Evaluation of Clays as Binding Agents for Reduction of Radionuclides in Milk

Effect of Belle Fourche Bentonite on Excretion of ^{134}CS in Lactating Goats

Julius Barth,[1] A. N. Mikalis, J. Y. Harris, and B. H. Bruckner

Sodium montmorillonite (Belle Fourche bentonite) effectively reduced the secretion of a single oral dose of ^{134}Cs in the milk of lactating goats when added to the ration at levels of 4% and 8% of the concentrate. The blood levels and urinary excretion of ^{134}Cs were reduced and the fecal excretion of ^{134}Cs was increased considerably.

Mraz and Patrick (1957) reported that bentonite fed to rats greatly increased fecal excretion of subcutaneously administered ^{134}Cs. Barth and Bruckner (1969b) reported that natural Belle Fourche bentonite bound a considerable portion of the ^{134}Cs in an artificial rumen and simulated bovine abomasal and intestinal fluids. Barth and Bruckner (1969a) also reported that in the same system, Belle Fourche bentonite increased the Ca^{2-} ion levels and had little effect on the levels of Mg^{2+}, K^{+}, and Na^{+}.

Although radiocesium is concentrated by certain bacteria and other plants, *in vitro* experiments by Barth and Bruckner (1969b) showed that ^{134}Cs was not concentrated by rumen microflora in an artificial rumen. This suggested that almost all of the radiocesium in rumen juice is in a form available to be acted upon by binding agents in the rumen. As indicated by *in vitro* studies by Barth and Bruckner (1969b), the rumen is the most favorable site in the digestive tract for the binding of radiocesium by natural Belle Fourche bentonite.

Hazzard (1966) reported that verxite, another clay material, reduced ^{134}Cs excretion in the milk of goats.

This paper describes the effects of natural Belle Fourche bentonite added to feed on the secretion and excretion of an orally administered dose of ^{134}Cs in lactating goats.

PROCEDURE

Twelve lactating goats of mixed breeding were randomly assigned and placed in metabolism stalls designed for the separation and collection of urine and feces. Each animal was fed 1500 grams of alfalfa pellets and 650 grams of concentrate mixture daily. The refused portion of the feed was weighed daily to determine consumption. The concentrate mixture contained 537 pounds of ground corn, 250 pounds of ground oats, 100 pounds of wheat bran, 113 pounds of soybean oil meal, 100 pounds of cane molasses, 11 pounds of iodized salt, and 11 pounds of mineral mix per lot.

Belle Fourche bentonite (Volclay B. C., American Colloid Co., Skokie, Ill.) was fed as 4 and 8% of the concentrate mixture. Four goats were kept on each treatment plus four on a control group which received the basal ration only. The animals were given a 10-day preliminary feeding period to allow for adjustment to both the ration and stalls.

U. S. Department of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, Environmental Control Administration, Bureau of Radiological Health, Division of Biological Effects, Rockville, Md. 20852

[1] Present address, Southwestern Radiological Health Laboratory, U. S. Public Health Service, Las Vegas, Nev. 89114

Table I. Percentage ^{134}Cs of Dose per Kilogram of Blood 48 Hours after Dosing

	Whole Blood	Plasma
Control	0.25 ± 0.04[a]	0.17 ± 0.04
4% clay	0.051 ± 0.008	0.030 ± 0.009
8% clay	0.025 ● 0.002	0.016 ± 0.001

[a] Mean ± 1 standard deviation.

One animal in the 8% clay group consistently refused a considerable portion of the concentrate. The data collected on this animal have been eliminated from all of the group averages; however, her results will be discussed on an individual basis.

Following the 10-day preliminary period, each animal was orally administered a single dose of 18 μCi of ^{134}Cs following the evening milking. Three separate trials were run with a 10-day collection period for each. Milking was done by hand, twice daily. A total collection of urine and feces was taken each morning, and samples were taken for radioassay. All animals were bled once per trial, 48 hours after dosing.

Radioassay of milk, blood, and urine samples was carried out in a well-type, dual-channel, gamma spectrometer with automatic sample changer. Ten milliliters of milk, 10 ml. of urine, 5 ml. of whole blood, and 4 ml. of plasma were counted in the first trial. The only difference in trials 2 and 3 was that 4 rather than 5 ml. of whole blood was counted. Fifty grams of dried feces were counted.

RESULTS AND DISCUSSION

Since the excitement of the animals due to the collection of blood samples can affect milk production, the goats were bled only once per trial. Blood samples were taken about 48 hours after dosing. The average radioactivity of both whole blood and plasma is shown in Table I. The addition of Belle Fourche bentonite to the diet clearly reduced the ^{134}Cs levels of both whole blood and plasma. In all cases the levels in the whole blood were higher than in the plasma since cesium enters the red blood cells from the plasma. Hood and Comar (1953) showed a definite entry of ^{137}Cs into the erythrocytes and an active accumulation of this ion by the cells against a concentration gradient. Threefoot *et al.* (1955) have shown that the rate of disappearance of ^{137}Cs from plasma was more rapid than that from whole blood.

There was considerable difference in the milk production of the three groups. Therefore, the milk radiocesium data are presented as percentage of dose per kilogram of milk

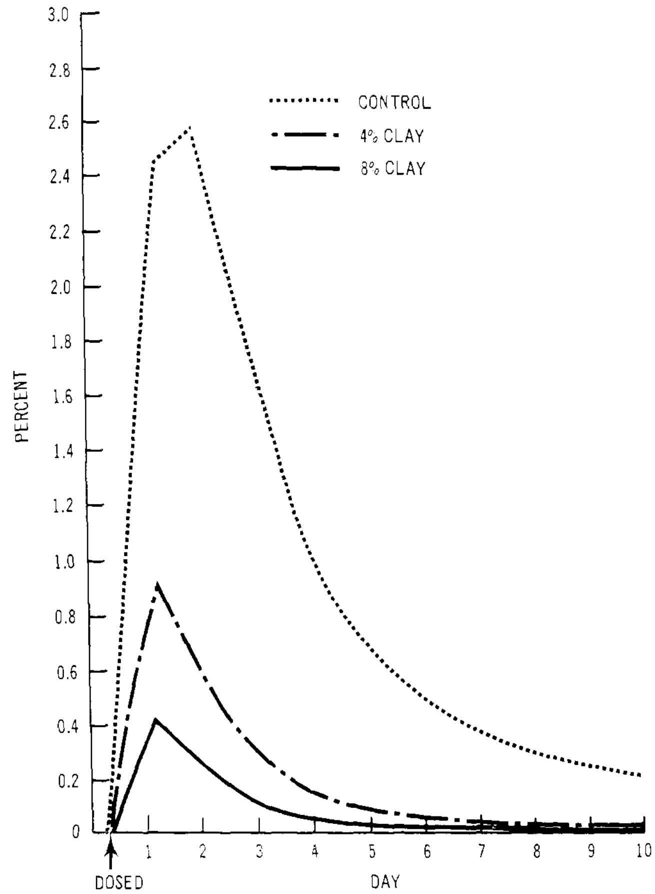

Figure 1. Milk radiocesium data as percentage of dose per kilogram of milk produced

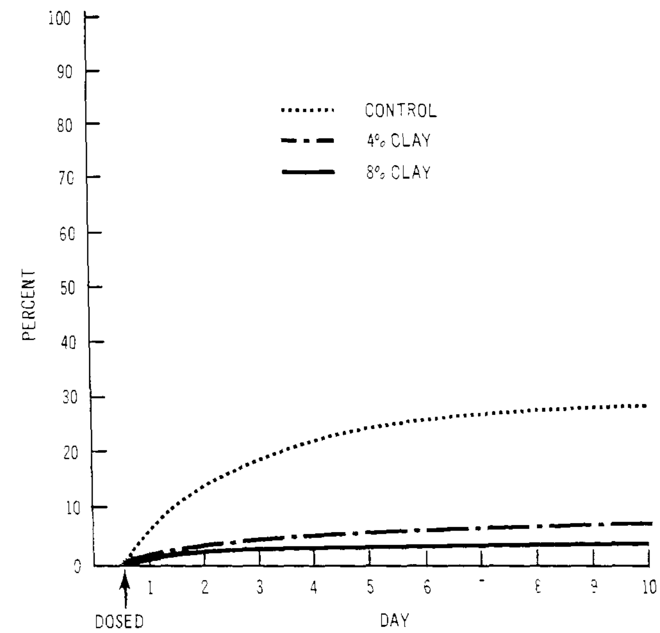

Figure 2. Cumulative urine excretion of radiocesium as percentage of dose per day

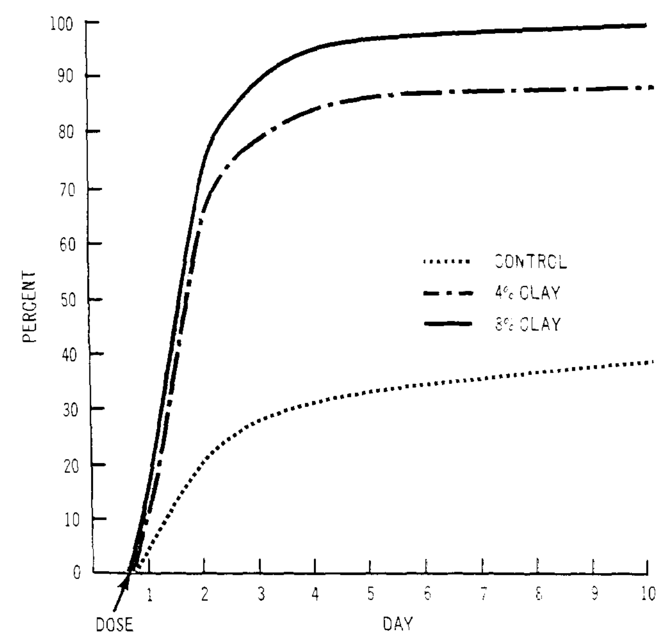

Figure 3. Cumulative fecal excretion of radiocesium as percentage of dose per day

Table II. Analysis of Variance of Cumulative Milk-^{134}Cs Excretion

Source of Variation	DF	SS	MS	F
Total	32	251.81		
Clay levels	2	160.80	80.40	21.85 (p <0.0001)
Trials	2	0.60	0.30	0.08
Clay levels × trials	4	2.19	0.55	0.15
Residual	24	88.22	3.68	

produced (Figure 1). On this basis the clay added to the ration as 4 and 8% of the concentrate reduced the ^{134}Cs excreted in the milk by about 64 and 83%, respectively, on the day of peak ^{134}Cs excretion in the milk. The cumulative 10-day milk excretion of ^{134}Cs, expressed as a percentage of the dose was 6.2 ± 0.3, 1.9 ± 0.3, and 1.2 ± 0.3 for the control, 4%, and 8% clay levels, respectively. All means are presented with ±1 standard deviation.

Table II gives the results of the analysis of variance for the total milk-^{134}Cs excretion observed in the three treatment groups during the three trials. It is obvious that the clay effectively reduced the quantity of ^{134}Cs excreted in the milk ($p < 0.0001$). It may also be noted that the variation between trials was not significant nor was the treatment by trial interaction significant.

Since one goat in the high clay group refused a considerable portion of her concentrate ration each day, her data were omitted from all of the reported group averages and subsequent comparisons. On the basis of the quantity of clay she actually consumed, however (39.4 grams per day), her peak milk radiocesium levels of 0.64% of the dose per kilogram were essentially identical to the value obtained by linear interpolation between the values observed for the 4 and 8% clay groups (0.66% of the dose per kilogram).

The cumulative daily urine excretion expressed as the percentage of dose per day is shown in Figure 2. The average 10-day cumulative excretion of ^{134}Cs *via* the urine for the group of four goats was 28 ± 1%, 7 ± 1%, and 2.6 ± 0.5% for the control, 4%, and 8% clay levels, respectively.

The cumulative daily fecal excretion expressed as the percentage of dose per day is shown in Figure 3. The 10-day cumulative fecal excretion of ^{134}Cs was 39 ± 2%, 88 ± 8%, and 99 ± 9% for the controls, 4%, and 8% clay levels, respectively. By the third day after dosing, about 90% of the dose had been excreted in the feces of goats receiving clay as 8% of the concentrate. This was not approached until the tenth day in goats receiving 4% clay.

The average daily milk production for the three groups was 0.7 ± 0.2 kg., 0.9 ± 0.2 kg., and 1.2 ± 0.1 kg. for the control, 4%, and 8% clay groups, respectively. In the control group, the average milk production fell about 24% between the preliminary period and the last trial. In the 4% clay group, the average milk production fell about 13% while in the 8% group the milk production went up slightly.

Since the differences in the milk production were large, a correlation analysis was made on the data to determine if a correction was required for milk production. The correlation was determined between milk production and milk cesium excretion in the control animals only. The number of values correlated was consequently small, however, neither the relationship between milk production and peak milk cesium levels ($r = 0.56$, $n = 2$), nor that between milk production and cumulative milk cesium excretion ($r = 0.61$, $n = 2$) was significant. Even if there were a general relationship between milk production and milk cesium levels that might have influenced our data, we might logically assume that it would have reduced rather than enhanced our findings with respect to the influence of Belle Fourche bentonite on milk cesium levels since those animals on the clay treatment happened to be the higher producers.

The average daily consumption of concentrate was 0.649 kg., 0.650 kg., and 0.629 kg. for the control, 4%, and 8% clay groups, respectively. The average daily consumption of alfalfa pellets was 1.182 kg., 1.354 kg., and 1.270 kg. for the control, 4%, and 8% clay groups, respectively. The average weight of the animals during the period was 103 ± 4 pounds, 103 ± 8 pounds, and 102 ± 9 pounds for the control, 4%, and 8% clay groups, respectively.

The animals were maintained in the metabolism stalls for a total of three trials and for a total time of 46 days. Milk production dropped in the control and 4% clay groups and most of the animals suffered a loss of weight during the experiment which may be an indication that the animals were restrained too long in the stalls without a rest period. The influence of cage weariness, however, seemed slight, if any, since the results from the three individual trials were very similar. The control group lost an average 6.7 pounds with a range of 1 to 15.5 pounds. The 4% clay group lost an average of 7.6 pounds with a range of 3 to 13.5 pounds. The 8% clay group, with the exception of the goat which refused a considerable portion of her concentrate ration each day, lost an average of 3.7 pounds with a range of 1 to 6 pounds. The goat which refused part of her concentrate lost 17 pounds.

The blood and milk levels and urinary excretion of ^{134}Cs were reduced and the fecal excretion was increased by the Belle Fourche bentonite. Possible toxicological effects, if any, of feeding this clay to ruminants over a long period have not been investigated by the authors; however, no gross adverse effects related to clay feeding for a period of 46 days were noted in this experiment.

The standard deviations of the net sample count rates for the various combinations of counting times utilized and observed background count rates were generally less than 2% of the net count rate for the milk and the urine samples, less than 3% for the feces samples, and less than 6% for the blood samples.

ACKNOWLEDGMENT

The authors thank Warren L. Ridgley, Alice G. Walters, John H. Harris, and Katherine M. Selby. They also thank Wellington Moore, Jr.

LITERATURE CITED

Barth, J., Bruckner, B. H., J. AGR. FOOD CHEM. **17**, 1340 (1969a).
Barth, J., Bruckner, B. H., J. AGR. FOOD CHEM. **17**, 1344 (1969b).
Hazzard, D. G., *J. Dairy Sci.* **49**, 743 (1966).
Hood, S. L., Comar, C. L., *Arch. Biochem. Biophys.* **45**, 423 (1953).
Mraz, F. R., Patrick, H., *Arch. Biochem. Biophys.* **71**, 121 (1957).
Threefoot, S. D., Burch, G. E., Ray, C. T., *J. Lab. Clin. Med.* **45**, 313 (1955).

Received for review July 25, 1968. Accepted July 16, 1969. Reference to a commercial product is not intended to constitute endorsement or recommendation by the Public Health Service over similar ones not mentioned.