# EFFECTS OF DIETARY CALCIUM LEVELS ON GROWTH-PERFORMANCE AND DIGESTIVE FUNCTION IN CATTLE FED A HIGH-FAT FINISHING DIET

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**ABSTRACT:** Sixty medium-framed crossbred yearling steers (395 kg) were used in a 90-d feeding trial to evaluate the effects of .5, .7, and .9% Ca in a high-fat (6%) finishing diet on growth-performance. Increasing dietary Ca level enhanced ADG (linear effect, $P < .10$) and feed efficiency (linear effect, $P < .05$). In both cases, the bulk of the improvement occurred when Ca level was increased from .7 to .9%. There were linear ($P < .05$) and quadratic ($P < .10$) components to Ca level effects on diet NE. As with ADG and feed efficiency, responses to .5 and .7% dietary Ca were similar. Increasing Ca level to .9% increased diet $NE_m$ and $NE_g$ by 6.5 and 8.0%, respectively. There also, were positive linear components ($P < .10$) to Ca level effects on dressing percentage and ribeye area. Ten Holstein steers (348 kg) with were used in a crossover design experiment to evaluate the influence of .7 and .9% dietary Ca on digestive function. Increasing Ca level decreased ruminal digestion of OM (5%, $P < .05$), ADF (37%, $P < .10$), and feed N (18%, $P < .05$), and increased ruminal microbial efficiency (12%, $P < .10$) and ruminal N efficiency (14%, $P < .01$). Increasing Ca level enhanced postruminal digestibility of OM (4%, $P < .05$) and N (4%, $P < .01$). There were no treatment effects ($P > .10$) on total tract digestion of OM, ADF, starch or N. The net effect of increasing Ca level was greater postruminal absorption of OM (12%, $P < .01$), N (19%, $P < .01$) and lipid (10%, $P < .10$). Increasing Ca level did not affect ($P > .10$) either ruminal pH or soluble Ca. Ruminal soluble Ca ($Ca_s$ mM) was closely associated with ruminal pH ($R^2 = .93$). It is concluded that dietary Ca levels greater than .7% are necessary to achieve optimal performance of feedlot steers fed a high-fat finishing diet.

## Introduction

Numerous metabolism trials have indicated that when Ca is increased in fat supplemented diets digestibility (usually fiber) also increases (Grainger et al., 1961; Davison and Woods, 1963; Galbraith et al., 1971; Galbraith and Miller, 1973; Jenkins and Palmquist, 1982; Drackley et al., 1985). Unfortunately, very little work has been reported which evaluates the influence of dietary Ca level on performance responses of feedlot cattle when fed high-fat finishing diets. Hatch et al (1972) compared intakes of 11, 22, 32, and 52 g/d Ca in steers fed a high-moisture corn-based finishing diet containing 0, 3 or 6% tallow. No interactions were observed between Ca level and supplemental fat. Surprisingly, there were no treatment effects (Ca level or supplemental fat) on ADG or feed efficiency. Bock et al. (1991) compared Ca intakes of 58 vs 87 g/d (.6 vs .9% Ca) in steers fed a 90% concentrate (wheat-based) finishing diet containing 3.5% tallow or soybean oil soapstock. An interaction was observed between fat source and Ca level. With soybean oil soapstock, increasing Ca level increased ADG (5%), with little difference in feed conversion. In contrast, with supplemental tallow, increasing Ca level decreased ADG (9%) and feed efficiency (6%). Zinn and Shen (1996) compared .45 vs .90% Ca in a barley-based finishing diet containing 0 vs 5% yellow grease. There was no interaction between dietary Ca and the feeding value of supplemental fat. However, total lipid intake in that trial was not extreme (6.8% of diet DM) The objective of this study was to further evaluate the influence of Ca levels in a high-fat (11.1% of diet DM) finishing diet on growth-performance and digestive function of feedlot steers.

## Experimental Procedure

Trial 1. Sixty medium-framed crossbred yearling steers (approximately 25% Brahman breeding with the remainder represented by Hereford, Angus, Shorthorn,

and Charolais breeds in various proportions) with an average initial weight of 395 kg were used in a 90-d feeding trial. The trial was initiated October 15, 1992. Steers were blocked by weight and randomly allotted to 15 pens equipped with automatic waterers and fence-line feed bunks. Treatments consisted of three levels of dietary Ca; .5, .7, and .9% of diet DM. Composition of experimental diets are shown in Table 1. Steers were implanted with Synovex-S (Syntex, Des Moines, IA). Diets were prepared at weekly intervals and stored in plywood boxes located in front of each pen. Steers were allowed ad libitum access to dietary treatments. Fresh feed was provided twice daily. Hot carcass weights were obtained from all steers at time of slaughter. After the carcasses were chilled for 48 h the following measurements were obtained: 1) ribeye muscle area, taken by direct grid reading of the muscle at the 12th rib; 2) subcutaneous fat over the ribeye muscle at the 12th rib taken at a location 3/4 the lateral length from the chine bone end; 3) kidney, pelvic and heart fat (KPH) as a percentage of carcass weight and 4) marbling score (USDA, 1965). Energy retention (ER, megacalories) was derived from measures of live weight (LW, kilograms) and ADG (kilograms/day) according to the following equation: Steers EG = $(.0493LW^{.75})ADG^{1.097}$ (NRC, 1984). Net energy content of the diet for maintenance and gain were calculated assuming a constant fasting heat production (MQ) of $.077LW^{.75}$ Mcal/d (Lofgreen and Garrett, 1968). From estimates of ER and MQ, the $NE_m$ and $NE_g$ values of the diets were obtained by process of iteration (Zinn, 1987) to fit the relationship: $NE_g = (.877NEm) - .41$ (NRC, 1984). This trial was analyzed as a randomized complete block design experiment (Cochran and Cox, 1950). Treatment effects were tested for linear and quadratic components by means of orthogonal polynomials.

Trial 2. Ten Holstein steers (348 kg) with "T" cannulas in the rumen and proximal duodenum (6 cm from the pyloric sphincter) were used in a crossover design experiment to evaluate the influence of .7 and .9% dietary Ca (treatments 2 and 3 of Trial 1) on digestive function. A basal diet was prepared which was the same as treatment 1 (Table 1), except that .5% chromic oxide was added as a digesta marker. All steers received the same basal diet in combination with either .63 or 1.25% limestone (DM basis). The limestone was hand-mixed into the basal diet at the time of feeding. Steers were allowed ad libitum access to experimental diets, with feed provided twice daily (0800 and 2000). Orts were mixed with subsequent feed allotments and refed. Following a 10-d treatment adjustment period, duodenal and fecal samples were taken from respective steers twice daily over a period of four successive days. The protocol for sample collection and analysis was the same as outlined by Zinn and Shen (1996). Microbial organic matter (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 (OMF) 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 contributions. Methane production was calculated based on the theoretical fermentation balance for observed molar distribution of VFA and OM fermented in the rumen (Wolin, 1960). Endogenous urinary energy loss was estimated as $.63W_{kg}^{.50}$ (derived from Brouwer, 1965 and NRC, 1984). This trial was analyzed as a crossover design experiment as follows: $Y_{ijk} = \mu + A_i + P_j + T_k + E_{ijk}$, where Y is the response variable, A is animal, P is period, T is treatment, and E is residual error (Cochran and Cox, 1950).

## Implications

It is concluded that dietary Ca levels greater than .7% are necessary to achieve optimal performance of feedlot steers fed a high-fat finishing diet.

Table 1. Composition of diets (Trials 1 and 2)[a].

| | Dietary calcium, % | | |
|---|---|---|---|
| Item | .50 | .70 | .90 |
| Ingredient composition, % of DM | | | |
| Alfalfa hay | 8.00 | 8.00 | 8.00 |
| Sudangrass hay | 4.00 | 4.00 | 4.00 |
| Steam-flaked corn | 72.50 | 71.87 | 71.25 |
| Soybean meal | 2.50 | 2.50 | 2.50 |
| Light grease | 6.00 | 6.00 | 6.00 |
| Cane molasses | 5.00 | 5.00 | 5.00 |
| Limestone | .55 | 1.18 | 1.80 |
| Dicalcium phosphate | .10 | .10 | .10 |
| Urea | .85 | .85 | .85 |
| Trace mineral salt[b] | .50 | .50 | .50 |
| Nutrient composition, DM basis | | | |
| $Ne_m$, Mcal/kg[c] | 2.38 | 2.36 | 2.35 |
| $NE_g$, Mcal/kg[c] | 1.67 | 1.66 | 1.65 |
| CP, % | 11.9 | 11.8 | 11.8 |
| Lipid, % | 11.2 | 11.1 | 11.1 |

| | | | |
|---|---|---|---|
| Ca, % | .47 | .67 | .88 |
| P, % | .33 | .33 | .32 |

[a]In Trial 2, .5% chromic oxide was added to the diets as a digesta marker.
[b]Trace mineral salt contained: $CoSO_4$, .068%; $CuSO_4$, 1.04%; $FeSO_4$, 3.57%; ZnO, 1.24%; $MnSO_4$, 1.07%; KI, .052%; and NaCl, 92.96%.
[c]Based on tabular values (NRC, 1984), except for light grease (Zinn, 1988)..

Table 2. Influence of calcium level on performance of steers fed a high-fat finishing diet (Trial 1)

| | Dietary calcium, % | | | |
|---|---|---|---|---|
| Item | .50 | .70 | .90 | SD |
| Pens replicates | 5 | 5 | 5 | |
| Days on test | 90 | 90 | 90 | |
| Weight, kg[a] | | | | |
| Initial | 397 | 394 | 394 | |
| Final[b] | 525 | 525 | 540 | |
| ADG, kg[c] | 1.42 | 1.45 | 1.61 | .15 |
| DMI, kg/d | 7.67 | 7.82 | 7.91 | .52 |
| DM conversion[d] | 5.40 | 5.40 | 4.92 | .25 |
| Diet NE, Mcal/kg | | | | |
| Maintenance[de] | 2.34 | 2.32 | 2.47 | .07 |
| Gain[de] | 1.64 | 1.63 | 1.76 | .06 |
| Observed/expected diet NE | | | | |
| Maintenance[de] | .98 | .98 | 1.05 | .03 |
| Gain[de] | .98 | .98 | 1.06 | .04 |

[a]Initial and final live weights reduced 4% to account for fill.
[b]Carcass adjusted final weight.
[c]Linear effect, $P < .10$.
[d]Linear effect, $P < .05$.
[e]Quadratic effect, $P < .10$.

Table 3. Influence of calcium level on carcass traits of steers fed a high-fat finishing diet (Trial 1)

| | Dietary calcium, % | | | |
|---|---|---|---|---|
| Item | .50 | .70 | .90 | SD |
| Carcass weight, kg | 332 | 333 | 342 | 9 |
| Dressing percentage[a] | 62.9 | 62.9 | 64.1 | .9 |
| Ribeye area[2a] | 82.6 | 84.2 | 86.5 | 3.3 |
| Fat thickness, cm | 1.54 | 1.67 | 1.32 | .3 |
| KPH, %[b] | 2.32 | 2.37 | 2.45 | .21 |
| Marbling score[c] | 4.2 | 4.3 | 4.5 | .5 |
| Retail yield, % | 49.4 | 49.3 | 50.1 | .8 |
| Liver abscess, % | 0 | 10 | 10 | 10 |

[a]Linear effect, P < .10.
[b]Kidney, pelvic and heart fat as a percentage of carcass weight.
[c]Coded: Minimum slight = 3, minimum small = 4, etc.

Table 7. Influence of dietary calcium on ruminal VFA, molar proportions and estimated methane production 4 h after feeding (Trial 2)

| | Dietary calcium, % | | |
|---|---|---|---|
| Item | .70 | .90 | SD |
| Ruminal VFA, mol/100 mol | | | |
| Acetate | 51.3 | 51.4 | 4.6 |
| Propionate | 37.1 | 36.5 | 5.0 |
| Butyrate | 11.7 | 12.1 | 2.5 |
| Methane production[a] | .40 | .40 | .06 |

[a]Methane, mol/mol glucose equivalent fermented.

Table 4. Influence of calcium level on characteristics of OM, starch, ADF, N, and lipid digestion (Trial 2)

| Item | Dietary calcium, % | | SD |
|---|---|---|---|
| | .70 | .90 | |
| Steer replicates | 10 | 10 | |
| Intake, g/d | | | |
| DM | 6,819 | 6,959 | 565 |
| OM | 6,450 | 6,540 | 535 |
| Starch | 2,930 | 2,971 | 243 |
| ADF | 549 | 556 | 45 |
| N | 130 | 132 | 11 |
| Lipid | 719 | 729 | 60 |
| Ruminal digestion, % intake | | | |
| OM[b] | 66.5 | 63.3 | 2.7 |
| Starch | 91.2 | 90.7 | 2.4 |
| ADF[a] | 24.4 | 15.3 | 10.3 |
| Feed N[b] | 56.1 | 45.8 | 6.9 |
| Microbial efficiency[ac] | 16.7 | 18.7 | 2.4 |
| N efficiency[de] | .99 | 1.13 | .09 |
| Postruminal digestion, % leaving abomasum | | | |
| OM[b] | 64.5 | 66.8 | 1.8 |
| Starch | 95.3 | 95.2 | 1.4 |
| ADF | 25.6 | 28.2 | 16.5 |
| N[d] | 77.0 | 79.9 | 1.2 |
| Lipid[a] | 56.6 | 58.0 | 3.7 |
| Total tract digestion, % intake | | | |
| OM | 84.3 | 84.0 | 1.3 |
| Starch | 99.6 | 99.6 | .1 |
| ADF | 44.3 | 42.2 | 5.7 |
| N | 76.6 | 76.8 | 1.4 |

[a]Treatments differ, P < .10.
[b]Treatments differ, P < .05.
[c]Microbial N, g/kg OM fermented.
[d]Treatments differ, P < .01.
[e]Duodenal non-ammonia N/N intake.

Table 5. Influence of calcium level on characteristics of calcium digestion (Trial 2)

| | Dietary calcium, % | | |
|---|---|---|---|
| Item | .70 | .90 | SD |
| Calcium, g/d | | | |
| Intake[a] | 48.6 | 66.3 | 4.2 |
| Leaving abomasum[a] | 44.3 | 65.3 | 7.1 |
| Fecal excretion[b] | 38.6 | 51.5 | 8.6 |
| Apparent calcium absorption, g/d | | | |
| Ruminal | 4.4 | 1.0 | 6.3 |
| Postruminal[c] | 5.7 | 13.8 | 9.6 |
| Total tract | 10.0 | 14.9 | 10.8 |

[a]Treatments differ, P < .01.
[b]Treatments differ, P < .05.
[c]Treatments differ, P < .10.

Table 6. Influence of dietary calcium level on ruminal pH and soluble calcium concentration (Trial 2)

| | Dietary calcium, % | | |
|---|---|---|---|
| Item | .70 | .90 | SD |
| Ruminal pH | | | |

| | | | |
|---|---|---|---|
| 2 h after feeding | 5.48 | 5.52 | .14 |
| 4 h after feeding | 5.62 | 5.62 | .21 |
| 8 h after feeding | 5.69 | 5.77 | .27 |
| Ionized calcium, mM | | | |
| 2 h after feeding | 3.93 | 4.29 | 1.32 |
| 4 h after feeding | 3.22 | 3.49 | 1.68 |
| 8 h after feeding | 3.00 | 2.64 | 2.16 |