

Year	Mean Pc. per Gram	Range of Means, Pc. per Gram
1959	1.0	0.8–1.4
1960	1.9	0.2–4.9
1961 (To 9/1/61)	0.8	0.1–1.2

On February 13, 1960 (day 44), a 60- to 80-kiloton nuclear device was detonated near Latitude 27° N, Longitude 0° (Sahara Desert). A rise in fallout was reported in early March along the 80th meridian in Ecuador (2°S), the Canal Zone (9°N), and in Puerto Rico (18°N), but not farther north (*12*). No increase in bovine thyroid I^{131} was observed in Reno (39°N) between February 13 and March 10. The fallout from this test went considerably south of the western United States during its first pass around the world. A rise in bovine thyroid I^{131} in Reno was noted on March 22, 37 days after the test (Figure 2), (mean, 4.0 pc. per gram; range, 2.4 to 5.4 pc. per gram). The data of Patterson and Lockhard (*12*) indicated the debris was moving about 20° longitude per day, west to east, in the tropics. Based on this figure, the rise of I^{131} in Reno 37 days after the test indicated the debris entered the Reno area on its second trip around the world. A much smaller yield detonation took place at the same location on April 1, 1960. Fallout debris from these tests is felt to be responsible for the instability of the bovine thyroid I^{131} concentrations during the late spring and early summer of 1960. On December 27, 1960, and April 25, 1961, two further atmospheric tests were conducted in the Sahara desert. The fallout from these tests did not result in any observable increase in the bovine thyroid I^{131} concentration in Reno.

The increase observed (Figure 2) in one set of samples on August 11, 1960, (mean: 4.9 pc. per gram; range: 2.7 to 8.0 pc. per gram) corresponds to no publicly announced release of fission products. All glands sampled on this date were uniformly high in I^{131} concentration.

Data on Reno slaughter cattle for the period September 1, 1961, through February 1, 1962, have been published previously (*2*). These data indicated a very marked response to a U.S.S.R. nuclear weapons test series conducted in the atmosphere.

Integration

In the absence of nuclear weapons tests, a small, uniform concentration of I^{131} was found in the thyroid glands of range cattle. In Reno slaughter cattle, this level was found to be about 1 pc. per gram. Range cattle tended to be slightly higher. These differences between categories of ruminant animals probably reflect different dietary conditions.

Possible sources for this I^{131} include unannounced testing of nuclear weapons, natural production of I^{131}, and release of reactor produced I^{131} to the atmosphere. The constancy of the 1959 and 1961 data on Reno slaughter cattle would tend to rule out unannounced testing as a source. The possible natural production of I^{131} could account for the consistency of the 1959 and 1961 data. Carbon-14 and hydrogen-3 are known to be produced in the upper atmosphere by cosmic ray interactions. If I^{131} were similarly produced, one would expect an increase in

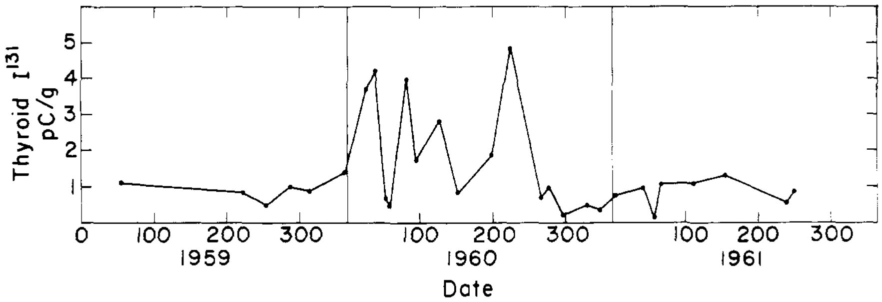

Figure 2. Thyroid I^{131} concentration of Reno packing plant cattle

Each point represents average of four to eight animals thyroid I^{131} in the spring due to increased mixing of air from the stratosphere across the tropopause into the troposphere. Examination of the 1961 data (Figure 2) indicates no increase of I^{131} during the first third of the year. This fact, as well as the lack of potential starting materials for I^{131} production in the stratosphere, would tend to rule out upper atmospheric formation of iodine-131. The release of reactor-produced I^{131} to atmosphere appears to be the most probable source of the constant low level of I^{131} observed in the bovine thyroid glands sampled.

Iodine-131 from nuclear weapons tests at considerable distances from Nevada gave variable results, depending probably on local weather patterns. The French test of February 13, 1960, was detected in Reno Slaughter cattle. The French test of April 1, 1960, however, did not result in increased thyroid I^{131} in cattle in northern Nevada but did elevate the thyroid I^{131} concentrations in cattle in southern Nevada. The north-south separation of these locations is only 150 to 300 miles. Twenty-nine days after this test the fallout cloud was still rather well defined with respect to I^{131} deposition.

In one experiment cattle were moved to forage in an area in which atmospheric nuclear weapons tests (low yield) took place immediately before. The thyroid dose resulting from grazing this highly contaminated range is estimated to be in the range of 50 to 100 rep, exclusive of the dose accumulated during the test series when the animals were grazing more distant ranges. No gross or histological abnormalities were observed in this herd at any subsequent slaughter date. Cattle were safely grazed in the ground zero area immediately after a low yield nuclear detonation. The suitability of the meat of these animals for consumption is unanswered by the present study.

The use of slaughter cattle for study of fallout I^{131} concentrations offers both advantages and disadvantages as compared to range or pasture cattle. The procurement of glands from packing plants is inexpensive; however, the histories of the animals prior to slaughter is unknown. In the present case, the authors are confident that over 90% of the animals spent the 60 days prior to slaughter within 100 miles of Reno and in a great basin environment. The source of feed for slaughter cattle is somewhat variable. Cattle are generally held at the abattoir for varying lengths of time, receiving feed grown many iodine half-lives previously. Prior to arrival at the abattoir, the source of feed and methods of feeding are not known. Thus for a variable period of time before slaughter the only oral intake of I^{131} would be by direct contamination of feed and water. If the principal source of fallout I^{131} is oral rather than respiratory or cutaneous (*7, 13*), then penned slaughter animals will receive less I^{131} than other animals, and their thyroid I^{131} concentration will be below that of the population at large (Table VI). From the standpoint of the study of maximum fallout accumulation by animals, it is preferable to sample range or pasture livestock. From the standpoint of public health the level of fallout contaminants in slaughter cattle is of most interest.

At the present time, it appears that the thyroid gland of ruminants (especially range cattle) is the most sensitive indicator of I^{131} in the biosphere.

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