MEDWELL PUBLISHING
Journal of Animal and Veterinary Advances 8 (6): 1116-1123, 2009
ISSN: 1680-5593

A Comparison of Ground Oyster Shell and Limestone as Potential Alkalizing Agents When Fed at Extra-Nutritional Levels for Enhancement of Growth-Performance and Digestive Function in Feedlot Cattle Fed Steam-Flaked Corn-Based Finishing Diets

[1]R.A. Zinn, [2]J. Salinas-Chavira, [3]J. Lenin, [3]M.F. Montano and [3]U. Sanchez
[1]University of California, Davis, USA
[2]Universidad Autonoma de Tamaulipas, Ciudad Victoria, Tam, MX
[3]Universidad Autonoma de Baja California, Mexicali, BC, MX

Abstract: Three experiments were conducted: in Experiment 1, 96 steers (334 kg) were used in a 126 days finishing trial to compare ground oyster shell and limestone as supplemental Ca sources at dietary Ca levels of 0.70 vs. 1.40%, in a 2×2 factorial arrangement. In Experiment 2, 96 heifers (354 kg) were used in a 149 days finishing trial to evaluate oyster shell and limestone as Ca sources at dietary Ca levels of 0.50 vs. 0.9%, in a 2×2 factorial arrangement. In Experiment 3, 4 steers (399 kg) with cannulas in the rumen and proximal duodenum were used in a 4×4 Latin square design to evaluate treatment effects on characteristics of digestion. The calcium content of limestone and oyster shell was 33.3 and 34.3%, respectively. Ca reactivity was 17.9 and 5.87 min, respectively for limestone and oyster shell. In Experiment 1, there were no treatment effects ($p>0.20$) on DMI, ADG, gain efficiency, dietary NE, dressing percentage, KPH, LM area and marbling score. Increasing dietary Ca level from 0.7-1.4% tended to slightly increase (1.2%, $p<0.10$) estimated carcass retail yield and there was a tendency ($p<0.10$) for an interaction between Ca level and source on fat thickness. Fat thickness was similar for oyster shell at the 2 levels of supplementation. However, with the limestone, fat thickness was 29% greater for diets supplemented to contain 0.7% Ca than for diets containing 1.4% Ca. There were no treatment effects ($p>0.20$) on fecal pH. As expected, increasing dietary Ca level increased ($p<0.01$) fecal Ca concentration. In Experiment 2, there were no treatment effects ($p>0.20$) on ADG, DMI, gain efficiency and dietary NE, dressing percentage or LM area. In contrast with Experiment 1, there were no treatment effects on fat thickness and retail yield. However, KPH was greater (8.9%, $p<0.1$) for oyster shell than for limestone supplemented diets. In Experiment 3, Ca source did not affect ($p>0.20$) ruminal microbial efficiency. However, ruminal OM digestion was greater (8.3%, $p<0.05$) for oyster shell than for limestone supplemented diets. The increase in OM digestion was associated with numerical increases (8.6 and 4.6%, respectively) in ruminal NDF and starch digestion. There was an interaction ($p<0.01$) between Ca source and level on postruminal OM digestion. Increasing dietary Ca level using oyster shell depressed (7.4%) postruminal OM digestion compared to that of the other treatments. Otherwise, there were n effects ($p>0.20$) of Ca level and source on apparent total tract digestion of OM, NDF, starch and N. There were no treatment effects ($p>0.20$) on ruminal pH, VFA molar proportions and estimated methane production. As expected, increasing dietary Ca level from 0.5-0.9% increased ($p<0.01$) Ca flow to the duodenum (32.3%) and fecal excretion (40.4%). Apparent ruminal digestion of Ca was low (1.2%) across treatments, being slightly negative (-10.7%) for the 0.5 levels of dietary Ca and slightly positive (13.2%), for the 0.9% level of dietary Ca ($p<0.05$). Conversely, apparent post-ruminal Ca absorption was greater (34.6%, $p<0.05$) for diets supplemented with 0.5 vs. 0.9% Ca. There were no treatment effects ($p>0.20$) on apparent total tract Ca digestion. We conclude that increasing dietary Ca levels beyond standard requirements for maintenance and tissue growth may not enhance performance of feedlot steers and heifers fed steam-flaked corn-based high concentrate finishing diets. Notwithstanding the greater reactivity of oyster shell vs. limestone, difference between sources in terms of growth performance and ruminal pH and digestive function are small.

Key words: Oyster shell, limestone, calcium, digestion, cattle, performance, feedlot

INTRODUCTION

In numerous studies (Varner and Woods, 1972; Brink *et al*., 1984; Russell *et al*., 1980; Zinn and Shen, 1996), a beneficial effect of extra-supplementation of dietary Ca levels above standards (NRC, 1996) for maintenance and tissue growth has not been apparent. Nevertheless, in some few cases, enhancements in growth-performance at levels of supplementation greatly in excess of standards have been clearly demonstrated;

Corresponding Author: R.A. Zinn, University of California, Davis, USA

the benefit being it's putative buffering or ruminal alkalizing effect. For example, Huntington (1983) conducted 2 growth performance trails evaluating dietary Ca levels ranging from 0.3-1.2% in a cracked corn-based finishing diet. In the 1st trial, they noted a significant linear increase in ADG with increasing dietary Ca level (maximal response occurring at the 1.2% dietary Ca). In the 2nd trial ADG was maximal at 0.6% dietary Ca (no additional observed benefit to higher levels of limestone supplementation). Likewise, Bock *et al.* (1991) observed that increasing dietary Ca level from 0.6-0.9% in a steam-rolled wheat-based finishing diet containing no supplemental fat or supplemented with 3.5% soybean oil soapstock, enhanced both ADG and gain efficiency. Noller *et al.* (1980) observed that differences in cattle performance responses to Ca supplementation might be explained by reactivity of the supplemental Ca source. In support of their findings, Brink *et al.* (1984) observed that supplemental limestone with smaller particle size and faster reactivity promoted greater ADG and gain efficiency in finishing feedlot cattle than supplemental limestone of coarser particle size and slower reactivity. The objective of the present study was to compare 2 common commercial Ca sources (oyster shell vs. limestone) with respect to their potential for enhancement of growth performance and digestive function of feedlot cattle at levels of supplementation in excess of standard requirements for maintenance and tissue growth.

MATERIALS AND METHODS

All procedures involving animal care and management were in accordance with and approved by the University of California, Davis, Animal Use and Care Committee.

Experiment 1

Animals and diets: Ninety-six steers (approximately 25% Brahman breed with the remainder represented by Hereford, Angus, Shorthorn and Charolais breeds in various proportions) with an average initial weight of 334 kg were used in a 126 days experiment to evaluate the influence of calcium source and level on growth performance of feedlot cattle fed a high-fat finishing diet. Steers were blocked by weight and randomly assigned within weight groupings to 16 pens (6 steers pen^{-1}). Pens were 43 m^2 with 22 m^2 overhead shade. Two supplemental calcium sources (oyster shell vs. limestone) were evaluated at 2 levels of supplementation (1.12 vs. 2.80%, DM basis) in 2×2 factorial arrangement of treatments. All diets contained 6% yellow grease (DM basis). Composition of experimental diets is shown in Table 1. Diets were prepared at weekly intervals and stored in plywood boxes located in front of each pen.

Table 1: Composition of experimental diets fed to steers (Experiment 1)

	Dietary Ca (%)			
	Oyster shell		Limestone	
Item	0.7	1.2	0.7	1.2
Ingredient composition (%) (DM basis)				
Alfalfa hay	8.00	8.00	8.00	8.00
Sudangrass hay	4.00	4.00	4.00	4.00
Flaked corn	73.08	71.40	73.08	71.40
Yellow grease	6.00	6.00	6.00	6.00
Cane molasses	6.00	6.00	6.00	6.00
Limestone			1.12	2.80
Oyster shell	1.12	2.80		
Urea	1.20	1.20	1.20	1.20
Dicalcium phosphate	0.10	0.10	0.10	0.10
Trace mineral salt[1]	0.50	0.50	0.50	0.50
Nutrient composition (DM basis)				
NE (Mcal kg^{-1})				
Maintenance	2.33	2.29	2.33	2.32
Gain	1.63	1.60	1.63	1.63
CP (%)	12.59	12.43	12.59	12.43
Ether extract (%)	9.40	9.23	9.40	9.23
NDF (%)	12.43	12.43	12.43	12.43
Calcium (%)	0.70	1.20	0.70	1.20
Phosphorus (%)	0.29	0.32	0.29	0.32
Potassium (%)	0.79	0.78	0.79	0.78
Sulfur (%)	0.18	0.18	0.18	0.18

[1]Trace mineral salt contained: $CoSO_4$, 0.68%; $CuSO_4$, 1.04%; $FeSO_4$, 3.57%; ZnO, 1.24%; $MnSO_4$, 1.07%; KI, 052% and NaCl, 92.96%; [2]Based on tabular values for individual feed ingredients (NRC, 1996)

Steers were allowed *ad libitum* access to their experimental diets. Fresh feed was provided twice daily. Steers were implanted with Synovex-S (Fort Dodge Animal Health, Fort Dodge, IA).

Estimation of dietary net energy: Energy Gain (EG) was calculated by the equation:

$$EG = ADG^{1.097}\ 0.0493\ LW^{0.75}$$

where:

EG = The daily energy deposited (Mcal day^{-1})
LW = The mean shrunk BW (kg; NRC, 1984)

Maintenance Energy (EM) was calculated by the equation:

$$EM = 0.077LW^{0.75}$$ (Lofgreen and Garrett, 1968)

Dietary Neg was derived from NEm by the equation:

$$Neg = 0.877\ Nem\text{-}0.41$$ (Zinn, 1987)

Dry matter intake is related to energy requirements and dietary NEm according to the equation:

$$DMI = EG/(0.877\ NEm - 0.41)$$

and can be resolved for estimation of dietary NE by means of the quadratic formula:

$$\left(x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2c} \right)$$

where:

x = NEm
a = -0.41 EM
b = 0.877 EM + 0.41 DMI + EG
c = -0.877 DMI (Zinn *et al.*, 1998)

Carcass data: Hot carcass weights were obtained at time of slaughter. After carcasses chilled for 48 h, the following measurements were obtained: LM area (ribeye area), by direct grid reading of the eye muscle at the 12th rib; subcutaneous fat over the eye muscle at the 12th rib taken at a location 3/4 the lateral length from the chine bone end (adjusted by eye for unusual fat distribution); KPH as a percentage of HCW; marbling score (USDA, 1965; using 3.0 as minimum slight, 4.0 as minimum small, etc.) and percentage carcass yield of boneless, closely trimmed retail cuts from the round, loin, rib and chuck (USDA, 1965).

Statistical design and analysis: For calculating steer performance, initial and final full weights were reduced 4% to account for digestive tract fill. Pens were used as experimental units. The experiment data were analyzed as a randomized complete block design in a 2×2 factorial arrangement, with 4 treatments and 4 blocks (Hicks, 1973).

Experiment 2: Ninety-six heifers (approximately 25% Brahman breed with the remainder represented by Hereford, Angus, Shorthorn and Charolais breeds in various proportions) with an average initial weight of 354 kg were used in a 149 days experiment. Heifers were blocked by weight and randomly assigned within weight groupings to 16 pens (6 heifers pen^{-1}). Pens were 43 m^2 with 22 m^2 overhead shade. Two supplemental calcium sources (oyster shell vs. limestone) were evaluated at 2 levels of supplementation (0.55 vs. 1.80%, DM basis) in 2×2 factorial arrangement of treatments. As in Experiment 1, all diets contained 6% of yellow grease (DM basis). Composition of dietary treatments is shown in Table 2. Heifers were implanted with Synovex-H (Fort Dodge Animal Health, Fort Dodge, IA) upon initiation of the study and reimplanted with Synovex-H on day 56. Feedlot heifer management, carcass data and statistical design and analysis were as indicated for Experiment 1. Estimation of dietary net energy was similar to that of Experiment 1, except that EG was calculated by the equation:

$$EG = ADG^{1.119}\ 0.0686\ LW^{0.75}\ \text{(NRC, 1984)}$$

Table 2: Composition of experimental diets fed to steers (Experiments 2 and 3)

	Dietary Ca (%)			
	Oyster shell		Limestone	
Item	0.50	0.90	0.50	0.90
Ingredient composition (%) (DM basis)				
Alfalfa hay	8.00	8.00	8.00	8.00
Sudangrass hay	4.00	4.00	4.00	4.00
Flaked corn	72.00	70.75	72.00	70.75
Yellow grease	6.00	6.00	6.00	6.00
Cane molasses	5.00	5.00	5.00	5.00
Soybean meal	2.50	2.50	2.50	2.50
Limestone	-	-	0.55	1.80
Oyster shell	0.55	1.80		
Urea	0.85	0.85	0.85	0.85
Dicalcium phosphate	0.10	0.10	0.10	0.10
Trace mineral salt[1]	0.50	0.50	0.50	0.50
Nutrient composition (DM basis)[2]				
NE (Mcal kg^{-1})				
Maintenance	2.36	2.32	2.36	2.32
Gain	1.65	1.63	1.65	1.63
CP (%)	12.84	12.50	12.84	12.46
NDF (%)	12.70	12.70	12.70	12.70
Ether extract (%)	9.40	9.34	9.40	9.34
Calcium (%)	0.50	0.90	0.50	0.90
Phosphorus (%)	0.33	0.30	0.33	0.30
Potassium (%)	0.80	0.80	0.80	0.80
Sulfur (%)	0.18	0.18	0.18	0.18

[1]Trace mineral salt contained: $CoSO_4$, 0.68%; $CuSO_4$, 1.04%; $FeSO_4$, 3.57%; ZnO, 1.24%; $MnSO_4$, 1.07%; KI, 052% and NaCl, 92.96%; [2]Based on tabular values for individual feed ingredients (NRC, 1984) with the exception of supplemental fat, which was assigned NE_m and NE_g values of 6.03 and 4.79, respectively

Experiment 3

Animals and sampling: Four steers (399 kg) with cannulas in the rumen and proximal duodenum (Zinn and Plascencia, 1993) were used in 4×4 Latin square experiment to study treatment effects on characteristics of digestion. Treatments were the same as those used in Experiment 2 (Table 2), with 0.40% chromic oxide added as a digesta marker. Steers were maintained in individual pens with access to water at all times. Diets were fed at 0800 and 2000 daily. Dry matter intake was restricted to 6.06 kg day^{-1} (1.52% BW). Experimental periods were 2 weeks, with 10 days for diet adjustment and 4 days for collection. During collection, duodenal and fecal samples were taken twice daily as follows: day 1,0750 and 1350; day 2,0900 and 1500; day 3,1050 and 1650 and day 4,1200 and 1800. Individual samples consisted of approximately 700 mL of duodenal chime and 200 g (wet basis) of fecal material. Samples from each steer and within each collection period were composited for analysis. During the final day of each collection period, ruminal samples were obtained from each steer via ruminal cannula at 1200 (4 h after feeding). Ruminal fluid pH was determined on fresh samples. Samples strained through 4 layers of cheesecloth. Two mL of freshly prepared 25% (wt vol^{-1}) meta-phosphoric acid was added to 8 mL of strained ruminal fluid. Samples were then centrifuged (17 000×g for 10 min) and supernatant fluid was stored at -20°C for VFA

analysis. Upon completion of the experiment, ruminal fluid was obtained via the ruminal cannula from all steers and composited for isolation of ruminal bacteria via differential centrifugation (Bergen *et al*., 1968).

Sample analysis and calculations: Samples were subjected to all or part of the following analysis: DM (oven drying at 105°C until no further weight loss), ash, ammonia N, Kjeldahl N (AOAC, 1984); NDF (Goering and Van Soest, 1970; adjusted for insoluble ash), chromic oxide (Hill and Anderson, 1958); purines (Zinn and Owens, 1986); starch (Zinn, 1990) and Ca (atomic absorption spectrophotometry; AOAC, 1984). Calcium reactivity was determined from the linear portion of the slope (k) of the pH vs. time plot with reactivity calculated as $t½ = 0.693/k$ (Brink *et al*., 1984). Microbial OM (MOM) and N (MN) leaving the abomasum were calculated using purines as a microbial marker (Zinn and Owens, 1986). Organic matter fermented in the rumen was considered equal to OM intake minus the difference between the amount of total OM reaching the duodenum and MOM reaching the duodenum. Feed N escape to the small intestine was considered equal to total N leaving the abomasum minus ammonia-N and MN and thus, includes any endogenous additions. Methane production (mol mol^{-1} glucose equivalent fermented) was estimated based on the theoretical fermentation balance for observed molar distribution of VFA (Wolin, 1960).

Statistical analysis: The experiment data were analyzed as a 4×4 Latin square experiment in a 2×2 factorial arrangement (Hicks, 1973). Dietary treatments were the same as in Experiment 2.

RESULTS AND DISCUSSION

Composition and physical characteristics of ground limestone and oyster shell used in this study are shown in Table 3. The calcium content of limestone was consistent (33.3 vs. 34.0% Ca) with standard tabular values (NRC, 1996). The calcium content of the oyster shell was 90.3% of the tabular value (34.3 vs. 38.0% Ca). The Ca reactivity was 17.9 and 5.87 min, respectively for limestone and oyster shell. The higher reactivity of oyster shell vs. limestone may be related to the greater proportion of fine particles (99% <1 mm, 68% <0.50 mm). Brink *et al*. (1984) noted that reactivity of limestone increased with decreasing particle size. Finely ground limestone had a reactivity of 5.2, similar to that of ground oyster shell in the present study.

The influence of Ca level (0.7 vs. 1.2%) and source (oyster shell vs. limestone) on growth performance and carcass characteristics of feedlot steers in Experiment 1 is shown in Table 4 and 5, respectively. There were no treatment effects (p>0.20) on DMI, ADG, gain efficiency

Table 3: Characteristics of limestone and oyster shell

Item	Limestone	Oyster shell
Calcium (%)	33.30	34.30
Calcium reactivity (min^{1})	17.90	5.87
Density (kg L^{-1})	1.92	1.18
Particle size distribution (%)		
≥2 mm diameter	0.20	0.30
<2, ≥1 mm	29.20	0.40
<1, ≥0.50 mm	27.40	31.10
<0.50, ≥0.25 mm	25.30	27.00
<0.25 mm	17.90	41.10

[1]Reactivity determined from linear portion of the slope (k) of the pH vs. time plot with reactivity calculated as $t½ = 0.693/k$ (Brink *et al*., 1984)

Table 4: Influence of source and level of Ca on growth performance of feedlot steers (Experiment 1)

	Dietary Ca (%)				
	Oyster shell		Limestone		
Item	0.7	1.2	0.7	1.2	SEM
Days on test	126.00	126.00	126.00	126.00	-
Live weight (kg)[1]					
Initial	333.80	334.20	333.50	333.50	2.10
Final	520.30	507.10	522.70	522.30	8.50
ADG (kg day^{-1})	1.48	1.37	1.50	1.50	0.06
DMI (kg day^{-1})	7.91	7.72	8.05	8.05	7.72
ADG:DMI	18.77	17.83	18.70	18.63	0.43
Dietary NE (Mcal kg^{-1})					
Maintenance	2.36	2.28	2.35	2.35	0.03
Gain	1.66	1.59	1.65	1.65	0.03
Observed/expected NE					
Maintenance	1.01	1.00	1.01	1.03	0.01
Gain	1.02	1.00	1.01	1.03	0.02
Fecal pH	5.98	6.12	6.13	6.09	0.05
Fecal Ca (%) DM basis[2, 3]	2.50	4.52	2.99	5.17	0.27

[1]Initial and final live weights reduced 4% to account for fill; [2]Calcium source (p<0.10); [3]Calcium level (p<0.01)

Table 5: Influence of source and level of Ca in finishing diets on carcass characteristics of steers (Experiment 1)

	Dietary Ca (%)				
	Oyster shell		Limestone		
Item	0.7	1.2	0.7	1.2	SEM
HCW (kg)	329.40	317.90	332.10	329.20	6.10
Dressing percentage	63.30	62.70	63.60	63.00	0.50
KPH (%)[1]	1.63	1.52	1.43	1.42	0.20
Fat thickness (cm)[2]	0.90	0.97	1.16	0.90	0.06
LM area (cm^2)	85.40	85.30	84.90	89.30	2.10
Marbling score[3]	3.41	3.58	3.50	3.65	0.09
Yield grade[4, 5]	51.50	51.70	50.90	52.10	0.30

[1]Kideney, pelvic and heart fat as a percentage of carcass weight; [2]Calcium level by source interaction (p<0.10); [3]Coded: minimum slight = 3, minimum small = 4, etc. (USDA, 1965); [4]Calcium level (p<0.10); [5]Percentage carcass yield of boneless, closely trimmed retail cuts from the round, loin, rib and chuck

or dietary NE (Table 4). Carcass weight, dressing percentage, KPH, LM area and marbling score also were not affected (p>0.10) by dietary treatments. Increasing dietary Ca level from 0.7-1.4% tended to slightly increase (1.2%, p<0.10) estimated carcass retail yield and there was a tendency (p<0.10) for an interaction between Ca level and source on fat thickness. Fat thickness was similar for oyster shell at the 2 levels of supplementation. However, with the limestone, fat thickness was 29% greater for diets

supplemented to contain 0.7% Ca than for diets containing 1.4% Ca. There were no treatment effects (p>0.20) on fecal pH. As expected, increasing dietary Ca level increased (p<0.01) fecal Ca concentration. Percentage fecal Ca tended to be lower (14%, p<0.10) for steers fed diets supplemented with oyster shell than for those fed limestone supplemented diets.

The influence of Ca level (0.5 vs. 0.9%) and source (oyster shell vs. limestone) on growth performance and carcass characteristics of feedlot heifers in Experiment 2 is shown in Table 6 and 7. As in Experiment 1, there were no treatment effects (p>0.20) on ADG, DMI, gain efficiency and dietary NE. Likewise, there were no treatment effects (p>0.20) on carcass dressing percentage or LM area. In contrast with Experiment 1, there were no treatment effects on fat thickness and retail yield. However, KPH was greater (8.9%, p<0.1) for oyster shell than for limestone supplemented diets.

Results of Experiments 1 and 2 are consist with previous studies (Varner and Woods, 1972; Brink *et al*., 1984; Russell *et al*., 1980; Zinn and Shen, 1996) indicating that increasing dietary Ca levels above 0.5% may not enhance growth performance of feedlot steers and heifers. Likewise, results are in agreement with NRC (1996) factorial assessments of Ca requirements based on maintenance and tissue growth estimates for steers and heifers in Experiments 1 and 2 (0.45 and 0.44%, respectively).

It has been considered that supplemental Ca as calcium carbonate might also provoke an extra-calcium (buffering) effect that in turn might enhance cattle performance. For example, Huntington (1983) conducted 2 growth performance trails evaluating dietary Ca levels ranging from 0.3-1.2% in a cracked corn-based finishing diet. Limestone was the supplemental Ca source. In the 1st trial, ADG increased linearly with increasing dietary Ca level (maximal response occurring at the 1.2% dietary Ca). In the 2nd trial, ADG was maximal at 0.6% dietary Ca. Likewise, Bock *et al.* (1991) observed that increasing dietary Ca level from 0.6-0.9% in a steam-rolled wheat-based finishing diet containing no supplemental fat or supplemented with 3.5% soybean oil soapstock, enhanced both ADG and gain efficiency. Surprisingly, when tallow was the supplemental fat source they observed a negative interaction with dietary Ca level. Increasing dietary Ca from 0.6-0.9% depressed ADG and gain efficiency.

Thus, whereas numerous studies (including the present) do not support Ca supplementation of growing-finishing feedlot cattle in excess of their factorial requirements for maintenance and tissue growth (NRC, 1996), other studies clearly demonstrate enhancements in growth-performance at levels of supplementation greatly in excess of standards; the benefit being it's putative buffering or ruminal alkalizing effect.

Table 6: Influence of source and level of Ca on growth performance of feedlot heifers (Experiment 2)

	Dietary Ca (%)				
	Oyster shell		Limestone		
Item	0.5	0.9	0.5	0.9	SEM
Days on test	149.00	149.00	149.00	149.00	-
Live weight (kg)[1]					
Initial	353.00	353.90	354.90	353.40	3.50
Final	466.70	471.00	475.80	478.70	13.40
ADG (kg day^{-1})	0.78	0.80	0.82	0.84	0.08
DMI (kg day^{-1})	5.75	5.99	6.00	6.08	0.28
ADG:DMI	7.50	7.6	7.40	7.20	0.6
Dietary NE (Mcal kg^{-1})					
Maintenance	2.32	2.28	2.31	2.30	0.09
Gain	1.63	1.59	1.61	1.61	0.08
Observed/expected NE					
Maintenance	0.98	0.98	0.98	0.99	0.04
Gain	0.98	0.98	0.97	0.99	0.05

[1]Initial and final live weights reduced 4% to account for fill

Table 7: Influence of source and level of Ca in finishing diets on carcass characteristics of heifers (Experiment 2)

	Dietary Ca (%)				
	Oyster shell		Limestone		
Item	0.5	0.9	0.5	0.9	SEM
Carcass weight (hot) (kg)	302.70	308.10	308.70	309.40	12.00
Dressing percentage	64.90	65.40	64.90	64.60	0.02
KPH (%)[1, 2]	2.02	1.92	1.66	1.87	0.18
Fat thickness (cm)	1.24	1.14	1.12	1.32	0.23
LM area (cm^2)	81.00	83.60	79.60	82.70	3.90
Retail yield (%)	50.70	51.10	50.80	50.60	0.70
Yield grade[3]	3.31	3.24	3.23	3.36	0.19

[1]Kideney, pelvic and heart fat as a percentage of carcass weight; [2]Calcium source (p<0.10); [3]Percentage carcass yield of boneless, closely trimmed retail cuts from the round, loin, rib and chuck

Growth-performance responses were not affected (p>0.20) by calcium source. Although, very little information is available in the literature comparing oyster shell vs. limestone as a Ca source for feedlot cattle, considerable attention (Perry *et al*., 1968; Haskins *et al*., 1969; White *et al*., 1969; Williams *et al*., 1970) has been directed at investigating it's potential as a ruminal alkalizing agent, due to its comparatively high reactivity or rate of acid neutralization (3-fold greater than that of limestone; Table 3). Haskins *et al.* (1969) observed enhanced performance of feedlot cattle fed an all-concentrate shelled-corn-based diet supplemented with 2% oyster shell. However, inclusion of 4% oyster shell dramatically depressed DMI and in turn, ADG. Likewise, White *et al.* (1969) observed marked depression in DMI and ADG with inclusion of 5% oyster shell in a sorghum grain-based all concentrate diet (basal and oyster shell supplemented diets contained 0.4 and 2.1% calcium,

respectively). Williams *et al.* (1970) observed marked depression in DMI and ADG with inclusion of only 2.4-3% oyster shell to either a ground ear corn-based diet or an all-concentrate shelled corn-based diet (basal diets also contained 0.4 or 0.5% limestone, respectively, in addition to oyster shell).

Treatment effects on characteristics of ruminal and total digestion (Experiment 3) is shown in Table 8. Diets fed in this trial were similar to those of Experiment 2 (Table 2). Calcium source did not affect ($p>0.20$) ruminal microbial efficiency. However, ruminal OM digestion was greater (8.3%, $p<0.05$) for oyster shell than for limestone supplemented diets. The increase in OM digestion was associated with numerical increases (8.6 and 4.6%, respectively) in ruminal NDF and starch digestion. There was an interaction ($p<0.01$) between Ca source and level on postruminal OM digestion. Increasing dietary Ca level using oyster shell depressed (7.4%) postruminal OM digestion compared to that of the other treatments. Otherwise, consistent with previous studies (Zinn and Shen, 1996) in which similar diets were fed, Ca level and source did not affect ($p>0.20$) of on apparent total tract digestion of OM, NDF, starch and N. Likewise, Goetsch and Owens (1985) observed that dietary Ca levels ranging from 0.5-1.1% did not affect total tract digestion of OM, starch, fiber and N. In contrast, Jenkins and Palmiquist (1982) and Drackley *et al.* (1985) reported a positive associative effect of increasing dietary Ca level on fiber digestion in fat supplemented diets. Christiansen and Webb (1990) observed that whereas increasing dietary Ca level from 0.54-1.04% with supplemental limestone did not affect apparent total tract N digestion, it reduced apparent ruminal N digestion and increased intestinal N digestion.

Consistent with Zinn and Shen (1996), there were no treatment effects ($p>0.20$) on ruminal pH, VFA molar proportions and estimated methane production (Table 9). Likewise, Russell *et al.* (1980) observed that increasing dietary limestone level in a finishing diet from 0.4-1.8% in a whole shelled corn-based diet did not affect ruminal pH. Williams *et al.* (1970) observed that the addition of 2.4-2.9% oyster shell to either conventional or all-concentrate finishing diets did not affect ruminal pH, VFA concentrations, ruminal papillae length, or liver abscesses.

Treatment effects on apparent Ca digestion are shown in Table 10. As expected, increasing dietary Ca level from 0.5-0.9% increased ($p<0.01$) Ca flow to the duodenum (32.3%) and fecal excretion (40.4%). Apparent ruminal digestion of Ca was low (1.2%) across treatments, being slightly negative (-10.7%) for the 0.5 levels of dietary Ca and slightly positive (13.2%), for the 0.9% level of dietary Ca ($p<0.05$). Conversely, apparent post-ruminal Ca absorption was greater (34.6%, $p<0.05$) for diets supplemented with 0.5 vs. 0.9% Ca. There were no treatment effects ($p>0.20$) on apparent total tract Ca digestion.

Table 8: Influence of level and source of supplemental calcium on ruminal and total digestion of steers (Experiment 3)

	Dietary Ca (%)				
	Oyster shell		Limestone		
Item	0.5	0.9	0.5	0.9	SEM
Steer weight (kg)	399.0	399.0	399.0	399.0	-
Intake (g day^{-1})					
DM	6,065	6,065	6,065	6,065	-
OM	5,815	5,667	5,815	5,667	-
NDF	1,311	1,309	1,311	1,309	-
N	117.0	116.0	117.0	116.0	-
Starch	2,909	2,858	2,909	2,858	-
Flow to the duodenum (g day^{-1})					
OM	3,016.7	2,804.6	3,227.7	3,097.3	133.90
NDF	479.10	443.40	553.80	492.20	47.70
Starch	468.90	308.40	551.40	452.70	75.20
Microbial-N	74.740	80.900	75.620	75.670	3.09
Non-Ammonia N	130.90	130.70	134.60	131.90	2.60
Feed-N	56.200	49.80	59.000	56.300	4.20
Fecal excretion (g day^{-1})					
DM	1,133.7	1,286.0	1,231.5	1,256.2	52.10
OM	986.70	1,097.7	1,078.7	1,075.5	51.90
NDF	358.90	376.50	408.80	424.30	26.90
Starch	24.800	14.430	31.410	27.310	7.67
N	31.300	32.390	33.300	31.750	2.07
Ruminal digestion (%)					
OM[1]	61.08	64.73	57.50	58.64	1.94
NDF	63.54	65.61	57.10	61.77	3.64
Starch	83.70	89.29	81.44	84.00	2.36
Feed-N	51.98	57.13	49.60	51.54	3.62
Microbial efficiency	21.86	22.06	23.33	22.89	1.50
$N_{efficiency}$	1.120	1.130	1.150	1.140	0.02
Post-ruminal digestion (%) of duodenal flow					
OM[234]	66.09	60.72	65.69	64.89	0.39
NDF	19.96	13.59	23.90	9.800	8.56
Starch	93.91	95.09	94.35	93.76	1.39
N	76.98	76.25	76.13	76.80	1.56
Total tract digestion (%)					
DM	81.3	78.8	79.7	79.3	0.90
OM	83.03	80.62	81.44	81.03	0.92
NDF	72.43	71.10	68.39	67.63	2.03
Starch	99.14	99.49	98.94	99.05	0.26
N	73.29	72.09	71.55	72.65	1.77

[1]Ca source effect ($p<0.05$); [2]Ca source effect ($p<0.01$); [3]Ca level effect ($p<0.01$); [4]Ca source×Ca level effect ($p<0.01$); Microbial N, g kg^{-1} OM truly fermented

Table 9: Influence of level and source of supplemental calcium on ruminal pH and VFA molar proportions (Experiment 3)

	Dietary Ca (%)				
	Oyster shell		Limestone		
Item	0.5	0.9	0.5	0.9	SEM
Ruminal pH	5.56	5.55	5.36	5.58	0.09
Total VFA, mM	107.80	104.90	128.20	104.80	10.40
Acetate (mol/100 mol)	46.00	49.90	45.60	46.60	3.10
Propionate (mol/100 mol)	35.90	30.80	36.00	35.30	3.10
Butyrate (mol/100 mol)	11.50	11.50	10.90	9.80	1.40
Acetate:propionate ratio	1.30	1.70	1.30	1.40	0.20
Methane[1]	0.38	0.44	0.38	0.38	0.04

[1]Methane production (mol/mol glucose equivalent fermented) was estimated bases on the theoretical fermentation balance for observed molar distribution of VFA (Wolin, 1960)

Table 10: Influence of level and source of supplemental calcium on ruminal and total digestion of calcium by steers (Experiment 3)

	Dietary Ca (%)				
	Oyster shell		Limestone		
Item	0.5	0.9	0.5	0.9	SEM
Steer weight (kg)	399.00	399.00	399.00	399.00	-
Intake (g day^{-1})	30.20	56.90	29.90	55.80	-
Flow to the duodenum (g day^{-1})[1]	34.80	48.70	30.90	49.20	2.70
Fecal excretion (g day^{-1})[1]	22.10	40.10	22.90	35.50	2.90
Ruminal digestion (%)[2]	-15.14	14.48	-3.49	11.88	7.19
Post-ruminal digestion[2, 3]	36.70	18.20	25.80	28.20	3.30
Total tract digestion (%)	26.70	29.70	23.30	36.30	6.70

[1]Level effect ($p<0.01$); [2]Level effect ($p<0.05$); [3]Interaction effect ($p<0.05$)

CONCLUSION

Increasing dietary Ca levels beyond standard requirements for maintenance and tissue growth may not enhance performance of feedlot steers and heifers fed steam-flaked corn-based high concentrate finishing diets. Notwithstanding, the greater reactivity of oyster shell vs. limestone, difference between sources in terms of growth performance and ruminal pH and digestive function were small.

REFERENCES

AOAC, 1984. Official Methods of Analysis. 14th Edn. Assoc. Off. Anal. Chem., Arlington, VA. ISBN: 0-935 584-24-2.

Bergen, W.G., D.B. Purser and J.H. Cline, 1968. Effect of ration on the nutritive quality of rumen microbial protein. J. Anim. Sci., 27: 1497-1501. http://jas.fass.org/cgi/reprint/27/5/1497.

Bock, B.J., D.L. Harmon, R.T. Brandt, Jr. and J.E. Schneider, 1991. Fat source and calcium level effects on finishing steers performance, digestion and metabolism. J. Anim. Sci., 69: 2211. http://jas.fass.org/cgi/reprint/69/5/2211.

Brink, D.R., O.A. Turgeon, Jr., D.L. Harmon, R.T. Steele, T.L. Mader and R.A. Britton. 1984. Effects of additional limestone of various types on feedlot performance of beef cattle fed high corn diets differing in processing method and potassium level. J. Anim. Sci., 59: 791-797. http://jas.fass.org/cgi/reprint/59/3/791.

Christiansen, M.L. and K.E. Webb Jr., 1990. Intestinal acid flow, dry matter, starch and protein digestibility and amino acid absorption in defluorninated rock phosphate, limestone or magnesium oxide. J. Anim. Sci., 68: 2105-2118. http://jas.fass.org/cgi/reprint/68/7/2095.

Drackley, J.K., A.K. Clarck and T. Sahlu, 1985. Ration digestibilities and ruminal characteristics in steers fed sunflower seeds with additional calcium. J. Dairy Sci., 68: 356-367. http://jds.fass.org/cgi/reprint/68/2/356.

Goering, H.K. and P.J. Van Soest, 1970. Forage Fiber Analyses (Apparatus, Reagents, Procedures and Some Applications). Agric. Handbook No. 379. ARS-USDA, Washington, DC.

Goetsch, A.L. and F.N. Owens, 1985. Effects of calcium source and level on site of digestion and calcium levels in the digestive tract of cattle fed high-concentrate diets. J. Anim. Sci., 61: 995-1003. http://jas.fass.org/cgi/reprint/61/4/995.

Haskins, B.R., M.B. Wise, H.B. Craigh, T.N. Blumer and E.R. Barrick, 1969. Effects of adding low levels of roughages or roughage substitutes to high energy rations for fattening steers. J. Anim. Sci., 29: 345: 353. http://jas.fass.org/cgi/reprint/29/2/345.

Hicks, C.R., 1973. Fundamental Concepts in the Design of Experiments. 2nd Edn. Holt, Rinehart and Winston, Inc., New York, pp: 77-79. ISBN: 0030617065.

Hill, F.N. and D.L. Anderson, 1958. Comparison of metabolizable energy and productive energy determinations with growing chicks. J. Nutr., 64: 587-603. http://jn.nutrition.org/cgi/reprint/64/4/587.pdf.

Huntington, G.B., 1983. Feedlot performance, blood metabolic profile and calcium status of steers fed high concentrate diets containing several levels of calcium. J. Anim. Sci., 56: 1003-1011. http://jas.fass.org/cgi/reprint/56/5/1003.

Jenkins, T.C. and D.L. Palmquist, 1982. Effect of added fat and calcium on *in vitro* formation of insoluble fatty acids soaps and cell wall digestibility. J. Anim. Sci., 55: 957-963. http://jas.fass.org/cgi/reprint/55/4/957.

Lofgreen, G.P. and W.N. Garrett, 1968. A system for expressing net energy requirements and feed values for growing and finishing beef cattle. J. Anim. Sci., 27: 793-806. http://jas.fass.org/cgi/reprint/27/3/793.

Noller, C.H., J.L. White, W. Wheeler, 1980. Characterization of cement klin dusts and animal response. J. Dairy Sci., 63: 1947-1952. http://jds.fass.org/cgi/reprint/63/11/1947.pdf.

NRC, 1984. Nutrient Requirements of Beef Cattle. 6th Rev. Edn. Natl. Acad. Press, Washington, DC, pp: 38-39. ISBN: 0-309-03447-7.

NRC, 1996. Nutrient Requirements of Beef Cattle. 7th Rev. Edn. Natl. Acad. Press, Washington, DC, pp: 55, 202, 203. ISBN: 0-309-06934-3.

Perry, T.W., H.F. Troutt, R.C. Peterson and W.M. Beeson, 1968. Oyster shell as a roughage replacer in fattening beef cattle rations. J. Anim. Sci., 27: 185-189. http://jas.fass.org/cgi/reprint/27/1/185.

Russell, J.R., A.W. Young and N.A. Jorgensen, 1980. Effect of sodium bicarbonate and limestone additions to high grain diets on feedlot performance and ruminal and fecal parameters in finishing steers. J. Anim. Sci., 51: 996-1002. http://jas.fass.org/cgi/reprint/51/4/996.

USDA, 1965. Official United States Standards for Grades of Carcass Beef. USDA, C and MS, SRA 99. http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELDEV3002979.

Varner, L.W. and W. Woods, 1972. Calcium levels in high grain beef cattle rations. J. Anim. Sci., 35: 415-417. http://jas.fass.org/cgi/reprint/35/2/415.

White, T.W., W.L. Reynolds and R.H. Klett, 1969. Roughage sources and levels in steer rations. J. Anim. Sci., 29: 1001-1005. http://jas.fass.org/cgi/reprint/29/6/1001.

Williams, D.B., N.W. Bradley, C.O. Little, M.W. Crowe and J.A. Boling, 1970. Effect of oyster shell with and without roughage in beff finishing rations. J. Anim. Sci., 30: 614-617. http://jas.fass.org/cgi/reprint/30/4/614.

Wolin, M.J., 1960. A theoretical rumen fermentation balance. J. Dairy Sci., 43: 1452-1459. http://jds.fass.org/cgi/content/abstract/43/10/1452.

Zinn, R.A., 1987. Influence of lasalosid and monensin plus tylosin on comparative feeding value of steam-flaked versus dry-rolled corn diets for feedlot cattle. J. Anim. Sci., 65: 256-266. http://jas.fass.org/cgi/reprint/65/1/256.

Zinn, R.A., 1990. Influence of flake density on the comparative feeding value of steam-flaked corn for feedlot cattle. J. Anim. Sci., 68: 767-775. http://jas.fass.org/cgi/reprint/68/3/767.

Zinn, R.A. and F.N. Owens, 1986. A rapid procedure for purine measurement and its use for estimating net ruminal protein synthesis. Can. J. Anim. Sci., 66: 157-166.

Zinn, R.A. and A. Plascencia, 1993. Interaction of whole cottonseed and supplemental fat on digestive function in cattle. J. Anim. Sci., 71: 11-17. http://jas.fass.org/cgi/reprint/71/1/11.

Zinn, R.A. and Y. Shen, 1996. Interaction of dietary calcium and supplemental fat on digestive function and growth performance in feedlot steers. J. Anim. Sci., 74: 2303-2309. http://jas.fass.org/cgi/reprint/74/10/2303.

Zinn, R.A., E.G. Alvarez, M.F. Montaño, A. Plascencia and J.E. Ramirez, 1998. Influence of tempering on the feeding value of rolled corn in finishing diets for feedlot cattle. J. Anim. Sci., 76: 2239-2246. http://jas.fass.org/cgi/reprint/74/10/2303.