Influence of Grazing Intensity on Cesium-137 Levels in Milk

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Abstract

The influence of grazing intensity on radiocesium concentrations in cows' milk was studied by the accepted rotational grazing system of the Department of Dairy Industry, Utah State University. Three comparable groups of Holstein cows were chosen. The first group was included in the main herd, the second group followed the main herd in the same rotation but always a plot behind, and the third group had no access to pasture. A difference (P < 0.1) based on per cent deviation was found in cesium-137 levels in the milk of the first and second groups. For further statistical analysis, the data for the first and second groups were classified into two periods, based on whether precipitation occurred during sample collection. No significant difference (P > 0.1) was evident during the rainy period, but a significant difference (P < 0.001) was observed for the dry interval. The correlation coefficient for the same periods was significant (P < 0.0001) and positive. For both groups a significant positive correlation (P < 0.0001) was also obtained for strontium-90 versus cesium-137 concentration in milk. The third group, consuming only hay and grain, excreted 9 to 10% of its total intake of cesium-137 into the milk.

Environmental contamination from the testing of nuclear weapons has created a practical need for a better understanding of the transfer of nuclides from the environment to man. The most significant transmission of radioactive cesium occurs through the pasture-cow-milk pathway (1, 3). Grazing large areas of pasture areas may result in a relatively large intake of the radionuclide by the cows, even when deposition per unit area is quite low. Consumption of fresh milk by the population completes the transfer to man within a few days.

In 1963, the U. S. Public Health Service conducted a cooperative study with the Agricultural Research Service, U. S. Department of Agriculture, and the Agriculture Experiment Stations at the Universities of Minnesota, Iowa, and Utah to investigate the level of strontium units (pCi "Sr/g Ca) in milk under various feeding and management systems. As part of the over-all objective, a corollary study was designed to determine whether the grazing intensity by itself has an effect on the strontium units in milk (2). The samples obtained in the study were also used to investigate the effect of the grazing intensity on the cesium-137 concentration in milk. This later investigation is reported here.

Since milk is consumed daily by most people, especially children, its contamination by radionuclides poses a potential hazard. If radionuclide concentrations in milk can be predicted, preferably before it is marketed, steps can be taken to prevent or reduce the cows' intake of radionuclides and thus assure a safer milk supply.

The radionuclide level in milk depends on the extent of fodder contamination, the amount remaining on the feed at the time of consumption, the amount ingested, and the amount excreted in milk by the cow. Fortunately, only approximately 10% of radiumesium, which is of biological concern, is excreted in the milk (3, 5, 8).

Experimental Procedure

Eight cows chosen from a herd of Holsteins were divided into two comparable groups. Selection of the animals was based on age, freshness date, and weight. The average age and weight of the cows were approximately 6 3/4 years and 585 kg, respectively, for the first group, and 6 1/2 years and 610 kg for the second group. All cows had passed the second month of lactation at the beginning of the experiment. A third group of comparable cattle was selected as a control, to ascertain that differences in cesium-137 concentrations in milk from the
two experimental groups were due only to dietary intake.

The cows of the first experimental group, referred to as the top grazers, were pastured with the main herd under the usual rotational grazing system of the University of Utah. They were moved to a new plot early enough to leave adequate pasture for the second group, the bottom grazers. The bottom grazers followed the top grazers immediately in the vacated plot and in the same rotation, so that they were always grazing one plot behind. Seven pastures divided into 16 experimental plots were utilized. Length of grazing on each plot was governed by the availability of pasture; during the 12 weeks of the study, 37 changes took place. In addition to pasture, the eight cows as a group received daily 36 kg (80 lb) of concentrate and 36 kg of hay ad libitum.

The control animals were individually fed, receiving the same concentrate and hay as the experimental groups. The cows were fed a 1-to-4 grain to 4% fat-corrected milk produced in excess of 9 kg (20 lb) per day and hay ad libitum.

The sampling procedure was quite extensive because the radionuclide concentration in the environment of the animals was not predictable, and rapid changes of activity levels for a given locality are common. Two air samplers, located on the roof of a shed adjacent to the pastures, continuously collected airborne particles. The daily airborne activity collected on glass fiber filters was counted four to six days after collection with a 17.8-em (7-inch)-diameter end-window counter. Approximately four-liter water samples from all possible drinking sources were obtained at weekly intervals. A standard rain gauge and two rain collectors, consisting of polyethylene funnel and disposable bottle, were placed adjacent to the grazing area. The rainwater, acidified at collection, was analyzed for both strontium-90 and cesium-137 by conventional chemical methods, and counted with an anticoincidence low-background beta counter (7). The one lot of hay fed throughout the experiment was sampled at the beginning and once during the study. Concentrate was also sampled at the beginning, again when a second batch had to be used, and at the end of the study period. The original schedule of sampling the pastures one day prior to admittance of the top grazers could not be maintained; however, each pasture was sampled by cutting forage from three random areas of 0.836 sq m (1 sq yd) each. The green material was immediately weighed and then dried at 60 C to obtain the dry-matter content. Cesium-137 in the feed samples was determined by chemical separation and beta counting with an anticoincidence counter. The pastures were flood-irrigated well in advance of the grazing schedules, providing firm soil for grazing.

Milk production of each animal was recorded throughout the study; milk fat tests were performed semimonthly, and composite milk samples from all three groups were obtained from the afternoon and following morning milking at bi-weekly intervals. All milk samples were analyzed for cesium-137 by gamma spectroscopy.

Results and Discussion

Air and Precipitation

The gross beta activity of air particulates, the amount of rainfall, and the cesium-137 deposited by it are shown in Fig. 1. Air filters with gross beta readings above 20 pCi/m² were gamma-scanned, but only one (6/29 to 6/30) revealed appreciable cesium-137. It was estimated that the air contained 0.85 pCi Cs/m², and that 800 pCi/m² was deposited during this 24-hr period. If a daily intake of 130 m³ air and complete retention of the radionuclide by the animals is assumed, they would have inhaled only 110 pCi. Compared to the total intake, this amount was negligible and, since all animals were exposed to the same degree, inconsequential. No attempt was made to relate the cesium-137 deposited by rain to the pasture and milk activities, because the time interval between the samples, which was not constant, had to be considered for each data point.

Drinking Water

Spring, irrigation, and city water samples, obtained from all the possible drinking water sources, contained less than 1 pCi Cs/liter. Based on a daily water intake of 70 liters, the animals could not have received more than 70 pCi/day, a negligible amount compared to the intake from pasture grass.

Feed

The hay used to feed all the animals contained approximately 1,200 pCi Cs/kg. The cesium-137 intake through the concentrate changed, since two feed batches of different radionuclide concentrations were fed. The average cesium-137 concentration for the batch used during June was 130 pCi/kg, and for the one used for the remainder of the period, approximately 500 pCi/kg. This uncertainty did not affect comparisons, however, because the same grain mixture was fed to all cows. Further, the cesium-137 concentration in the grain...
mixture was low at all times compared to that of hay and pasture, and it can be assumed it approximated only 25% of the daily feed intake.

The cesium-137 concentration per pasture area and the wide variations encountered are presented in Fig. 2. Good correlation existed between cesium-137 and strontium-90 values. With one exception, the ratio of cesium-137 to strontium-90 varied only from 1.2 to 1.6, with an average of 1.4; the ratio for the sample obtained on 6/25 was 1.9. The curves for the cesium-137 and strontium-90 concentrations per dry weight were very similar to the one in Fig. 2. All increases and decreases coincided, with the exception of the sample collected on June 14. On this date, the activity on a weight basis was intermediate between the previous and the following level, whereas on an area basis, it was lower than the adjacent levels.

**CONTROL GROUP**

During the study period, the control herd produced approximately 5,825 liters (12,445 lb milk), with an average milk fat content of 3.5%. Based on 21 analyses of milk from the controls, the cesium-137 concentration in milk during this period was $80 \pm 2$ pCi/liter. Since the feed consumption for the same period was approximately 4,000 kg hay and 800 kg grain, the percentage of cesium-137 transferred to the milk can be calculated, assuming that each grain mixture was fed throughout the entire study. For the 130 pCi/kg grain mixture, the excretion was 8.9%, and for the 500 pCi/kg it was 9.5%. The range is well within reported values for tracer studies (4-6, 8).

**EXPERIMENTAL GROUPS**

The cesium-137 concentration in milk from the top and bottom grazers is presented in Fig. 3. An analysis of variance of the cesium-137 per cent deviation between the top and bottom grazers revealed a significant difference ($P < 0.06$). This phenomenon is attributed to the difference in consumption of radioactive cesium while pasturing.

Although the milk radionuclide concentration of the experimental groups was significantly different during the experiment, Fig. 3 shows

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$2 \sigma$ mean error.
only one period where the bottom grazers had consistently more cesium-137 in their milk than the top grazers. A comparison of Fig. 1 with Fig. 3 discloses that this period coincides with dry weather. Therefore, the data were classified into two groups: one included the results from the samples collected during the period when precipitation occurred, i.e., June 6 to July 9 and August 7 to August 23; the other, the results of samples from the dry period. Again, an analysis of variance based on per cent deviation was performed. No significant difference was evident during the rainy period, but a significant difference (P < 0.001) was obtained for the dry interval.

To evaluate the reasons for the difference, data for the same periods were used to calculate the correlation coefficients and their significance. A significant positive correlation was not only obtained for the complete study (r = 0.92; P < 0.0001), but also for the wet (r = 0.93; P < 0.0001) and dry (r = 0.97; P < 0.0001) periods, which indicates the validity of the findings.

That no significant difference was observed during the period when precipitation occurred may be explained as follows: the rain deposited most of the contamination. This is evident by the decreased activity in milk after the July 9, 1963, rain, which was the beginning of the dry period. During rain, both groups had the same amount of wet deposition available, thereby obscuring possible grazing effects. After precipitation ceased, the top grazers, which had more opportunities to graze on wet pastures than the bottom grazers, could have received a greater fraction of the newly deposited radionuclides.

The cesium-137 levels in the milk of the bottom grazers, however, was consistently higher than those in the milk of top grazers during the dry period. Since the study was designed to determine if the grazing intensity affected the radionuclide concentration in milk, and not to elucidate the mechanism for the observed phe-
nomena, the reason for this is not known. It cannot be explained by either air, water, or hay and concentrate consumption. The radionuclide concentrations in air and water were low, and the animals in both groups should have received equal amounts. Concentrate and hay were fed ad libitum to both groups together, but it is unreasonable to assume that the bottom grazers consistently consumed less stored feed and more pasture than the top grazers. Conversely, if the bottom grazers, due to sparse forage, consumed more supplement to receive their fill, their radionuclide intake would have been lowered.

Differences in milk production are factors to consider. The total amount of radionuclides excreted over a period of two days was calculated from the volume of milk produced during the days that contributed to the sample. A comparison of Fig. 3 with Fig. 4, in which the total excretion of cesium-137 is illustrated, shows no important differences and eliminates the milk yields as contributors to the observed effects. This leaves only grazing responsible for the higher radionuclide concentration in the milk of the bottom grazers.

The cows in the second group—the bottom grazers—probably consumed more mat material because they grazed closer to the ground and larger areas. This would increase their radionuclide intake and increase the radioesium concentration in their milk. The mechanism resulting in elevated activity levels in the mat layer is thought to involve washing some of the contamination into the axils of leaves, into the crowns of plants or into the root mat, and the trapping of radionuclides on particles and decaying vegetation where it can be absorbed by the surface roots. Also, in addition to contamination being retained on leaves and on inflorescences of plants, some of it is initially trapped by the basal part of plants. The effect of the choice by the top grazers of more palatable portions of the plant that possibly contained less radioactivity can be ruled out, because of the results of a concurrent study that eliminated selection by utilizing greenchop. Since the difference in the cesium-137 content of milk was noticeable a very short time after deposition of contamination by precipitation, it is unlikely that differential absorption influenced the observed effect. If the described route of entry is correct, it should apply to both cesium-137 and strontium-90, because prefer-

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**Fig. 3.** Cesium-137 concentration per liter milk for top and bottom grazers.
ential uptake by plants and retention by soil would affect only the magnitude of the levels.

Therefore, the correlation coefficients and their significance of strontium-90 versus cesium-137 for both groups were calculated. The correlation coefficients of 0.95 and 0.97 at the 99.99% confidence level for the top and bottom grazers, respectively, strengthen the findings that increased grazing will increase the cesium-137 and strontium-90 concentrations in cows' milk.

Acknowledgments

The author expresses his gratitude to Drs. B. Kahn, G. F. Fries, G. E. Stoddard, and M. J. Anderson and to W. Cox for their valuable suggestions and assistance. I also would like to acknowledge the assistance of Mrs. B. Jacobs and Mrs. M. Hawkins, Radiological Health Research Activities, Robert A. Taft Sanitary Engineering Center, who performed most of the radiochemical analyses, and the Radionuclide Analysis Group, Radiological Health Research Activities, for performing the radioactive measurements.

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