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Effect of Supplemental Calcium Levels on Feedlot Growth Performance and Dietary Net Energy Utilization during the Receiving Feeding Period of Calf-Fed Holstein Steers

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Abstract

Ninety-six calf-fed Holstein steer (127 kg) were used to evaluate the influence of supplemental dietary calcium (Ca) on growth-performance, and dietary net energy (NE) utilization during the initial 112-d of receiving period. Treatments consisted of steam flake corn-based growing-finishing diets supplemented with limestone to achieve 0.60%, 0.70%, 0.80%, or 0.90% dietary Ca (DM basis). Morbidity was low (6.3%) and it was not affected ($P > 0.87$) by dietary treatments. During the initial 84-d period (181 kg average BW), increasing dietary Ca did not influence ($P > 0.10$) DMI, ADG, gain efficiency or observed/expected DMI. Observed DMI was 19% greater than expected based on diet formulation and growth. Estimated metabolizable protein and methionine supply during the initial 84-d period averaged 92% and 79% of the required, respectively. The apparent decrease in efficiency of energy utilization in the present study is in close agreement with previous studies involving calf-fed Holstein steers in the early growing phase fed conventional growing-finishing diet that is otherwise deficient in metabolizable amino acids. Thus, it is considered that the anticipated growth-performance responses to dietary Ca treatments may have been masked by expected inefficiencies due to metabolizable amino acid deficiency. During the final 28-d period (256 kg of average BW), increasing supplemental Ca reduced feed intake (linear effect, $P = 0.04$) and enhanced gain efficiency (linear effect, $P = 0.03$). During this period, predicted ([1] Level 1) metabolizable protein and methionine supply were 110% and 94% of the required, respectively. Nevertheless, improvements in gain efficiency during the final 28-d period with increasing levels of supplemental Ca were not sufficient to influence ($P > 0.10$) overall

112-d growth-performance. It is concluded dietary Ca requirements of calf-fed Holstein steers during the initial 112-d feeding period appear to be secondary to deficiencies of conventional steam-flaked corn-based diets in meeting metabolizable amino acid requirements. However, when those requirements are met during the early growing phase, gain efficiency responses are optimized at approximately 0.90% dietary Ca.

Keywords

Holstein, Feedlot, Performance, Calcium

1. Introduction

The effect of supplemental Ca on feedlot growth-performance of yearling cattle has been inconsistent. In some instances, dietary levels over a wide range (0.3% to 1.8%) did not affect performance [2] [3] [4]. However, in other trials, dietary Ca levels greater than 0.7% enhanced ADG and gain efficiency [5] [6]. Studies evaluating the calcium (Ca) requirements of calf-fed Holstein steers have not been previously reported. Calf-fed Holstein steers are typically fed a single diet formulation throughout the entirety of the feedlot growing-finishing period. Based on factorially estimated Ca requirements for maintenance and gain [1], the average Ca requirement for the 310 to 340-d feedlot period in Holstein steers fed a steam flaked corn-based diet is 0.57% of diet DM. However, due to their comparatively high potential for growth, the factorially derived average Ca requirement during the initial growing phase (initial 112 d on feed) is much greater (≈0.90% of diet DM). Gain efficiency (ADG/DMI) of calf-fed Holstein steers during this initial 112-d period is typically less than 87.5% [7] [8] of expected based on diet energy density and DMI. The basis of the inefficiencies on dietary NE utilization is not clear but seems to be the result of several factors involved such as metabolizable amino acids supply [9] or dietary Ca level [5] [6]. The objective of the present study is to evaluate the influence of dietary calcium level on growth-performance of calf-fed Holstein steers fed a conventional steam flaked corn-based diet during the initial 112 d on feed.

2. Materials and Methods

Animal care and handling techniques were approved by the University of California Animal Care and Use Committee.

Feedlot Growth Performance

Ninety-six calf-fed Holstein steer (127 ± 8 kg) were used to evaluate the effect of Ca supplementation on initial 112-d feedlot growth-performance, and dietary energetics. Treatments consisted of steam-flaked corn-based growing-finishing diets supplemented to provide 0.60%, 0.70%, 0.80%, or 0.90% Ca (DM basis). Dietary treatments evaluated in this study were formulated to provide 100%,

115%, 131% or 146% of Ca requirements [10]. Calves originating from Tulare, California were received at the University of California Desert Research Center, Holtville, CA on January 23, 2018. Upon arrival, calves were vaccinated for IBR, BVD, PI_3, and BRSV (Bovi-shield® Gold One Shot, Zoetis Animal Health, New York, NY), clostridials (Ultrabac® 7, Zoetis Animal Health, New York, NY), treated for parasites (Dectomax® Injectable, Zoetis Animal Health, New York, NY), and injected with 500,000 IU vitamin A (Vital EA-D, Stuart Products, Amarillo, TX). Steers were allowed ad libitum access to water and dietary treatments (Table 1). Fresh feed was provided twice daily. Weight gain was based on initial off-truck shrunk weight and 112-d final weight reduced 4% to adjust for digestive tract fill. Energy gain (EG, Mcal/d) was calculated by the equation:

Table 1. Composition of experimental diets (% DMB).

	Calcium supplementation level[1]			
Item	0.60	0.70	0.80	0.90
Ingredient, % DM				
Sudangrass hay	12.00	12.00	12.00	12.00
Tallow	2.50	2.50	2.50	2.50
Molasses, cane	4.00	4.00	4.00	4.00
Distillers Grain	20.00	20.00	20.00	20.00
Steam flaked corn	58.65	58.35	58.06	57.95
Urea	0.95	0.95	0.95	0.95
Limestone	1.17	1.47	1.76	2.06
Dicalcium phosphate	0.25	0.25	0.25	0.25
Magnesium oxide	0.06	0.06	0.06	0.06
Rumensin 90	0.0165	0.0165	0.0165	0.0165
Nutrient composition, DM basis (tabular values, NRC, 1996)				
DRY MATTER, %	89.3	89.3	89.3	89.3
NEm, Mcal/kg	2.18	2.18	2.18	2.17
NEg, Mcal/kg	1.51	1.51	1.51	1.51
Crude protein, %	15.3	15.3	15.3	15.3
Rumen DIP, %	58.2	58.2	58.2	58.2
Rumen UIP, %	41.8	41.8	41.8	41.8
Ether extract, %	7.25	7.25	7.25	7.25
Ash, %	6.33	6.33	6.33	6.33
Nonstructural CHO, %	51.9	51.9	51.9	51.9
NDF, %	22.3	22.3	22.3	22.3
Calcium, %	0.60	0.70	0.80	0.90
Phosphorus, %	0.44	0.44	0.44	0.44
Potassium, %	0.83	0.83	0.83	0.83
Magnesium, %	0.26	0.26	0.26	0.26
Sulfur, %	0.19	0.19	0.19	0.19

[1]Analyzed dietary calcium were as follow 0.555 ± 0.034, 0.654 ± 0.021, 0.786 ± 0.069 and 1.010 ± 0.087 for the expected dietary Ca level of 0.60%, 0.70%. 0.80% and 0.90%, respectively.

$$\mathrm{EG} = 0.0557W^{0.75} \times \mathrm{ADG}^{1.097}, \quad (1)$$

where EG is the daily deposited energy, and W is the body weight [11]. Maintenance energy (EM, Mcal/d) was calculated by the equation:

$$\mathrm{EM} = 0.086W^{0.75} \quad (2)$$

[12] [13] [14]. From the derived estimates of energy required for maintenance and gain, the $\mathrm{NE_m}$ and $\mathrm{NE_g}$ values of the diet were obtained using the quadratic formula:

$$x = \left(-b - \sqrt{b^2 - 4ac}\right) \Big/ 2c, \quad (3)$$

where x = diet $\mathrm{NE_m}$, Mcal/kg,

$$a = -0.41\mathrm{EM}, \quad (4)$$

$$b = 0.877\mathrm{EM} + 0.41\mathrm{DMI} + \mathrm{EG}, \quad (5)$$

$$c = -0.877\mathrm{DMI}, \quad (6)$$

and

$$\mathrm{NE_g} = 0.877\mathrm{NE_m} - 0.41 \quad (7)$$

[15]. Expected DMI (expDMI) was estimated accordingly:

$$\exp\mathrm{DMI} = \left(0.0557W^{0.75} \times \mathrm{ADG}^{1.097} \Big/ \mathrm{tNE_g}\right) + \left(0.086W^{0.75} \Big/ \mathrm{tNE_m}\right), \quad (8)$$

where $\mathrm{tNE_m}$ and $\mathrm{tNE_g}$ are tabular NE values of the diet based on formulation ([1]; **Table 1**).

The trial was analyzed as a randomized complete block design experiment, considering initial shrunk weight groupings for blocks, and pen as experimental unit (Statistix 10, Analytical Software, Tallahassee, FL), according to the following statistical model:

$$Y_{ij} = \mu + B_i + T_j + \varepsilon_{ij}, \quad (9)$$

where μ is the common experimental effect, B_i represents initial weight block effect, T_j represents dietary treatment effect, and ε_{ij} represents the residual error. Treatment effects were evaluated by means of orthogonal polynomials.

3. Results and Discussion

Observed dietary calcium levels were 91%, 93%, 98% and 112% of expected based on diet formulation and tabular values for feed ingredients ([10]; **Table 1**) for the 0.60%, 0.70%, 0.80% and 0.90% Ca treatments, respectively.

The vast majority (98% to 99%) of empty body Ca is located in bone tissue, the remaining distributed in extracellular fluids and soft tissues where it plays basic physiological roles [10] [16] [17] [18] [19]. Studies with young calves between 30 and 180 days indicate that body Ca concentration increases 3-fold (from 0.015 to 0.044 g/d per kg BW; [20]). Another study observed that empty body Ca content is influenced by the rate of gain [21]. In growing bulls from 200 to 350 kg, increasing rate of gain from 0.9 to 1.2 kg/d decreased empty body Ca from 15.0 to 12.7 g/kg empty body weight (reflecting differences rate of growth

effects on bone:lean ratio). Current estimates of Ca requirements for maintenance (0.0154 g/kg BW) and growth (0.07 g/kg protein gain) were established by converting estimated absolute Ca requirements to dietary Ca assuming a 50% true absorption of dietary Ca [10] [17]. However, there have been no rigorous attempts to define the calcium requirements of cattle based on growth performance [18], and those available are not sufficiently consistent to justify specified factorial allowances [3] [10].

Treatment effects on growth-performance of calf-fed Holstein steers are presented in Table 2. Morbidity during the study was low, averaging 6%, and was

Table 2. Influence of Ca level on growth-performance and dietary energetics of calf-fed Holstein steers.

	Dietary Ca, %					P-value	
Expected Ca level	0.60	0.70	0.80	0.90	SEM	Linear	Quadratic
Analyzed Ca level	0.555 ± 0.034	0.654 ± 0.021	0.786 ± 0.069	1.010 ± 0.087			
SD	0.034	0.021	0.069	0.087			
Days on Treatment	112	112	112	112			
Pen replicates	4	4	4	4			
1 - 84 d							
ADG, kg	1.32	1.29	1.30	1.30	0.02	0.49	0.42
DMI, kg/d	5.31	5.15	5.24	5.24	0.09	0.59	0.28
Gain:Feed	0.25	0.25	0.25	0.25	0.002	0.81	0.66
Dietary NE, Mcal/kg							
Maintenance	1.89	1.88	1.87	1.87	0.02	0.37	0.88
Gain	1.25	1.24	1.23	1.23	0.01	0.37	0.88
Observed/expected DMI	1.18	1.19	1.20	1.20	0.01	0.37	0.86
85 - 112 d							
ADG, kg	1.38	1.39	1.45	1.45	0.04	0.29	0.72
DMI, kg/d	6.42	6.30	6.10	6.10	0.09	0.04	0.72
Gain:Feed	0.22	0.22	0.24	0.24	0.006	0.03	0.54
Dietary NE, Mcal/kg							
Maintenance	2.05	2.06	2.17	2.17	0.04	0.05	0.32
Gain	1.38	1.40	1.49	1.49	0.03	0.05	0.32
Observed/expected DMI	1.08	1.07	1.01	1.01	0.02	0.04	0.29
1 - 112 d							
Weight, kg							
Initial	129	126	126	126	1.26	0.13	0.33
Final	279	273	276	276	3.33	0.53	0.33
ADG, kg	1.34	1.31	1.34	1.34	0.02	0.98	0.45
DMI, g/d	5.59	5.44	5.46	5.46	0.09	0.29	0.43
Gain:Feed	0.24	0.24	0.25	0.25	0.003	0.23	0.90
Dietary NE, Mcal/kg							
Maintenance	1.94	1.94	1.96	1.96	0.02	0.49	0.70
Gain	1.29	1.29	1.31	1.31	0.02	0.49	0.70
Observed/expected DMI	1.15	1.15	1.13	1.13	0.01	0.48	0.68

not affected (P > 0.87) by dietary treatments. During the initial 84-d period (181 kg average BW), increasing dietary Ca did not influence (P > 0.10) DMI, ADG, gain efficiency or observed/expected DMI. Observed DMI was 19% greater than expected based on diet formulation and growth. The ratio of observed/expected dietary NE is a sensitive indicator of metabolizable amino acids deficiencies, particularly methionine [15] [22]. The observed decrease in efficiency of energy utilization in the present study is in close agreement with previous studies involving calf-fed Holstein steers in the early growing phase fed conventional growing-finishing diet that is otherwise deficient in metabolizable amino acids [7] [8] [23] [24]. In these studies, between 91% and 95% of the variation in observed vs. expected DMI was explained by limiting metabolizable amino acid supply. In the present study, estimated metabolizable protein and methionine supply during the initial 84-period averaged 92% and 79% of required, respectively. Thus, it is considered that the anticipated growth-performance responses to dietary Ca treatments may have been masked by expected inefficiencies due to metabolizable amino acid deficiency.

During the final 28-d period (256 kg of average BW), increasing supplemental Ca reduced DMI (linear effect, P = 0.04; **Figure 1**) and enhanced gain efficiency (linear effect, P = 0.03; **Figure 2**). These improvements were reflected in an 8% enhancement (linear effect, P = 0.05; **Figure 3**) in estimated efficiency of energy utilization. During this period predicted ([1] Level 1) metabolizable protein and methionine supply were 110% and 94% of required, respectively. Nevertheless, improvements in gain efficiency during the last 28-d period with increasing levels of supplemental Ca were not sufficient to influence (P > 0.10) overall 112-d growth-performance.

There were no treatment effects (P > 0.10) on ADG. Although, even at the lowest dietary Ca level (0.60%), overall (112-d) ADG averaged 1.34 kg/d, 7%

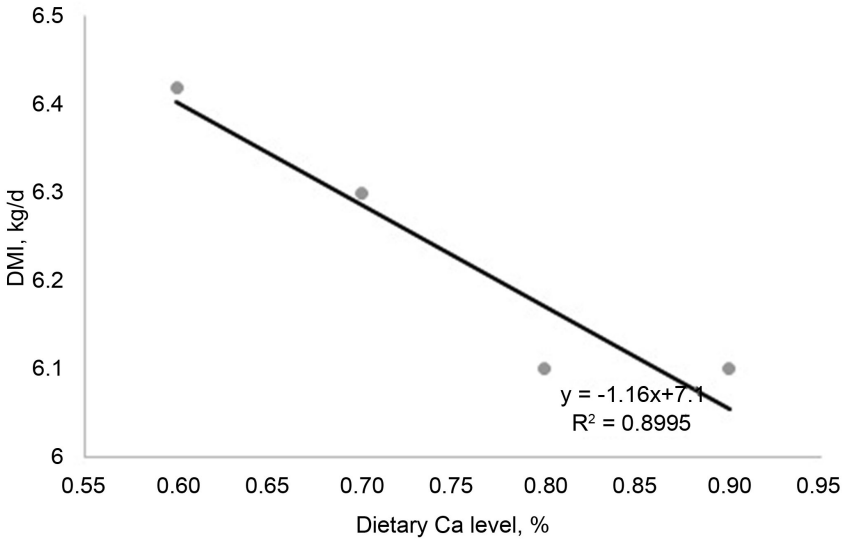

Figure 1. Performance of DMI, kg/d on late receiving period (85 - 112 d) as a function of dietary Ca level (Ca): DMI, kg/d = 7.1 − 1.16 Ca, R^2 = 0.90. P = 0.04.

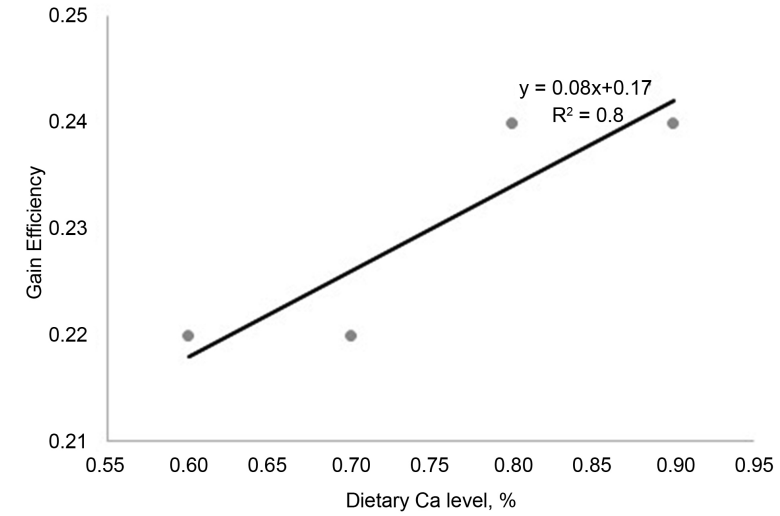

Figure 2. Performance of Gain Efficiency on late receiving period (85 - 112 d) as a function of dietary Ca level (Ca): Gain Efficiency = 0.17 + 0.08 Ca, R^2 = 0.80. P = 0.03.

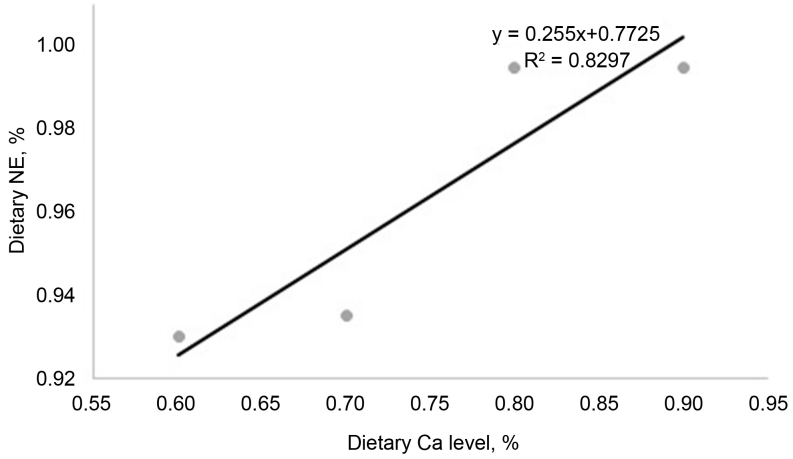

Figure 3. Performance of Dietary Net Energy on late receiving period (85 - 112 d) as a function of dietary Ca level (Ca): Dietary NE = 0.7725 + 0.255 Ca, R^2 = 0.83. P = 0.05.

greater than projected based on the generalized equation for non-implanted calf-fed Holstein steers (1.24 kg/d; [25]).

4. Implications

Dietary Ca requirements of calf-fed Holstein steers during the initial 112-d feeding period appear to be secondary to deficiencies of conventional steam-flaked corn-based diets in meeting metabolizable amino acid requirements. However, when those requirements are met during the early growing phase, gain efficiency responses are optimized at approximately 0.90% dietary Ca.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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