The Effects of Adequate and Excessive Calcium When Fed with Adequate Phosphorus in Growing Rations for Beef Calves

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THE EFFECTS OF ADEQUATE AND EXCESSIVE CALCIUM WHEN FED WITH ADEQUATE PHOSPHORUS IN GROWING RATIONS FOR BEEF CALVES [1]

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GROWING beef calves are generally fed high roughage—low concentrate rations. Rations which are composed chiefly of roughages frequently contain wide ratios of calcium to phosphorus. Further, mineral supplements added to growing rations often have wide ratios of calcium to phosphorus. Therefore, it occasionally happens that beef calves are fed rations with 6 or 8 times as much calcium as phosphorus.

A calcium phosphorus ratio between 2 to 1 and 1 to 2 is generally considered desirable for optimum nutrition (Maynard and Loosli, 1956). Evidence indicates that adequate nutrition can occur outside of these ratios provided that each element is present in adequate amounts, and that ample vitamin D is present.

Ruminants apparently are not as sensitive to wide calcium-phosphorus ratios as are monogastric animals like pigs. Bohstedt (1955) summarized the results obtained with swine fed different ratios of calcium to phosphorus. He stated, "The results indicate that ratios ranging from 1.1 to 1.5 parts of calcium to 1 part of phosphorus have been observed as favorable." Lactating dairy cows have been fed rations with calcium-phosphorus ratios varying from 0.6–1.0 to 10.5–1.0 (Kuhlman *et al.*, 1936; Haag *et al.*, 1932) without apparent ill effect. Colovos *et al.* (1952, '53, '54 and '55) reported that excess calcium does depress the digestibility of protein and energy in rations fed to dairy heifers. However, few data are available showing the effects of excessive levels of calcium on the performance of growing beef calves.

The objective of this experiment was to compare the effects of feeding adequate and excessive calcium on the performance of growing calves fed adequate phosphorus.

Experimental Procedure

Two 140-day feeding trials were conducted with Hereford steer calves of an approximate initial age and weight of 8 months and 475 lb., respectively. In both years the calves were purchased from the same herd, insuring similar background and treatment immediately prior to each trial.

All calves were given free access to prairie hay and were also fed 4 lb. of ground shelled corn and 1 lb. of soybean oil meal per head daily. The

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ground limestone fed to the steers in lots 2, 3 and 4 was mixed with the ground shelled corn and soybean oil meal and fed in open bunks once daily in the morning. The calves had free access to an ample supply of water. No supplemental vitamin D was fed in this experiment, but they were exposed to usual sunshine.

The rations, shown in table 2, furnished 4 different calcium-phosphorus ratios, but approximately equal levels of other nutrients. The average level of phosphorus fed daily per calf in all lots was approximately 12 gm., the amount suggested by the National Research Council Subcommittee on Beef Cattle (1950). Thus, all calves received an adequate amount of

TABLE 1. PROXIMATE COMPOSITION OF FEEDS

	Dry matter	Crude protein	Fat	Fiber	Ash	NFE	Ca	P	Ca Gm.	P Gm.
		%	%	%	%	%	%	%	lb.	lb.
Prairie hay										
Trial I	89.0	6.4	1.4	32.4	6.5	42.7	0.31	0.10	1.41	0.45
Trial II	89.5	6.5	1.7	30.4	6.6	44.3	0.32	0.08	1.45	0.36
Average	89.2	6.45	1.55	31.4	6.5	43.5	0.315	0.09	1.43	0.40
Corn										
Trial I	87.0	9.3	3.2	2.0	2.0	70.5	0.03	0.28	0.14	1.27
Trial II	86.1	9.0	3.0	1.9	2.0	70.2	0.03	0.30	0.14	1.36
Average	86.6	9.2	3.1	2.0	2.0	70.4	0.03	0.29	0.14	1.32
Soybean oil meal										
Trial I	91.0	42.2	5.3	5.6	6.0	31.9	0.29	0.52	1.32	2.36
Trial II	89.6	40.9	4.9	5.0	5.8	35.0	0.28	0.54	1.27	2.45
Average	90.3	41.6	5.1	5.3	5.9	33.4	0.29	0.53	1.30	2.40
Limestone										
Trial I	....	....	....	....	....	....	38.0	....	172.52	....
Trial II	....	....	....	....	....	....	37.0	....	167.98	....
Average	....	....	....	....	....	....	37.5	....	170.25	....

phosphorus and either an adequate or an excessive amount of calcium. The calcium was varied by adding ground limestone to the rations fed in lots 2, 3 and 4.

The composition of the feeds used as determined by conventional feed analysis is presented in table 1.

In each trial the steer calves were randomly assigned to the treatments on the basis of weight. In trial I, 10 calves were used on each of the 4 treatments. In trial II, 9 calves were used on each of the 4 treatments. Otherwise trial II was a replication of trial I. The initial and final weights, shown in table 2, are the averages of 3 weights taken on consecutive days at the beginning and end of each trial.

Blood samples of about 50 ml. were taken from the jugular veins of all calves at the beginning and end of trial I. During trial II blood samples were taken from the calves only in lots 1 and 4. The plasma calcium was

TABLE 2. SUMMARY OF TRIALS I AND II (140 DAYS)

	1949–1950				1950–1951			
Lot number	1	2	3	4	1	2	3	4
No. steers/lot	10	10	10	10	9	9	9	9
Av. initial wt., lb.	483.7	482.9	483.5	482.5	464.4	464.4	466.1	464.4
Av. final wt., lb.	666.5	654.0	640.0	633.5	653.3	657.8	627.2	622.8
Av. gain/head, lb.	182.8	171.1	156.5	151.0	188.9	193.4	161.1	158.4
Av. daily gain/head, lb.	1.31	1.22	1.11	1.08	1.35	1.38	1.15	1.13
Average daily ration per head, lb.:								
Prairie hay	9.76	9.51	9.75	9.64	9.56	9.93	9.86	9.69
Corn	4.00	4.00	4.00	4.00	4.06	4.06	4.06	4.06
Soybean oil meal	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	none	0.19	0.53	0.86	none	0.22	0.53	0.83
Feed consumed per 100 lb. live weight gain, lb.:								
Prairie hay	748	778	872	894	708	716	858	853
Corn	306	327	358	371	301	293	353	357
Soybean oil meal	77	82	89	93	74	72	87	87
Limestone	none	16	47	80	none	16	46	73

determined by the method of Clark and Collip (1925) and the plasma inorganic phosphorus was determined by the method of Fiske and Subbarow (1925) as outlined by Hawk *et al.* (1947).

Results and Discussion

The results of the two trials are summarized in table 2. In table 3 the average amounts of calcium and phosphorus consumed per calf daily are presented. The average daily gains per head for the two trials are presented in table 4.

These data (table 4) show that the average rate of gain decreased as the calcium-phosphorus ratios in the rations became wider. When the average

TABLE 3. AVERAGE DAILY CALCIUM AND PHOSPHORUS CONSUMPTION (GRAMS)

Lot number	1	2	3	4
Calcium				
Trial I	15.6	48.0	107.8	163.8
Trial II	15.7	53.2	105.2	155.3
Average	15.6	50.6	106.5	159.6
Phosphorus				
Trial I	11.8	11.7	11.8	11.8
Trial II	11.5	11.6	11.6	11.5
Average	11.6	11.6	11.7	11.6
Ratio of calcium phosphorus				
Trial I	1.3–1.0	4.1–1.0	9.1–1.0	13.9–1.0
Trial II	1.4–1.0	4.6–1.0	9.1–1.0	13.5–1.0
Average	1.4–1.0	4.4–1.0	9.1–1.0	13.7–1.0

TABLE 4. THE AVERAGE DAILY GAINS PER HEAD FOR THE TWO TRIALS

Lot Number	1	2	3	4	
Ca-P Ratio	1.34–1	4.34–1	9.10–1	13.70–1	Average
			lb.		
Trial I	1.31	1.22	1.11	1.08	1.18
Trial II	1.35	1.38	1.15	1.13	1.25
Average	1.33	1.30	1.13	1.10	1.22

total gains per calf for the two trials were analyzed statistically (Snedecor, 1946) the differences among treatments were highly significant (table 5). The year-treatment interaction was not statistically significant.

The average daily gains made by the calves that were fed rations which furnished calcium-phosphorus ratios of 1.3:1.0 (lot 1) and 4.3:1.0 (lot 2) did not differ greatly. Further, the average daily gains made by the calves that were fed rations which furnished calcium-phosphorus ratios of 9.1:1.0 (lot 3) and 13.7:1.0 (lot 4) did not differ greatly. However, the average daily gains made by the steers in lots 1 and 2 did differ rather widely from the average daily gains made by the steers in lots 3 and 4. This is an indication that a critical calcium-phosphorus ratio for growing calves may exist between 4.3:1 and 9.1:1. Lamb *et al.* (1934) fed dairy heifers rations in which the calcium-phosphorus ratios varied from 3.7:1 to 6.5:1. They reported that the wider calcium-phosphorus ratio did not appear to affect the efficient utilization of phosphorus under the conditions of the experiment. In view of the findings of Lamb *et al.* and the results reported here, a critical calcium-phosphorus ratio, if such exists for growing calves, would fall between 6.5:1 and 9.1:1.

The excess calcium fed as ground limestone in this experiment may have interferred with the absorption and utilization of phosphorus and possibly other essential minerals; or it may have depressed the digestibility of other nutrients in the rations. Colovos *et al.* (1952) reported that feeding ground limestone at the rate of 100 gm. per day to dairy heifers, 12 to 18 months of age, caused a drop of 6 to 8% in the digestibility of the protein in the silage fed. Colovos *et al.* (1953, '54) fed limestone at the rate of 0, 50 and

TABLE 5. ANALYSIS OF VARIANCE OF TOTAL POUNDS OF GAIN PER HEAD

Source	D F	SS	MS	F
Total	75	75,758.35		
Years	1	1,939.20	1,939.20	2.31
Treatments	3	14,210.66	4,736.89	5.64**
Error	71	59,608.49	839.56	

** Significant at the 1% level.

100 gm. per head daily with silage to dairy heifers. Adding 50 gm. of limestone per head daily did not significantly affect the digestibility of the protein and energy in the rations. However, feeding 100 gm. of limestone per head daily did significantly lower the digestibility of both the protein and the energy in the rations. Colvos *et al.* (1955) studied the effects of pulverized limestone and dicalcium phosphate on the digestibility and utilization of protein and energy of a ration fed to dairy heifers. The addition of 2% limestone to the basal ration decreased the digestibility of both protein and energy, confirming their previous results. The addition of 2% dicalcium phosphate to the basal ration did not have any appreciable effect. The addition of 2% dicalcium phosphate with the 2% limestone minimized the depressing effect of the limestone.

Lewis *et al.* (1951) reported that the feed consumed by steer calves per 100 lb. of body weight and the rate of gain were reduced by borderline or deficient phosphorus intakes, and that excess calcium added to a ration of borderline phosphorus content further reduced both feed consumption and rate of gain. However, when excess calcium was added to a phosphorus-deficient ration, feed consumption was decreased, but rate of gain was not affected.

Haag *et al.* (1932) reported the results from a series of metabolism studies in which the nitrogen, calcium and phosphorus balances of dairy cows were determined for 16 five-day periods, during which the daily milk yield varied from approximately 10.5 to 15.0 kg. Supplementing the basal ration with calcium carbonate did not appear to affect the storage of either calcium or phosphorus. These workers concluded that the failure of calcium carbonate in depressing phosphorus retention apparently means that a calcium-phosphorus ratio of 10.5:1 was no more detrimental than one of 7.6:1. These workers stated that this does not necessarily mean that such rations are without detrimental effects, but does indicate that under certain conditions, at least, such ratios may be quite high without producing nutritional disaster.

Feed consumption and utilization. The average daily consumption of prairie hay which was fed ad libitum was approximately equal for all lots. The pound of soybean oil meal and 4 lb. of corn fed per calf daily were all consumed without weighback. Thus, the limestone fed in lots 2, 3 and 4 did not depress the calves appetites for roughage in this experiment.

The feed required per 100 lb. of gain increased as the calcium in the rations was increased and as the calcium-phosphorus ratios became wider. This is an indication that the excess calcium may have interfered with the utilization of the nutrients in those rations. Since feed required per 100 lb. of gain is a function of both total gain and total feed consumption it was to be expected that a depression of gain without a depression of feed consumption would result in a lowered apparent efficiency of feed utilization. However, the lower efficiency of feed utilization observed in

this experiment is in line with the lower digestibility of protein and energy observed by Colovos *et al.* (1952, '53, '54 and '55).

Blood studies. Haag *et al.* (1932), in a series of metabolism trials, fed lactating dairy cows rations which furnished calcium-phosphorus ratios of 10.5:1. The high level of calcium did not depress phosphorus retention. Lewis *et al.* (1951) fed steer calves rations that furnished excess calcium and either borderline or adequate phosphorus. They reported that the phosphorus plasma levels were related in a general way to the phosphorus intake, but the calcium plasma levels showed a characteristic fluctuation which was unaffected by treatments or by phosphorus plasma levels.

The initial and terminal plasma calcium and inorganic phosphorus levels were determined for all calves in trial I. In trial II initial and terminal

TABLE 6. AVERAGE CALCIUM AND INORGANIC PHOSPHORUS PER 100 ML. OF BLOOD PLASMA (MG.)

Lot number	1		2		3		4	
Ca – P ratio	1.34–1.0		4.34–1.0		9.10–1.0		13.70–1.0	
				Calcium				
	Initial	Terminal	Initial	Terminal	Initial	Terminal	Initial	Terminal
Trial I	11.3	10.3	11.3	11.1	11.2	10.7	11.1	11.4
Trial II	10.8	9.7	....	....	....	....	11.1	8.8
				Phosphorus				
Trial I	8.6	7.3	8.2	7.0	8.8	7.1	8.9	6.2
Trial II	8.2	8.6	....	....	....	....	8.1	8.1

plasma calcium and inorganic phosphorus levels were determined for the calves in only lots 1 and 4. The average levels of calcium and inorganic phosphorus in the blood plasma are presented in table 6.

The initial and terminal plasma levels of calcium and inorganic phosphorus (table 6) are within the ranges that have been reported as normal for cattle. Savage and Heller (1947) found that calcium varied from 9.9 mg. per 100 ml. of plasma to 11.3 mg. with a yearly average of 10.7 mg. The inorganic phosphorus content of the plasma varied from 4.3 mg. per 100 ml. to 7.5 mg. with a yearly average of 5.8 mg. Knox *et al.* (1941) working with beef cows reported a range of 10.6 mg. to 12.8 mg. of calcium per 100 ml. of plasma, and 1.4 mg. to 4.9 mg. of inorganic phosphorus per 100 ml. of plasma. Lamb *et al.* (1934) reported calcium levels ranging from 10.2 mg. to 10.8 mg. and phosphorus levels ranging from 6.30 mg. to 6.57 mg. per 100 ml. of plasma for dairy heifers before calving.

The initial and terminal calcium and phosphorus levels were subjected to an analysis of variance between treatments within trials, table 7. There were no statistically significant differences between treatments in initial plasma levels of either calcium or phosphorus. This was to be expected

TABLE 7. ANALYSIS OF VARIANCE MG. OF CALCIUM AND INORGANIC PHOSPHORUS PER 100 ML. OF BLOOD PLASMA

Trial I

		Calcium						Phosphorus					
		Initial			Terminal			Initial			Terminal		
Source	DF	ss	ms	F	ss	ms	F	ss	ms	F	ss	ms	F
Total	39	51.87			55.85			33.29			29.66		
Treatment	3	0.36	0.12	0.083	1.82	0.61	0.41	2.74	0.913	1.08	6.91	2.30	3.64*
Error	6	51.51	1.43		54.03	1.50		30.55	0.849		22.75	0.60	

Trial II

Source	DF	ss	ms	F	ss	ms	F	ss	ms	F	ss	ms	F
Total	17	8.82			2.02			30.48			10.94		
Treatments	1	0.56	0.56	1.08	0.07	0.07	0.58	0.08	0.08	0.042	1.28	1.28	2.13
Error	16	8.26	0.52		1.95	0.12		30.40	1.90		9.66	0.60	

* Significant at the 5% level.

because of the similar backgrounds of the calves. The terminal calcium levels did not differ significantly between treatments. Even though excesses of calcium were fed, these excesses were not reflected in the blood plasma. In trial I the terminal phosphorus levels did differ significantly between treatments, in trial II they did not. In trial I it appeared that the excess calcium may have in some way affected phosphorus absorption and/or utilization, however, in trial II this effect was not observed.

The average inorganic phosphorus per 100 ml. of blood plasma did not fall below 6.2 mg. for any of the lots, (table 6). This is above the level considered adequate for normal nutrition (Knox *et al.,* 1941; Savage and Heller, 1947; Lamb *et al.,* 1934). Palmer and Eckles (1927) and Green and DuToit (1927) reported that the blood of cattle suffering from phosphorus deficiency is low in inorganic phosphorus. Henderson and Weakley (1930) and Huffman *et al.* (1933) reported that a low concentration of inorganic phosphorus in the blood plasma is an indication of a ration deficient in phosphorus. Stanley (1938) reported that blood phosphorus levels consistently below 5 mg. per 100 ml. of blood serum are usually a definite indication of a lack of available phosphorus in the feed. W. H. Black, as quoted by Savage and Heller (1947) considered 4 mg. of phosphorus per 100 ml. of blood serum to be the danger point for two-year old steers. Thus, the excess calcium fed in this experiment did not depress plasma phosphorus below a level that could be considered adequate for normal nutrition on the basis of previous work. This might be considered as further circumstantial evidence that the excess calcium depressed gains by interferring with the digestibility and/or absorption of nutrients and mineral elements other than phosphorus. This is in agreement with the findings of Colovos *et al.* (1952, '53, '54, '55).

Summary

Two 140-day feeding trials were conducted to compare the effects of adequate calcium with excess calcium on the performance of beef calves fed adequate phosphorus in a growing ration.

Calcium-phosphorus ratios of 1.3:1, 4.3:1, 9.1:1, and 13.7:1 were fed to steer calves in lots 1, 2, 3 and 4, respectively. The phosphorus fed in all lots was approximately 12 gm. per calf daily. Calcium in the rations was varied by adding ground limestone. The calves in all lots consumed about the same amount of feed per day.

Gains decreased as the calcium in the rations was increased. The average gains made by the calves in lots 1 and 2 did not differ greatly and the average gains made by the calves in lots 3 and 4 did not differ greatly. However, the average gains made by the calves in lots 1 and 2 did differ widely from the gains made by the calves in lots 3 and 4. Thus, if gains are used as a criterion, a critical calcium-phosphorus ratio may exist between 4.3:1 and 9.1:1.

Initial and terminal calcium and inorganic phosphorus levels in the blood plasma were determined for all calves in trial I and for the calves from lot 1 and lot 4 in trial II. The excess calcium intake was not reflected by a change in the blood plasma calcium levels. In trial I, the terminal inorganic phosphorus in the plasma differ significantly between treatments. In trial II, the inorganic phosphorus in the plasma did not differ significantly between the lots. The inorganic phosphorus content was not depressed below a level considered adequate for proper nutrition. Thus, the excess calcium appeared to depress gains by interferring with the digestibility and/or absorption of nutrients and mineral elements other than phosphorus.

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