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Influence of Day-to-Day Fluctuations in Feed Intake on Feedlot Cattle Growth-Performance and Digestive Function

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Abstract: A growth-performance trial and a metabolism trial were conducted to evaluate the influence of an imposed 20% fluctuation in daily DMI on performance (Forty steers; BW 363 kg) and digestive function (6 steers; BW 363 kg) in Holstein steers. Feed intake was adjusted at weekly increments according to projected changes in live weight. The experimental diet contained (DM basis): 8.00% sudangrass hay, 77.45% steam-flaked corn, 3.00% yellow grease, 8.00% cane molasses, 1.78% limestone, 1.27% urea and 0.50% trace mineralized salt. Steers were fed twice daily. Two treatments were compared: constant daily feed intake versus variable daily feed intake. With the "variable" feeding group, steers were fed in a cycle of 10% more followed by 10% less than that of the "constant" feeding group. That is, the first day they received 10% more than the constant feeding group, the second day they received 10% less than the constant feeding group, the third day they received 10% more than the constant feeding group, etc., until the end of the trial. Feed intake by steers in the constant feeding group was programmed to allow for an ADG of 1.1 kg day^{-1}. Daily fluctuation in feed intake did not influence ($p>0.20$) ADG, DM intake, gain efficiency, dietary NE, or carcass characteristics. Furthermore, fluctuating intake did not affect ($p>0.20$) ruminal or total tract digestion of OM, ADF, starch and N, ruminal pH, or ruminal VFA molar proportions. We conclude that fluctuating day-to-day DM intake by as much as 20% (1.5 kg day^{-1}) will not adversely affect growth-performance or digestive function in calf-fed Holstein steers during the late finishing phase.

Key words: Cattle, intake, digestion, performance

INTRODUCTION

In feedlot cattle with ad libitum access to high-concentrate finishing diets, average individual daily fluctuations in feed intake range between 20 and 30% (Stock *et al*., 1995; Schwartzkopf-Genswein *et al*., 2004). Although better-performing feedlot cattle have shown greater (0.36 kg day^{-1}) variation in daily feed intake than poorer-performing cattle (Hickman *et al*., 2002). Fluctuation in feed intake is often considered the contributing cause of sub-clinical acidosis and associated with depressed growth performance of feedlot cattle (Elam, 1976; Britton and Stock, 1987). Gaylean *et al*. (1992) observed that 10% daily fluctuations in feed delivery reduced ADG (6.5%) and gain efficiency (6.9%). In contrast Cooper *et al*. (1999), observed that a 17% fluctuation in daily feed delivery did not affect feedlot cattle growth performance or ruminal acidosis. Likewise, Soto-Navarro *et al*. (2000) observed that a 10% daily fluctuation in feed delivery in cattle fed either once or twice daily did not have detrimental effects on ruminal pH, DMI or ADG. Schwartzkopf-Genswein *et al*. (2004) evaluated the effect of fluctuating DMI by 10% every 3 day. Ruminal pH tended to be lower for the variable intake group. Nevertheless, DMI and growth performance was not affected.

The objective of the present study was to gain further insight into the effects of 20% daily fluctuations in feed intake on both growth-performance and digestive function of finishing calf-fed Holstein steers.

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. Forty Holstein steers (363 kg) were used in a 138 day feeding trial to evaluate the effects of day-to-day variation in feed intake on growth performance during the late finishing phase.

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Table 1: Ingredient composition of experimental diets fed to steers (Trials 1 and 2[1])

Item	Basal diet
Ingredients, % DM basis	
Sudangrass hay	8.00
Steam-flaked corn	77.45
Yellow grease	3.00
Cane molasses	8.00
Limestone	1.78
Urea	1.27
Trace mineral salt[2]	0.50
Laidlomycin premix[3]	+
Nutrient composition (DM basis)[4] NE, Mcal kg^{-1}	
Maintenance	2.24
Gain	1.55
Crude protein (%)	12.0
ADF (%)	5.7
Calcium (%)	0.9
Phosphorus (%)	0.3

[1]Chromic oxide (0.4%) was added as a digesta marker in Trial 2, [2]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, 93.4%, [3]Laidlomycin propionate (Cattlyst, Alpharma Inc., Fort Lee, NJ), fed to provides 11.5 mg of Laidlomycin kg^{-1} of diet, DM basis, [4]Based on tabular NE values for individual feed ingredients (NRC, 1996) with exception of supplemental fat that was assigned NEm and NEg values of 6.03 and 4.79 Mcal kg^{-1}, respectively

Steers were blocked by weight and allotted randomly to 8 pens (5 steers/pen) equipped with automatic waterers and fence-line feed bunks. The trial was conducted during the months of May through September. Steers were program-fed to gain 1.1 kg day^{-1} according to the following equation: $FI = (0.0557W^{.75} (G^{1.097}))/Ne_g) + (0.084W^{.75}/NE_m)$, where FI is daily feed intake in kg, G is daily weight gain in kg, W is the average full weight reduced 4% to account for the digestive tract fill and NE_m and NE_g are expressed in Mcal kg^{-1}. Feed intake was adjusted at weekly increments according to projected changes in live weight. Composition of experimental diet is shown in Table 1. Steers were fed in equal proportions twice daily. Two treatments were compared: constant daily feed intake versus variable daily feed intake. With the variable feeding group steers were fed in a cycle of 10% more followed by 10% less than that of the constant feeding group. That is, the first day they received 10% more than the constant feeding group, the second day they received 10% less than the constant feeding group, the third day they received 10% more than the constant feeding group, etc., until the end of the trial. Thus, the change in feed intake from day to day was 20%. Upon initiation of the study and at day 56, steers were implanted with Synovex-S® (Fort Dodge Animal Health, Fort Dodge, IA). Diets were prepared at weekly intervals and stored in plywood boxes located in front of each pen.

Estimation of dietary NE: Energy retention (EG, Mcal day^{-1}) was derived from measures of live weight and ADG (kg day^{-1}) according to equation: $EG = (0.0557\ W^{0.75}) ADG^{1.097}$ (NRC, 1984). Net energy content of the diet for maintenance and gain were calculated assuming a constant maintenance energy (EM, Mcal day^{-1}) cost of $0.084W^{.75}$ (NRC, 2001). The NE values of the diets for maintenance and gain were obtained by means of the quadratic formula: NE_m, Mcal kg^{-1} = $(-b - \sqrt{b^2 - 4ac})/2c$ (Zinn and Shen, 1998) where: a = -0.877DMI, b =0.877EM + 0.41DMI+EG, c = -0.41EM and $NE_g = 0.877NE_m - 0.41$.

Carcass data: Hot carcass weights were obtained at time of slaughter. After carcasses chilled for 48 h, the following measurements were obtained: LM area, by direct grid reading of the 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 and marbling score (USDA, 1996; using 3.0 as minimum slight, 4.0 as minimum small, etc.).

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 experiment, with 2 treatments and 4 blocks (Cochran and Cox, 1955), pen was the experimental unit.

Experiment 2

Animals and sampling: Six Holstein steers (421 kg) with cannulas in the rumen and proximal duodenum (Zinn and Plascencia, 1993) were used in a crossover design experiment to evaluate treatment effects on characteristics of ruminal and total tract digestion. Composition of the experimental diet fed was the same as in Trial 1 with inclusion of 0.4% chromic oxide as a digesta marker. The diet was fed in equal proportions at 0800 and 2000 daily. Daily feed intake of the constant feeding group was restricted to 6.7 kg day^{-1} (90% of feed intake of steers in Experiment 1). Experimental periods were of 14 day duration. Following a 10 day treatment adjustment period, duodenal and fecal samples were taken from each steer twice daily over a period of 4 successive days. The time sequence for sampling steers during the collection periods was as follow: 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 500 mL duodenal chyme and 200 g (wet basis) of fecal material. Fecal samples represented a composite of fecal material which accumulated on the floor slats during a collection interval. Duodenal and fecal samples from each steer, within each 4-days period, were composited for analysis. During the final day of each collection period, ruminal

samples were obtained from each steer at 4 h after feeding via the ruminal cannula. Ruminal fluid pH was determined and subsequently, 2 mL of freshly prepared 25% (wt/vol) metaphosphoric acid was added to 8 mL of strained ruminal fluid. Samples were then centrifuged (17,000× for 10 min) and supernatant fluid stored at -20°C for VFA analysis. Upon completion of the trial, ruminal content was obtained from all steers and composited for isolation of ruminal bacteria, via differential centrifugation (Bergen *et al*., 1968).

Sample analysis and calculations: Feed, duodenal and fecal samples were prepared for analysis by oven drying at 70°C and then grinding in a lab mill (Micro-Mill , Bell-Arts Products, Pequannock, NJ). Samples were then oven dried at 105°C until no further weight loss and stored in tightly sealed glass jars. Samples were subjected to all or part of the following analyses: ash, Kjeldahl N, ammonia N (AOAC, 1975); starch (Zinn, 1990); purines (Zinn and Owens, 1986); VFA concentrations of ruminal fluid (gas chromatography) and chromic oxide (Hill and Anderson, 1958). 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 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 is 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).

Statistical analysis: Data were analyzed as a crossover design (Cochran and Cox, 1955), each animal/period was considered as experimental unit.

RESULTS AND DISCUSSION

Treatment effects on growth performance of Holstein steers are shown in Table 2. An imposed 20% daily fluctuation in feed intake did not affect (p>0.20) ADG, DMI, or gain efficiency. Cooper *et al*. (1999) conducted two finishing trials evaluating an imposed daily intake variation of 16% in steers fed high-concentrate diets (81-93% grain) from d 35 through harvest (140-147). As with the present study, they too observed that daily intake variation, per se, did not affect either ADG or G: F. Schwartzkopf-Genswein *et al*. (2004) conducted two finishing trials evaluating effects of imposed intake

Table 2: Influence of a 20% variation in daily feed intake on growth performance of feedlot steers (Trial 1)

	Daily feed allowance[1]		
Item	Constant	Variable	SD
Days on test	138	138	
Pen replicates	4	4	
Live wt, kg[2]			
Initial	363.5	363.1	4.8
Final	514.2	517.9	12.3
Weight gain, kg day^{-1}	1.09	1.12	0.10
DM intake, kg day^{-1}	7.51	7.57	0.23
DM intake/gain	6.92	6.75	0.54
Gain/DMI	0.145	0.148	0.01
Diet net energy, Mcal kg^{-1}			
Maintenance	2.21	2.23	0.09
Gain	1.52	1.54	0.08
Observed/expected diet net energy[3]			
Maintenance	0.98	0.99	0.04
Gain	0.98	1.00	0.05

[1]There was not found differences between treatments, p>0.20, [2]Initial and final weights were reduced 4% to account for digestive tract fill. Final weight adjusted for carcass weight by dividing carcass weight by the average dressing percentage, [3]Expected NE based on tabular NE values for individual feed ingredients (NRC, 1996) with exception of supplemental fat which was assigned NE_m and NE_g values of 6.03 and 4.79, respectively (Table 1)

Table 3: Influence of a 20% variation in daily feed intake on carcass characteristics of feedlot steers (Trial 1)

	Daily feed allowance[1]		
Item	Constant	Variable	SD
Days on test	138	138	
Pen replicates	4	4	
Final [2]	514.2	517.9	12.3
Carcass wt, kg	323.9	326.3	7. 7
Dressing percentage	63.0	63.0	0.5
Rib eye area, cm^2	79.4	80.2	1.4
Fat thickness, cm	0.84	0.82	0.09
KPH, %	2.32	2.35	0.18
Marbling score [3]	4.16	4.62	0.38
Retail yield (%)	50.8	50.9	0.4
Liver abscess (%)	5.0	15.0	24.5

[1]There was not found differences between treatments, p>0.20, [2]Final weights were reduced 4% to account for digestive tract fill. Final weight adjusted for carcass weight by dividing carcass weight by the average dressing percentage, [3]Code: Minimum slight = 3, minimum small = 4, etc

fluctuations on growth performance in steers feed a high-concentrate (87% barley grain) finishing diet. "Ad libitum" intake was compared with 3 day cycles of 110% followed by 90% of average ad libitum allowances for control steers. Consistent with Cooper *et al*. (1999), fluctuating intake in steers with ad libitum access to feed did not affect ADG and gain efficiency. Burrin *et al*. (1988) and Stock *et al*. (1995) evaluated the potential benefits of dietary supplementation with an intake regulating additive (monensin) on growth performance. In every case, monensin supplementation reduced variation in individual daily DMI. However, in no case was reduced variation in daily intake associated with enhanced ADG. In contrast, Galyean *et al*. (1992) observed that a 10% fluctuation in daily feed intake decreased ADG and gain efficiency (6.8 and 6.9%, respectively).

Table 4: Influence of a 20% variation in daily feed intake on characteristics of ruminal and total tract digestion (Trial 2)

	Daily feed allowance[1]		
Item	Constant	Variable	SD
Observations	6	6	
Intake (g d^{-1})			
DM	6,720	6,720	
OM	6,346	6,346	
Starch	3,077	3,077	
ADF	501	501	
N	146	146	
Leaving abomasum (g d^{-1})			
OM	2,840	2,840	141
Starch	350	378	37
ADF	361	349	62
Non-ammonia N	126	125	6
Microbial N	68.3	66.6	2.6
Feed N	57.8	58.3	5.0
Ruminal digestion (% intake)			
OM	66.0	65.7	2.2
Starch	88.6	87.7	1.2
ADF	28.0	30.0	12.4
Feed N	60.5	60.2	3.5
Microbial efficiency [2]	16.3	16.0	0.8
N efficiency [3]	0.86	0.85	0.04
Total tract digestion (%)			
OM	85.0	84.9	0.1
Starch	99.4	99.4	0.2
ADF	49.4	47.0	3.5
N	77.5	78.3	1.1

[1]There was not found differences between treatments, p>0.20, [2]Microbial N, g kg^{-1} of OM fermented, [3]Duodenal non-ammonia N/N intake

Table 5: Influence of a 20% variation in daily feed intake on characteristics of ruminal and total tract digestion (Trial 2)

	Daily feed allowance [1]		
Item	Constant	Variable	SD
Observations	6	6	
Ruminal pH	5.89	5.92	0.27
Ruminal VFA, mol 100 mol^{-1}			
Acetate	62.3	62.1	4.5
Propionate	25.5	25.1	3.4
Butyrate	12.1	12.9	1.8
Methane [2]	0.55	0.55	0.05

[1]There was not found differences between treatments, p>0.20, [2]Methane, mol mol^{-1} glucose equivalent fermented

Observed dietary NE was in close agreement with expected (observed/expected = 0.99) based on diet formulation (NRC, 1996) and was not affected (p>0.20) by intake fluctuation. There were no treatment effects (p>0.20) on carcass characteristics of Holstein steers (Table 3).

Treatment effects on characteristics of ruminal and total tract digestion (Trial 2) are shown in Table 4. Consistent with results of the growth-performance trial (Trial 1), intake fluctuation did not affect (p>0.20) ruminal and total tract digestion of OM, starch, ADF and N and ruminal microbial and N efficiency. The influence of daily intake variation on characteristics of ruminal digestion has not been reported previously. Soto-Navarro *et al.* (2000) observed that when a daily intake fluctuation of 10% was imposed on cattle limit-fed a 90% concentrate (steam-flaked corn) diet once daily; intake fluctuation increased (6.6%) total tract digestion OM; whereas, when steers were fed twice daily, a 10% intake fluctuation decreased (9.1%) OM digestion.

Influence of intake fluctuation on ruminal pH, VFA molar proportions and estimated methane production are shown in Table 5. There were no treatment effects (p>0.20) on ruminal VFA and estimated methane production. Likewise, Soto-Navarro *et al.* (2000) did not observe an influence of imposed feed intake fluctuation on VFA molar proportions.

Ruminal pH was not affected (p>0.10) by intake fluctuation, averaging 5.9. Although this average value was in close agreement with predicted (5.83; Pitt *et al.*, 1996) based on effective NDF content of the diet, individual animal measures were quite variable. The 95% confidence intervals for ruminal pH were 5.66-6.13 for the constant intake steers and 5.58-6.26 for the variable intake steers. This high degree of variation among the constant intake group where steers were fed the same amount of feed and at the same times each day, underscores the observation (Schwartzkopf-Genswein *et al.*, 2003) that factors other than intake variation (rate and frequency of eating, saliva production during eating and rumination, water intake, temperament, health, etc.) have the greater impact on ruminal pH and potential for subclinical acidosis. Accordingly, restricting feed access, as occurs when programming intake reduces daily intake variation (Hicks *et al.*, 1990; Zinn and Borquez, 1993), but may increase risk of subclinical acidosis due to a tendency for increased rate of feed intake and meal size (Cooper *et al.*, 1999). In limit-fed cattle, variance in ruminal pH increased two fold; notwithstanding average ruminal pH was not affected (Fanning *et al.*, 1999).

Consistent with the present study, Cooper *et al.* (1999) also did not observe an effect of intake fluctuation in limit-fed steers on average ruminal pH. However, intake fluctuation increased the length of time ruminal pH remained less than 5.6 by 1.1 h per day. Schwartzkopf-Genswein *et al.* (2004) did not observe and effect of intake fluctuation on either ruminal pH or length of time the pH was less than 5.8. However, the percentage of days average ruminal pH was less 5.8 tended to increase (17%). Likewise, Soto-Navarro *et al.* (2000) did not observe an effect of intake variation on ruminal pH in limit-fed steers fed twice daily. Although, in contrast with Cooper *et al.* (1999) the length of time ruminal pH was less than 6.2 was actually reduced (5.1 h day^{-1}) in steers with imposed fluctuation (10%) in feed intake. In comparisons with "ad

libitum" feeding, Cooper *et al.* (1999) observed that imposed intake variation (up to 17%) tended to increase average ruminal pH, due to a marked reduction in the length of time ruminal pH was below 5.6.

IMPLICATIONS

A daily fluctuation in feed intake of 20% (1.5 kg day^{-1}) is not sufficient to adversely affect growth-performance or digestive function in calf-fed Holstein steers during the late finishing phase.

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