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High Calcium Consumption And Nutrient Digestion In Growing and Finishing Cattle

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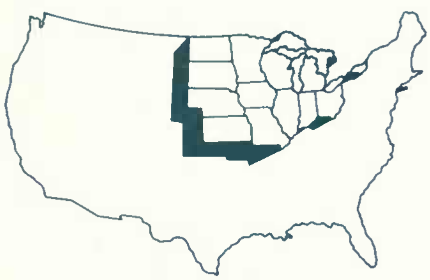

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This publication was prepared by North Central Regional Committee 88 on Beef Growing-Finishing Systems. Members of the regional committee are:

Iowa — A. H. Trenkle
Illinois — L. L. Berger
Indiana — T. W. Perry
Kansas — J. G. Riley
Michigan — J. Waller
Minnesota — S. D. Plegge
Missouri — J. E. Williams
Nebraska — R. Stock
North Dakota — W. E. Dinusson
Ohio — S. C. Loerch
South Dakota — R. M. Luther
Wisconsin — D. M. Schaefer
ARS, USDA — C. L. Ferrell
CSRS, USDA — C. R. Richards
Administrative Adviser — R. G. Cragle (past adviser)
W. H. Pfander (present adviser)

D. M. Schaefer organized the material presented in this report and prepared the initial draft of the manuscript.

April 1986

HIGH CALCIUM CONSUMPTION AND NUTRIENT DIGESTION IN GROWING AND FINISHING CATTLE

Calcium, the most abundant mineral in animal tissues, accounts for 46 percent of all minerals in the body. Major deposits are found in bones and teeth, but muscle, nervous, circulatory, and lactational systems also depend on calcium for associated physiological functions. Calcium absorption, mobilization, and excretion are controlled homeostatically by vitamin D, calcitonin, and parathyroid hormone (16).

The calcium concentrations currently recommended in diets fed to growing and finishing steers and to heifers are based upon the following assumptions:

- One gram of calcium is required for each 100 grams of protein required for maintenance.
- In protein gain, the calcium deposition is 1.7 times greater than the phosphorus deposition (43.2 grams of phosphorus per kilogram of protein gain).
- Calcium availability in various sources averages 70 percent.

Thus the diet of a 350-kilogram steer — at maintenance or gaining up to 1.3 kilograms daily — should contain 0.18 to 0.32 percent calcium in the dry matter (21).

Overt symptoms of calcium deficiency are rarely observed in practice, yet diets composed of large amounts of grain and limited amounts of nonlegume roughage can be deficient in calcium. When dietary phosphorus levels exceed calcium levels, phosphate salts may precipitate in the urinary tract, leading to calculi formation. One management practice that helps prevent this disorder involves incorporating additional calcium, for example in the form of ground limestone, to provide a calcium to phosphorus ratio of 2.5 to 1 (10). The literature on calcium as a nutrient for beef cattle was reviewed extensively several years ago (4) and will not be repeated here.

Some test results suggest that animal performance benefits from calcium levels greater than those recommended to satisfy the nutritional requirement. It has also been suggested that additional calcium, in the form of ground limestone added to diets just before feeding, serves to neutralize acidity within the gastrointestinal tract, thus improving starch digestion (46, 47). These two observations have prompted interest in evaluating the effects that increased levels of dietary calcium have on growing and finishing beef cattle. The purpose of this review is twofold: first, to summarize experimental results collected in one region of the United States on this topic and, second, to relate these results to others published in the scientific literature.

Results of feeding trials conducted in the North Central Region and other results published in journals are tabulated according to whether the trials were conducted after 1975 (Table 1) or before that time (Table 2). This distinction was drawn to help evaluate the progress made in understanding calcium needs in the diets of growing and finishing cattle. Categories of information were chosen for their descriptive and interpretive value, and all results were converted to the metric system. Percentage responses of cattle are relative to the treatment considered to be the most appropriate control. Progress reports of feeding trials are not included here, nor are trials involving the use of ground limestone as an additive to corn silage before ensiling. Table 3 contains several comparisons of cattle responses to various calcium sources or concentrations as influenced by diets containing different grains or monensin.

Performance of Growing and Finishing Cattle

For all trials reported in Tables 1 and 2, increases in the percentage of dietary calcium resulted in a slight reduction (0.3 percent) in the average daily gain and an improvement of similar magnitude (0.6 percent) in feed conversion (Table 3, comparison 1). Their respective standard errors indicate no appreciable difference from zero response, a characteristic of nearly all means in Table 3. Responses were also near zero when trial results were separated according to those collected recently and those obtained earlier (Table 3, comparisons 2 and 3).

When the source of supplemental calcium, for example limestone, kiln dust, or oyster shell, was scrutinized, the elevated percentage of calcium was seen to have little if any effect on average daily gain or feed conversion (Table 3, comparisons 4, 5, 6). Cement kiln dusts (Table 4) have been incorporated into beef

Table 1. Responses of Cattle to Various Concentrations of Dietary Calcium,[a] Summary of Research After 1975

Trial	Calcium source[b]	Type of cattle	Basal diet	Calcium[c]	DMI[d]	ADG[e]	F/G[f]	Response relative to control ADG	Response relative to control F/G	Reference number
				percent	*kilogram*			*percent*		
1	Limestone	Yearling steers	90% corn + supple-	NR[g]	9.1	1.29	7.06	. .	. .	
			ment (S), 10% hay	.38	9.4	1.27	7.38	−1.6	4.5	43
2	Limestone	Yearling steers	90% corn + S,	.39	9.5	1.28	7.47	. .	. .	
		self-fed	10% hay	1.14	9.3	1.29	7.24	0.8	−3.1	42
3	Limestone	Yearling heifers	90% corn + S,	.30	9.8	1.25	7.87	. .	. .	
		self-fed	10% cobs, monensin (M)[h]	.87	9.5	1.14	8.27	−8.8	5.1	44
4	Limestone	Finishing steers	92% high-moisture (HM)	.4	7.9	.98	8.06	. .	. .	
			corn + S, 8% corn stalks	.8	7.7	.96	8.32	−2.0	3.2	27
5	Limestone	Yearling steers	Full-fed corn, limited	Normal (N)	. .	1.12	6.77	. .	. .	
			corn silage (CS), M	2 N	. .	1.18	6.53	5.4	−3.5	30
6	Limestone	Yearling steers	Full-fed corn,	N	. .	1.17	6.27	. .	. .	
			limited CS, M	2 N	. .	1.15	6.53	−1.7	4.1	30
7	Limestone	Yearling steers	93% corn + S,	.31	9.7	1.43	6.76	. .	. .	
			7% cobs	.54	9.5	1.37	6.91	−4.2	2.2	
				.77	9.3	1.33	7.01	−7.0	3.7	37
8	Limestone	Yearling steers	60% corn + S,	.31	10.3	1.01	10.18	. .	. .	
			40% CS	.64	10.1	1.02	9.89	1.0	−2.8	37
9	None	Yearling steers	84% corn + S,	.10	9.2[i]	1.42[i,j]	6.43	7.6	−0.6	
	Limestone		16% cobs, M	.25	8.5[j]	1.32[j]	6.47	. .	. .	
	Kiln dust			.23	9.0[i,j]	1.46[i]	6.15	10.6	−4.9	
	Kiln dust			.73	8.6[j]	1.38[i,j]	6.18	4.5	−4.5	
	Kiln dust			1.33	7.4[k]	1.15[k]	6.47	−12.9	0	
	Kiln dust			1.68	7.6	1.12	6.72	−15.1	3.9	35
10	Limestone	Finishing steers	85% corn + S,	1 Ca:1 P	8.9	1.15	7.70	. .	. .	
			15% CS	2 Ca:1 P	8.9	1.06	8.45	−7.8	9.7	
				1 Ca:2 P	8.6	.97	8.90	−15.6	15.6	9
11	Limestone	Growing-finishing	18% corn + S,	.3	7.6	1.07[l]	7.05	. .	. .	
		steers	82% CS;	.4	7.4	1.04[l]	7.09	−2.8	0.6	
			65% corn + S,	.5	7.5	1.08[l]	6.94	0.9	−1.6	
			35% CS, M	.6	7.7	1.13[l]	6.83	5.6	−3.1	48
12	Limestone	Growing-finishing	18% corn + S,	.3	7.4	1.12	6.59	. .	. .	
		steers	82% CS;	.5	7.3	1.09	6.73	−2.7	2.1	
			67% corn + S,	.7	7.4	1.15	6.43	2.7	−2.4	
			33% CS, M	.9	7.2	1.09	6.69	−2.7	1.5	48
13	Limestone	Growing-finishing	35% S + barley	.3	7.9	1.12	7.01	. .	. .	
		steers	or corn, 65% CS, M	.6	7.8	1.10	7.07	−1.8	0.8	48
14	Limestone	Finishing steers	80% corn (whole or	.3	8.3	1.25	6.72	. .	. .	
			cracked), 20% CS	.6	8.3	1.25	6.68	0	−0.6	5
15	Limestone	Finishing steers	95% corn + S,	.35	7.0[m]	1.01	7.12	. .	. .	
			5% CS, M	.70	7.2[m]	1.06	6.88	5.0	−3.4	
				1.05	6.6[m]	.95	6.98	−5.9	−2.0	38
16	Limestone	Finishing steers	90% corn + S,	.35	8.4	1.43	5.93	. .	. .	
			10% alfalfa hay	.70	8.1	1.42	5.79	−0.7	−2.4	38
17,	Limestone	Finishing steers	90% HM corn + S,	.35	8.6	1.13	7.59	. .	. .	
18			10% CS	.70	8.5	1.16	7.36	2.6	−3.0	34
19	Limestone	Finishing steers	90% corn + S,	.35	9.1	1.30	7.03	. .	. .	
			10% CS, M	.70	8.8	1.30	6.84	0	−2.7	34
20	Limestone	Finishing steers	90% HM corn + S,	.35	8.7	1.32	6.60	. .	. .	
			10% CS, M	.70	8.4	1.24	6.76	−6.1	2.4	34
21	Limestone	Finishing steers	85% barley,	.23	8.3	.92	9.06	. .	. .	
			15% CS	.45	8.2	.98	8.38	6.5	−7.5	
				.83	8.3	.95	8.74	3.3	−3.5	
				1.59	8.8	.90	9.76	−2.2	7.7	1

Continued

Table 1. — continued

Trial	Calcium source[b]	Type of cattle	Basal diet	Calcium[c]	DMI[d]	ADG[e]	F/G[f]	Response relative to control ADG	Response relative to control F/G	Reference number
				percent	kilogram	kilogram		percent	percent	
22	Limestone	Finishing steers	85% barley,	.23	12.3	.99	12.4	..	..	
			15% CS	.45	11.3	.99	11.4	0	−8.1	
				.83	12.3	1.08	11.3	9.1	−8.9	
				1.59	11.1	1.03	10.8	4.0	−12.9	2
23	Limestone	Finishing heifers	Full-fed corn,	.46	7.9	1.16	6.79	..	..	
			limited CS, M	1.06	7.7	1.16	6.59	0	−2.9	24
24	Limestone	Yearling steers	90% HM corn	.35	8.2	1.31	6.27	..	..	
			10% CS	1.05	8.0	1.21	6.54	−7.6	4.3	15
25	Limestone	Heifer calves	100% corn + S, M	.45	6.1	.90	6.82	..	..	
				.90	6.0	.95	6.33	5.6	−7.2	25
26	Limestone	Heifer calves	35% corn + S,	.45	5.7	1.01	5.67	..	..	
			65% CS, M;	.90	5.8	1.06	5.45	5.0	−3.9	
			75% corn + S,	.45	5.7	1.11	5.19	..	..	
			25% CS, M	.90	5.6	1.09	5.15	−1.8	−0.8	26
27	Limestone	Finishing steers	91% corn + S,	.30	10.1	1.34	7.55	..	..	
			9% haylage	.90	9.6	1.27	7.61	−5.2	0.8	31
28	Limestone	Finishing steers and heifers	84% corn + S,	.40	10.6	1.33	8.22	..	..	
			16% haylage, M	.80	10.8	1.33	8.29	0	7.0	32
29	Limestone	Finishing steers	85% corn + S,	.45	11.7	1.67[n]	6.98	..	..	
			15% CS or haylage, M	.82	11.4	1.51[o]	7.53	−9.6	7.9	32
30	Limestone	Finishing steers	85% corn + S,	.32	8.0	1.47[n]	5.44[n]	..	..	
			15% CS or haylage, M	.68	7.8	1.56[o]	5.02[o]	6.1	−7.7	33
31	Limestone	Steer calves	90% barley + S,	.23	6.3	.92[n]	6.84	..	..	
			10% hay	.73	7.6	1.22[o]	6.19	32.6	−9.5	3
32	Limestone	Finishing steers	85% corn + S,	.44	10.1	1.37	6.40[p]	..	..	
			15% cottonseed hulls	1.00	10.4	1.40	6.50[p]	2.2	1.6	7

[a] Additional treatments were included in some of the experiments summarized here, but only those pertaining to the evaluation of supplemental calcium are listed. Treatments involving cement kiln dust are not listed unless dietary calcium concentrations were reported. If interactions with calcium levels were not reported to be significant in factorial designs, treatment means were averaged to obtain the calcium main effect.
[b] Limestone was assumed to contain 38 percent calcium. All sources were ground.
[c] Calcium percentage in diet dry matter unless indicated otherwise.
[d] Daily dry matter intake.
[e] Average daily gain.
[f] Feed dry matter per gain.
[g] Not reported.
[h] Monensin present in basal diet.
[i, j, k] P < .05.
[l] Linear effect of calcium level (P < .01).
[m] Quadratic response (P < .05).
[n, o] Means in a column within a trial that have different superscripts are different (P < .05).
[p] Organic matter per gain.

cattle diets because of their relatively high concentrations of calcium, which is present as calcium carbonate (23). However, the presence of many other potentially toxic minerals has caused some concern. Fairly high levels of lead, cadmium, and fluorine have been noted in kiln dust (12), as well as increased lead content in feed containing kiln dust. Nevertheless, it was concluded that kiln dust did not increase the concentration of lead, selenium, cadmium, arsenic, or mercury in liver, kidney, or muscle tissues (35).

Steele et al. (34) fed two ground limestones that differed in their rates of acid neutralization and particle size. The limestone with the smaller particle size had the faster rate. In relation to animal performance, no significant interactions occurred between calcium level and rate of acid neutralization. These results are consistent with an early report in which the availability of calcium in fine-textured and coarse-textured limestones was found to be the same (19).

Likewise, Turgeon et al. (38) used two limestone sources to formulate three calcium levels in finishing diets. No significant improvements due to limestone source were observed in animal performance, nor were significant interactions detected between calcium level and limestone source. Calcium chloride has also been fed as a calcium source, but it adversely affected dry matter intake and average daily gain, probably because the chloride ion caused chronic metabolic acidosis (30, 36). When designing experiments in which calcium intake is a critical factor, researchers must be aware that calcium concentration in drinking water can vary appreciably (35).

With the addition of limestone, increases into the range of from 0.5 percent to 0.8 or 1.0 percent dietary calcium generally have been without major effect on animal performance (Table 3, comparisons 7, 8). Average daily gain has not been affected by this increase in calcium (6, 17, 18, 32, 34, 37, 38, 48). Feed conversion has also been unaffected (6, 7, 17, 18, 37, 38, 48). In some cases, reduced average daily gain or a trend in that direction has been reported (15, 31, 32, 42, 49); less desirable feed conversion has also been reported (31). In other cases, increases or trends toward increases in average daily gain have been found (24, 33, 34, 48), along with improved feed conversion (33, 34, 38).

A quadratic response to calcium additions (up to 1.05 percent dietary calcium) in the form of limestone has been detected (38). There was a weak trend toward reduced average daily gain when calcium concentration was increased above 1.0 percent (Table 3, comparison 9). This discovery provides some broader evidence that excessive calcium supplementation may be detrimental to performance of feedlot cattle. Average daily gains were reduced when kiln dust was added to increase calcium concentrations to 1.33 and 1.68 percent (35).

The effect of these high calcium concentrations on feed conversion was less pronounced. Decreased an-

Table 2. Responses of Cattle to Various Concentrations of Dietary Calcium,[a] Summary of Research Before 1975

Trial	Calcium source[b]	Type of cattle	Basal diet	Calcium[c]	DMI[d]	ADG[e]	F/G[f]	Response relative to control: ADG	Response relative to control: F/G	Reference number
				percent	*kilogram*			*percent*		
33	NR[g]	Growing heifer and steer calves	42% corn, 50% corn silage (CS), 8% alfalfa hay	.33	4.9	.64	7.65	..	..	
				.44	4.9	.64	7.60	0	−0.6	
				.56	4.9	.64	7.71	0	0.8	
				.67	4.9	.62	7.94	−3.1	3.8	28
34	Oyster shell	Finishing heifers	85% corn + supplement (S), 10% cobs, 5% alfalfa	.33	8.5	1.27	6.70	..	..	
				.56	8.9	1.31	6.81	3.1	1.6	
				.78	8.2	1.19	6.94	−6.3	3.6	28
35	NR[g]	Yearling steers	74% corn S, 17% CS, 9% hay	.33	9.5	1.44	6.59	..	..	
				.56	9.4	1.39	6.76	−3.5	2.6	28
36	Limestone	Finishing steers	100% corn + S	.17	7.8	1.44	5.39	0.7	2.1	
				.33	7.6	1.43	5.28	..	..	
				.67	7.6	1.43	5.28	0	0	6
37	Limestone	Finishing steers	100% corn + S	.22	8.3	1.22	6.82	..	..	
				.67	8.1	1.16	6.99	−4.9	2.5	
				1.33	8.4	1.25	6.74	2.4	−1.2	18
38	Limestone	Finishing steers	85% corn + S, 15% corn cobs	.20	8.8[h]	.97[h]	9.07[h]	−11.8	8.9	
				.31	9.2[h,i]	1.10[i]	8.33[i]	..	..	
				.41	9.3[i]	1.18[i]	7.85[i]	7.2	−5.8	
				.50	8.9[h,i]	1.06[h,i]	8.40[h,i]	−3.6	0.8	39
39	Limestone	Heifer and steer calves	100% corn + S	.28	5.0	.72	7.09	..	..	
				2.18	5.4	.81	6.79	12.5	−4.2	49
40	Limestone	Steer calves	100% corn + S	.28	6.0	1.14	5.21	..	..	
				1.23	6.3	1.23	5.13	7.9	−1.5	49
41	Limestone	Steer calves	100% corn + S	.40	8.3	1.26[h]	6.59	..	..	
				1.75	7.6	1.14[i]	6.66	−9.5	1.1	49
42	Limestone	Steer calves	100% corn + S	.40	7.5	1.33[h]	5.62	..	..	
				1.98	6.6	1.19[i]	5.49	−10.5	−2.3	49

[a] Additional treatments were included in some of the experiments summarized here, but only those pertaining to the evaluation of supplemental calcium are listed. Treatments involving cement kiln dust are not listed unless dietary calcium concentrations were reported. If interactions with calcium levels were not reported to be significant in factorial designs, treatment means were averaged to obtain the calcium main effect.
[b] Limestone was assumed to contain 38 percent calcium. All sources were ground.
[c] Calcium percentage in diet dry matter unless indicated otherwise.
[d] Daily dry matter intake.
[e] Average daily gain.
[f] Efficiency of feed conversion expressed as feed dry matter per gain.
[g] Not reported.
[h,i] Means in a column within a trial that have different superscripts are different ($P < .05$).

imal performance at high concentrations of dietary calcium has been attributed to reduced palatability in complete mixed diets (38) and to poor hand mixing of top-dressed limestone (49). In addition, depressed feed consumption with high calcium diets has been reported without explanation (15, 37, 42).

Monensin has been shown to be effective in protecting cattle from lactic acidosis (20). In diets composed of large amounts of grain, limestone in the form of calcium carbonate is thought to serve as a buffer. It is therefore conceivable that levels of dietary calcium may interact with monensin. This interaction might manifest itself as an enhanced effect of elevated calcium levels on animal performance when monensin is absent from the diet, thereby allowing for increased lactic acid concentrations in rumen fluid. However, such an effect was not apparent when ground limestone was used to increase the dietary calcium concentration to 1.0 percent, either with or without monensin (Table 3, comparisons 10, 11).

Lactic acidosis is likely to occur when cattle are shifted rapidly from predominantly forage diets onto grain diets. Turgeon et al. (38) and Schaefer et al. (33) have found that most of the observed benefit, if any, from limestone additions occurs during the first four weeks of the feeding trial. Dunn et al. (8) found that the addition of limestone to ground corn diets fed to lambs resulted in significant increases in dry matter intake and average daily gain.

In contrast, Hendrix et al. (15), who abruptly shifted steers from a corn silage diet to a 90 percent high-moisture corn diet over a six-day period, noted that higher calcium levels depressed feed intake and daily gain for the entire trial. Severity of ruminal parakeratosis in steers was unaffected by additions of ground limestone (6). The effects of higher limestone additions to feedlot diets during dietary adjustment are neither consistent nor clearly understood, as the findings indicate.

The most noteworthy effect of elevated limestone level (greater than or equal to 1.0 percent calcium) was its effect on animal performance relative to the type of grain in the basal diet (Table 3, comparisons 12, 13). The responses for average daily gain and feed

Table 3. Comparisons of Cattle Responses to Various Concentrations of Dietary Calcium

Comparison	Basis	Control: table reference	Treatment	Trials	No. of calcium level comparisons	Response relative to control[a] ADG[b]	F/G[c]
						percent	
1	All trials	Tables 1, 2	Elevated Ca%[d]	1-42	59	−.3 ± 0.9	−.6 ± 0.6
2	Trials in Table 1	Table 1	Elevated Ca%	1-32	44	−.2 ± 1.1	−.8 ± 0.8
3	Trials in Table 2	Table 2	Elevated Ca%	33-42	15	−.6 ± 1.6	.1 ± 0.7
4	Oyster shell as Ca source	Table 2	Elevated Ca%	34	2	−1.6 ± 4.7	2.6 ± 1.0
5	Kiln dust as Ca source	Table 1	Elevated Ca%	9	4	−3.2 ± 6.4	−1.4 ± 2.1
6	Limestone as Ca source	Tables 1, 2	Elevated Ca%	1-8, 10-32, 36-42	51	.0 ± 1.0	−.6 ± 0.7
7	Limestone	Table 1	.5-.8% Ca	1, 4-8, 11-22, 28, 30, 31	24	1.6 ± 1.6	−1.2 ± 0.9
8	Limestone	Table 1	.5-1.0% Ca	1, 3-8, 10-22, 25-32	34	.9 ± 1.2	−.8 ± 0.8
9	Limestone	Table 1	1.0% Ca	2, 15, 21-24	6	−1.8 ± 1.8	−1.5 ± 2.9
10	Limestone in diets without monensin	Table 1	.5-1.0% Ca	1, 4, 7, 8, 10, 14, 16-18, 21, 22, 27, 31, 32	16	1.8 ± 2.4	−1.3 ± 1.4
11	Limestone in diets with monensin	Table 1	.5-1.0% Ca	3, 5, 6, 11-13, 15, 19, 20, 25, 26, 28-30	18	.1 ± 1.2	−.3 ± 1.1
12	Limestone in diets with greater than 50% barley	Table 1	.5-1.0% Ca	21, 22, 31	5	10.3 ± 5.8	−7.5 ± 1.1
13	Limestone in diets with greater than 50% corn	Table 1	.5-1.0% Ca	1, 3-8, 10, 14-20, 25-30, 32	22	−1.3 ± 1.0	.8 ± 1.0

[a] Mean ± standard error.
[b] Average daily gain.
[c] Efficiency of feed conversion expressed as feed dry matter per gain.
[d] Excludes trial 9 treatment of 0.23 percent calcium from kiln dust and trial 10 treatment of a 1 to 2 calcium to phosphorus ratio.

Table 4. Mineral Composition of Cement Kiln Dusts, Dry Matter Basis

	Source of kiln dust	
	Iowa[a]	Georgia[b]
	percentage of dry matter	
Calcium	32.0	18.70
Phosphorus	0	.02
Magnesium	1.1	.35
Sodium	0	.08
Potassium	1.9	1.84
Sulfate-sulfur	1.5	1.11
Aluminum	1.4	.53
Iron	.58	0
	parts per million	
Manganese	0	137.7
Fluorine	0	519.9
Zinc	0	98.7
Copper	0	10.5
Nickel	4.6	27.8
Cobalt	0	21.0
Molybdenum	0	15.0
Chromium	0	38.5
Lithium	0	38.2
Strontium	0	163.7
Cadmium	0.3	34.5
Arsenic	4.5	11.6
Lead	50.0	139.4
Vanadium	0	50.0
Mercury	.1	0
Selenium	.78	0

[a] Trenkle and Farquhar (34).
[b] Galyean and Chabot (12).

conversion were larger when barley rather than corn was the grain component. Note especially that feed conversion was improved consistently in three trials by an average of 7.5 percent. Similarly, when wheat was substituted for 50 percent of the corn in the basal diet, compensatory responses to elevated dietary calcium were observed in dry matter intake, average daily gain, and feed conversion, as noted by Weichenthal and Cmarik (42). Ruminal digestion and fermentation of barley starch are known to be nearly complete, and wheat starch is considered to be equally digestible (41).

The site of greatest limestone buffering activity has not been elucidated in vivo. However, acid neutralization was probably a factor leading to the appreciable increase in animal performance. Further research is necessary to determine if animal responses to limestone are influenced by the rate and extent of ruminal starch digestion. Studying the type of starch and the method of processing may be a fruitful approach to increasing our understanding of potential benefits to cattle that are fed elevated levels of limestone or of calcium.

Increased calcium consumption has been shown to be without effect on the incidence of urinary calculi (6) or liver condemnations (6, 17, 18, 34, 37, 38). Carcass quality and yield grades are also unaffected (7, 15, 17, 18, 31, 34, 35, 37, 38, 39, 48).

Nutrient Digestion

Numerous experiments have been conducted to evaluate the effects that high concentrations of dietary calcium have on digestive function in ruminants. The calcium source has usually been ground limestone. This research has been undertaken to obtain information that might explain inconsistencies in animal response to high calcium diets.

The effects on rumen pH have been variable. While some increases have been reported (14, 15, 31), the most common finding is that no change occurs in pH (12, 13, 14, 22, 29, 31). In contrast, fecal pH is typically more alkaline when calcium consumption levels are elevated (3, 7, 12, 13, 14, 15, 29, 31, 35, 37, 38, 48). Several possible explanations have been offered to account for an effect on fecal pH in the absence of one on rumen fluid pH. As already suggested, the addition of limestone to diets may increase starch digestibility. This finding has been reported recently for lactating dairy cows fed 75 percent corn grain plus supplement and 25 percent corn silage (29). If increased limestone helps improve the digestion of ruminal starch, then perhaps a reduced flow of starch to the lower gastrointestinal tract would support less bacterial fermentation and the associated production of acid (13).

A second suggestion is that limestone may influence the rate at which liquid passes through the digestive tract (13). However, the osmolality of rumen fluid and the rates at which fluid and solids pass from the rumen have not been altered by increased dietary levels of limestone or kiln dust (12, 13, 29). A third suggestion relates to the influence of pH on the ability of limestones to neutralize acid. Limestones have greater buffering activity at a pH less than 5.5 (13, 14, 45). The buffering activity of ingested limestone would therefore be greatest when it passes through the abomasum and proximal duodenum. Perhaps this activity reduces the total quantity of acid flowing to the lower digestive tract, allowing the pH to rise in response to alkaline biliary and pancreatic secretions. The observed differences between rumen fluid and fecal pH need to be clarified through further research.

Although high calcium consumption has consistently raised fecal pH, the increase has not necessarily been associated with reductions in the percentage of fecal starch (46, 47). Decreased fecal starch was found in some instances (3, 11, 29, 38), whereas other research groups have detected no significant relationship between fecal pH and starch percentage (7, 9, 31). The validity of assessing the effects on starch digestibility based upon the percentage of fecal starch is questionable because the digestibility of other nutrients, such as crude protein, is also altered (29, 40).

Previous research has indicated that feeding mineral salts influenced the proportions of volatile fatty acids in the rumen. Generally, this effect does not seem to apply to limestone in the diet. No effect has been observed in terms of the total concentration of volatile fatty acids (6, 13, 14, 29, 31), molar proportion of propionate (7, 12, 29), and acetate to propionate ratio (6, 7, 13, 29). The effects of higher limestone feeding on ruminal digestion therefore seem to be minimal.

Summary

The forty-two feeding trials summarized here involved the evaluation of dietary calcium levels that exceed the current recommendations of the National Research Council. Although improvements in the performance of growing and finishing cattle fed a high calcium diet have been found in some experiments, they have not occurred consistently. Including limestone has been beneficial in a few trials when subclinical lactic acidosis may have been a problem. Animal responses to increased limestone intake have been greater when barley rather than corn was the grain component. The rate and extent of starch fermentation may have been causative factors in the responses.

Several researchers investigated the effects of limestone on buffering and digestion in the gastrointestinal tract. Fecal pH was more alkaline with increased limestone consumption but was not found to be a reliable indicator of fecal starch percentage or performance of feedlot cattle. Microbial fermentation within the rumen was unaffected in most experiments. In general, we do not recommend the practice of feeding levels of dietary calcium above the National Research Council requirement for growing and finishing beef cattle to increase nutrient digestion and animal performance.

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