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MONTMORILLONITE CLAY IN FEED LOT RATIONS

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With the advent of the field hay-cubing machine, increased use of pellets in livestock rations, and the use of bentonite as a binding agent in cubes and pellets, the possible nutritional role of this material is of interest. There are numerous reports indicating that some silicates have no nutritional value and may be considered as diluents in the diet (Moody, 1963; Ershoff and Bajwa, 1965; Jones and Handreck, 1965). However, there are also reports indicating that some silicates are of nutritional benefit (Jordan, 1953; Erwin, Elam and Dyer, 1957; Quisenberry, 1966; Ershoff and Bajwa, 1965).

The objective of these experiments was to study the nutritional value of a desert clay in feedlot rations.

Experimental Procedure

Ration Processing. All rations were ground and milled. The hay was ground through a 2.5 cm screen, and the barley through a 9.5 mm screen. Nonpelletized beet pulp and stabilized animal tallow were included in all rations. The clay was obtained from the same source as that studied by Ershoff and Bajwa (1965), Quisenberry (1966) and Almquist, Christensen and Maurer (1967), (table 1).

Experiment I. Forty-eight head of crossbred (Hereford x Angus) steers, 15 to 18 months of age, were randomly allotted to two ration treatments in a fattening program (table 1). The animals were kept six to a pen; each treatment was replicated four times. The first 14 days constituted an adjustment period in which increasing amounts of the ration were offered, thereafter they were fed *ad libitum*. Noniodized block salt was available in the pens at all times. All animals were implanted with 36 mg diethylstilbestrol and no vaccines were administered. Initial and final shrunk weights were obtained after 14 to 16 hr. without feed or water.

Experiment II. One hundred sixty-eight crossbred (Hereford x Angus) steers, 6 to 8 months of age, were randomly allotted to four growing rations (table 1). The animals were kept four or five to a pen and fed *ad libitum* after an initial 14-day adjustment period. Ration C_0 was replicated 11 times with one pen containing 5 animals, whereas rations C_2, C_4 and C_4NI were replicated 10 times; rations C_4 and C_4NI each had one pen containing 5 animals (table 3). Eight additional animals were randomly selected from the same group of animals, at time of allotment for slaughter, to determine initial body energy composition (Garrett, Meyer and Lofgreen, 1959). Empty body weight (EBW) gains of the remaining animals, as estimated from eight animals killed at the beginning of the trial were calculated from the ratio of EBW to SBW (shrunk body weight). Body composition was also determined in these animals so as to estimate the energy composition of all animals on each treatment. Data for estimating energy gains were obtained from six randomly selected animals from each ration treatment slaughtered at the conclusion of the growing period. The data were analyzed by analysis of variance; mean differences were analyzed by Duncan's multiple range test (Duncan, 1955).

No implants or vaccines were used. Salt availability and weighing conditions were the same as in Experiment I. All animals were bled at the beginning of the experiment and again at the end to determine changes, if any, in the serum alkaline phosphatase activity. The activity was measured colorimetrically after the serum was incubated at 38 C with a buffered substrate of p-nitrophenyl phosphate (Sigma Chemical Company, 1958).

Results and Discussion

Experiment I. Daily weight gains, feed intake, and feed efficiency data are summarized in table 2. Daily weight gain was not statistically different between the two rations nor was there any significant difference in feed intake or feed efficiency. These results indicate that the clay may have been an inert dilu-

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TABLE 1. RATION FORMULAS AND ESTIMATED NET ENERGY CONTENTS OF FEED USED IN CLAY EXPERIMENTS

	Experiment no.					
	I		II			
Ration[a]	C_o	C_2	C_o	C_2	C_4	C_4NI[b]
Ingredient, %						
Alfalfa	12	12	50	50	50	50
Sudan	5	5	5	5	5	5
Barley	47.2	45.2	28	28	28	28
Beet pulp	20	20	10	10	10	4.66
Fat (stabilized tallow)	5	5	0.0	0.95	1.85	1.34
Molasses (cane)	10	10	7	4.05	1.15	7
Urea	0.8	0.8	..	..	..	..
Clay	0.0	2.0	0.0	2.0	4.0	4.0
Estimated energy						
NE_m, megcal/kg	..	..	1.52	1.52	1.52	1.49
NE_p, megcal/kg	..	..	0.80	0.80	0.80	0.75

[a] C_o, C_2, C_4=0, 2, 4% clay content of the ration.
[b] C_4NI represents a ration that contained 4% clay and was nonisocaloric to the other rations.

ent in the fattening ration. It is of interest, though, that weight gains were 7% less in the treated group with no indication that compensatory feed intake occurred. Ershoff and Bajwa (1965) have found, however, that similar clay prevented bone pathology in young, growing rats, mice, hamsters and miniature pigs. Consequently, the next experiment was designed to investigate the nutritional benefit of clay in the ration of growing steers since the clay may be more concerned with growth than with fattening.

Experiment II. Three of the rations used in this phase of the work were isocaloric, the fourth ration, C_4NI (table 1), was included for the purpose of determining whether compensatory intake would occur as the result of caloric dilution. Concentrations of beet pulp, molasses and fat in this ration were changed to accommodate 4% clay.

TABLE 2. RESPONSE OF CROSSBRED STEERS FED A FATTENING RATION CONTAINING 2% CLAY

	Ration	
Item	C_o[c]	C_2[d]
Days fed	98	98
No. of animals	23[a]	24
Initial shrunk wt., kg	323.8	322.4
Final shrunk wt., kg	460.3	451.2
Daily wt. gain, kg	1.4	1.3
Daily feed, kg/hd[b]	9.7	9.6
Feed/kg gain	6.9	7.3

[a] Steer killed after 27 days because of broken leg.
[b] As fed basis.
[c, d] C_o and C_2 represent rations containing 0 and 2% clay, respectively.

Daily weight gains were not significantly increased when clay was included in the isocaloric ration (table 3). However, daily weight gains were significantly less with ration C_4NI ($P<.05$) than with either of the other rations containing clay, even though feed consumption was approximately the same as on all rations, except C_4. In this case, consumption of C_4NI was slightly greater than C_4 suggesting that some compensatory consumption did occur.

The ratios of EBW/SBW for C_o, C_2, C_4, and C_4NI were 0.863, 0.875, 0.878 and 0.862, respectively. Calculated EBW gains were significantly less ($P<.01$) in animals fed ration C_4NI than in animals fed rations C_2 or C_4, but not in those fed C_o (table 3).

Caloric intake [(NE_m+NE_p) x daily D.M.] by animals fed ration C_4NI was 2% less than by those fed ration C_4. However, 15% more dry matter was required from ration C_4NI to produce a kilogram of EBW and also rate of gain was 10% slower.

A doubling of fat and clay concentrations in the ration (rations C_2 and C_4) had no significant affect on EBW gain. There was, however, a significantly smaller EBW gain on ration C_4NI (table 3). Thus, the small difference in fat concentration between rations C_4 and C_4NI probably had no relationship to EBW gain. The inverse relationship between level of molasses in the ration and EBW gain would logically lead one to the conclusion that EBW gain was depressed by molasses. However, this seems quite improbable in view of the high digestibility of molasses. Another suggestion is that the level of molasses may

TABLE 3. RESPONSE OF GROWING STEERS TO ISOCALORIC AND NONISOCALORIC RATIONS CONTAINING CLAY

Item	Ration[g]			
	C_0	C_2	C_4	C_4NI
Days fed	84	84	84	84
No. of animals	45	40[a]	41	41
Initial wt., kg	206.8	208.6	209.1	207.2
Final wt., kg	298.4	306.6	306.1	296.1
Daily wt. gain, kg	1.09[c, d]	1.16[d]	1.16[d]	1.06[c]
Daily empty body wt. gain, kg	1.12[e]	1.23[f]	1.29[f]	1.13[e]
Daily dry matter kg/hd	7.01	7.29	7.12	7.21
Dry matter/kg EBW gain	6.25	5.93	5.52	6.38
Energy gain, megcal/day	4.40	4.51	4.68	3.89
B. L. units[b]	0.932	1.035	0.561	0.442

[a] Steer died from unknown causes on 11th-day of experiment.
[b] Bessie-Lowry units expressing average alkaline phosphatase activity per ml of serum. These data represent the difference (increase) in enzyme activity between the first and second blood sampling.
[c, d] Means having different superscripts are significantly different ($P<.05$).
[e, f] Means having different superscripts are significantly different ($P<.01$).
[g] See table 1.

have affected fiber digestibility. On the average, 10% less dry matter was required per pound of empty body weight gain when the ration contained either 2 or 4% clay, as compared to an isocaloric ration with no clay (table 3).

Although serum alkaline phosphatase activity is not specific for calcium metabolism, B. H. Ershoff (*personal communication*) observed (in rats) a 20-fold increase in such activity when clay was added to rations deficient in calcium, fat and protein. Alexander, Krueger and Bogart (1958) showed rate of gain in beef cattle to be positively related to activities of serum alkaline phosphatase and serum acid phosphatase. In the present experiment, there was no relationship between serum alkaline phosphatase activity and rate of gain, empty body weight gain or feed efficiency (table 3).

Ershoff and Bajwa (1965) found that adding calcium carbonate to an unheated ration low in calcium, protein, and fat resulted in less weight gain and less protection against bone pathology, compared to that induced by substituting an equivalent amount of calcium, as clay, for the carbonate. The authors concluded that the beneficial effects of clay were due in large part to some factor or factors other than its calcium content. In the present experiment, it seems unlikely that ration mineral levels were deficient, since salt was provided free choice, calcium and phosphorus levels were, respectively 0.99 and 0.34% or higher.

Quisenberry (1966) found that laying hens produced more and larger eggs when 3% clay was included in the ration. From subsequent work he concluded that nutritionally active clays could be considered as caloric "extenders" (Quisenberry, 1968). He estimated that clay mined from the same site as the clay in the present study, had about two calories of metabolizable energy per gram. These workers also reported a significant reduction in moisture content of the chicken feces. Almquist and co-workers (1967) recently reported increased protein retention by turkey poults when rations were supplemented with a similar clay.

Bentonite has been used on a limited basis in feedlots of the southwestern U.S. for a number of years. It is typically fed as 2 to 3% of the total ration, but, in some instances, has been fed free-choice (H. K. Hebbard, *personal communication*). Eartheating from the pen floor and fence chewing by the cattle often cease when bentonite is added to the ration.

Bentonite, a mixture of clays in which the predominant clay is montmorillonite has been used as a pelleting aid in manufacturing operations for many years (Burns, 1968). Most nutritional studies have referred to the material used as bentonite, kaolin or simply as clay, none of the terms being very meaningful. Without x-ray analysis and data on ion-exchange capacity to identify the silicates involved, it is difficult to relate the nutritional value to the clay being used (Burns, 1968). Although chemical and spectographic analyses have been reported (Ershoff and Bajwa, 1965), they shed little light on the nutritional quality of clay. Burns (1968) claims that nutritionally active clays have been noted only in the phyllosilicate group. These silicates have high cation-exchange capacity, sheet-like cleavage, are soft, and have relatively low specific gravity. A high cation-exchange capacity could be of nutritional interest with respect to Ca^{++}, Na^{+}, K^{+}, NH_4^{+}, and perhaps other cations.

In the present study, analysis revealed the clay mixture to be predominantly montmorillonite (80%), with an ion-exchange capacity of 83 mequiv./100 gram. Such a high exchange capacity may explain the increased empty body weight gain noted in the growing animals fed ration C_2 and C_4. It is possible that the clay may in some way influence absorption from the gut.

Summary

Feeding a ration supplemented with clay containing 80% montmorillonite and having a relatively high ion-exchange capacity, produced no deleterious effects on either fattening or growing steers. Performance of fattening steers was 7% less when fed 2% clay with no difference in food intake. Shrunk body weight gains in growing steers were not significantly affected by inclusion of either 2 or 4% clay in isocaloric rations; but when 4% clay was substituted for beet pulp and fat, animal performance was significantly reduced ($P<.05$). Empty body weight gains were significantly ($P<.01$) increased by the inclusion of 2 or 4% clay in isocaloric growing rations.

Compared to an isocaloric control, an average of 10% less dry matter was required per pound of empty body weight gain when either 2 or 4% clay was included in a growing ration but not in a fattening ration.

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