Influence of Dietary Sulfur level on Growth-Performance and Digestive Function in Feedlot Cattle

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ABSTRACT: Three levels of dietary S (.15, .20, and .25%, DM basis) were evaluated in finishing trial involving 108 yearling crossbred heifers (384 kg). The basal diet contained (DM basis) 4% alfalfa hay, 6% sudangrass hay, 74% steam-flaked corn, 4% yellow grease, 6% cane molasses, and 6% protein-mineral supplement. Dietary S levels were achieved by supplementing the basal diet with 0, .20, or .40% ammonium sulfate. Increasing dietary S level decreased ADG (linear effect, $P < .05$; quadratic effect, $P < .10$), DMI (linear effect, $P < .10$), feed efficiency (linear effect, $P < .05$; quadratic effect, $P < .10$), diet NE (linear effect, $P < .05$; quadratic effect, $P < .10$), and longissimus muscle area. Six Holstein steers (218 kg) with cannulas in the rumen and proximal duodenum were used to evaluated treatment effects on characteristics of digestion. Treatment effects on ruminal and total tract digestion of OM and N were small ($P > .10$). However, ruminal digestion of ADF and starch was slightly lower (quadratic effect, $P < .10$), and postruminal digestion of ADF and starch was correspondingly greater (quadratic effect, $P < .05$) with supplemental S. Dietary S level did not influence ($P > .10$) ruminal synthesis of microbial N. Increasing dietary S level did not influence ($P > .10$) ruminal pH or lactic acid. Increasing S level decreased molar proportions of acetate (linear effect, $P < .10$; quadratic effect, $P < .10$), increased molar proportions of propionate (linear effect, $P < .10$). We conclude that S levels in excess of .20% of dietary DM may have detrimental effects on growth-performance and dietary NE. Excessive dietary S may also compromise carcass merit by decreasing longissimus muscle area.

Introduction

The requirement for S in diets for feedlot cattle has been set at .1% (NRC, 1984). However, supplementation with sulfates to control urinary calculi, as well as the liberal use of feedstuffs that are intrinsically high in S (ie. high-sulfate molasses, distillers solubles), can result in dietary S levels considerably in excess of requirements. Qi et al. (1993) observed that dietary S levels in excess of .2% depressed ADG, DMI, and feed efficiency in growing-finishing wether goats. The objective of this study was to further evaluate the influence of S levels in the finishing diet on growth-performance and digestive function of feedlot steers.

Experimental Procedure

Trial 1. One hundred twenty yearling crossbred heifers

(approximately 12.5% Brahman breeding with the remainder represented by Hereford, Angus, Shorthorn, and Charolais breeds in various proportions) were received at the University of California, Desert Research Center on February 7, 1996. Upon arrival heifers were vaccinated for bovine rhinotracheitis-parainfluenza$_3$ (TSV-2®, SmithKline Beecham, West Chester, PA), clostridials (Ultrabac 8®, SmithKline Beecham, West Chester, PA), treated for parasites (Ivomec Plus®, Merck, Rahawy, NJ), and injected with 500,000 IU vitamin A (Vita-jec® A&D "500", RXV Products, Porterville, CA). Heifers were palpated per rectum for pregnancy. Only nonpregnant heifers were used in this trial. The trial was initiated March 21, 1996. Heifers were blocked by weight and randomly assigned, within weight groupings, to 18 pens (six per pen). Pens were 43 m^2 with 22 m^2 overhead shade, automatic waterers and 2.4-m fence-line feed bunks. Average daily minimum and maximum air temperatures during the trial were 16 and 33°C, respectively. There was no precipitation; average daily relative humidity was 28%. Heifers were implanted with Synovex-H® (Syntex Corp., Des Moines, IA) upon initiation of the trial. Three levels of dietary S (.15, .20, and .25%, DM basis) were evaluated in a randomized complete block design. Heifers were adapted to the basal (.15% S) diet for 7 d before initiation of the trial. Composition of experimental diets is shown in Table 1. Diets were prepared at approximately weekly intervals and stored in plywood boxes located in front of each pen. Heifers were allowed ad libitum access to feed. Approximately 40% of daily feed consumption was provided in the morning feeding and 60% in the afternoon feeding. At slaughter, incidence of liver abscesses were evaluated. Hot carcass weights were obtained from all heifers at time of slaughter. After the carcasses were chilled for 48 h the following measurements were obtained: 1) longissimus muscle area (ribeye area), taken by direct grid reading of the eye muscle at the twelfth rib; 2) subcutaneous fat over the eye muscle at the twelfth 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). Retail yields (boneless, closely trimmed retail cuts from the round, loin, rib, and chuck as a percentage of carcass weight) were estimated using the equation of Murphey et al. (1960). Estimates of heifer performance were based on pen means. Assuming the primary determinant of energy gain is weight gain, energy gain (EG, Mcal/d) was calculated by the equation: $EG = (.0686\ BW^{.75})ADG^{1.119}$ (NRC, 1984). Maintenance energy expended (Mcal/d, EM) was calculated by the equation: $EM = .077BW^{.75}$. From the derived estimates for energy required for maintenance and gain, the NE for maintenance (NE_m) and gain (NE_g) of the diets was obtained by the process of iteration to fit the relationship: $NE_g = .877NE_m - .41$ (Zinn and Plascencia, 1996). The trial was analyzed as a randomized complete block design experiment. Treatment effects were tested for linear and quadratic components

by means of orthogonal polynomials (Hicks, 1973).

Trial 2. Six Holstein steers (218 kg) with cannulas in the rumen and proximal duodenum (Zinn and Plascencia, 1992) were used in a replicated 3x3 Latin square experiment. Composition of experimental diets was the same as in Trial 1, with .35% chromic oxide added as a digesta marker. Feed intake was restricted to 2.1% of BW. Diets were fed at 0800 and 2000 daily. Experimental periods consisted of a 10-d diet adjustment period followed by a 4-d collection period. During the collection period duodenal and fecal samples were taken from all steers, twice daily as follows: d 1, 0750 and 1350; d 2, 0900 and 1500; d 3, 1050 and 1650; and d 4, 1200 and 1800. Individual samples consisted of approximately 500 ml duodenal chyme and 200 g (wet basis) 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 4 h after the morning feeding via the ruminal cannula. Ruminal fluid pH was determined (Digi-Sense LCD pH Meter, Cole-Parmer, Chicago, IL) on fresh samples, and samples were strained through four layers of cheesecloth. Two milliters of freshly prepared 25% (w/v) meta-phosphoric acid was added to 8 mL of strained ruminal fluid. Samples were then centrifuged (17,000 x g for 10 min) and supernatant fluid stored at -20°C for VFA analysis. Upon completion of the trial, ruminal fluid was obtained from all steers and composited for isolation of ruminal bacteria via differential centrifugation (Bergen et al., 1968). Samples were subjected to all or part of the following analysis: DM (oven drying at 105°C until no further weight loss); ash, Kjeldahl N, ammonia N (AOAC, 1975); ADF (Goering and Van Soest, 1970); purines (Zinn and Owens, 1986); sulfur (atomic emission spectroscopy); VFA concentrations of ruminal fluid (gas chromatography; Zinn, 1988); chromic oxide (Hill and Anderson, 1958) and starch (Zinn, 1990). Microbial organic matter (MOM) and N (MN) leaving the abomasum was 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) and ruminal OM digestion. The trial was analyzed as a replicated 3 X 3 Latin square according to the following statistical model: $Y_{ijkl}=\mu + B_i + A_{j(i)} + P_k + T_l + E_{ijkl}$, where B_i is block, $A_{j(i)}$ is steer within block, P_k is period, T_l is treatment and E_{ijkl} is residual error. Treatment effects were tested for linear and quadratic components by means of orthogonal polynomials (Hicks, 1973).

Implications

Dietary sulfur levels in excess of .20% of dietary dry matter may have a detrimental effect on average daily gain, feed intake and net energy value of the diet. The decrease in dietary net energy value with increasing dietary sulfur level is not due to decreased ruminal protein synthesis or component digestibility of the diet. Excessive dietary sulfur may also compromise carcass merit by decreasing longissimus muscle area.

Table 1. Composition of experimental diets fed to steers (Trials 1 and 2[a])

Item	Dietary sulfur, %		
	.15	.20	.25
Alfalfa hay	4.00	4.00	4.00
Sudangrass hay	6.00	6.00	6.00
Flaked corn	73.60	73.49	73.38
Yellow grease	4.00	4.00	4.00
Molasses cane	6.00	6.00	6.00
Cottonseed meal	2.00	2.00	2.00
Limestone	1.65	1.65	1.65
Urea	1.20	1.11	1.02
Sodium bicarbonate	1.00	1.00	1.00
Magnesium oxide	.15	.15	.15
Trace mineral salt[b]	.40	.40	.40
Ammonium sulfate		.20	.40
Nutrient composition (DM basis)			
NE, Mcal/kg[c]			
Maintenance	2.26	2.26	2.26
Gain	1.58	1.58	1.58
Crude protein, %	11.8	11.8	11.8
Ether extract, %	7.3	7.3	7.3
ADF, %	6.8	6.8	6.8
Calcium, %	.70	.70	.70
Phosphorus, %	.32	.31	.31
Potassium, %	.75	.75	.75
Magnesium, %	.28	.28	.28
Sulfur, %	.15	.20	.25

[a]Chromic oxide (.35%) was added as a digesta marker in Trial 2.

[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 for individual feed ingredients (NRC, 1984) with the exception of supplemental fat, which was assigned $\mathbf{NE_m}$ and $\mathbf{NE_g}$ values of 6.03 and 4.79, respectively.

Table 2. Influence of sulfur level on growth-performance response of feedlot steers and dietary NE (Trial 1)

	Dietary sulfur, %			
Item	.15	.20	.25	SD
Days on test	76	76	76	
Pen replicates	6	6	6	
Live weight, kg[a]				
Initial	385.7	386.0	380.6	17.6
Final[b]	487.9	489.7	464.4	16.4
Weight gain, kg/d[bc]	1.35	1.37	1.08	.17
DM intake, kg/d[d]	8.51	8.64	7.83	.60
DM intake/gain[bc]	6.40	6.32	7.44	.69
Diet net energy, Mcal/kg				
Maintenance[bc]	2.23	2.24	2.07	.10
Gain[bc]	1.55	1.55	1.41	.09
Observed/expected diet NE				
Maintenance[bc]	.99	.99	.92	.04
Gain[bc]	.99	.99	.90	.06

[a]Initial and final BW reduced 4% to account for fill.
[b]Linear effect ($P < .05$).
[c]Quadratic effect ($P < .10$).
[d]Linear effect ($P < .10$).

Table 3. Influence of sulfur level on carcass characteristics of feedlot steers (Trial 1).

	Dietary sulfur, %			
Item	.15	.20	.25	SD
Carcass wt, kg[a]	301.9	301.0	288.1	12.8
Dressing percentage	61.9	61.4	62.1	1.1
Longissimus area, cm^{2}[b]	81.8	78.7	75.1	3.9
Fat thickness, cm	1.38	.95	1.06	.48
KPH, %[c]	1.92	1.87	1.90	.21
Marbling score, degree[d]	3.06	2.86	3.06	.29
Retail yield, %	50.5	51.2	50.8	1.3
Liver abscess, %	11.1	16.7	16.7	11.7

[a]Linear effect ($P < .10$).
[b]Linear effect ($P < .05$).
[c]Kidney, pelvic, and heart fat as a percentage of carcass weight.
[d]Coded: Minimum slight = 3.0, minimum small = 4.0, etc.

Table 4. Influence of sulfur level on characteristics digestion in steers (Trial 2)

Item	Dietary sulfur, % .15	.20	.25	SD
Steer weight, kg	218	218	218	
Steer replicates	6	6	6	
Intake, g/d				
DM	4,617	4,607	4,613	
OM	4,343	4,334	4,339	
ADF	314.0	313.3	313.7	
N	87.3	87.1	87.2	
Starch	2,332	2,327	2,330	
Flow to the duodenum, g/d				
OM[a]	2,163	2,212	2,273	107
ADF[b]	198.1	227.4	216.2	23.1
Starch[a]	395.7	441.7	451.4	46.3
Nonammonia N	91.7	87.6	92.1	7.7
Microbial N	54.5	51.6	54.7	7.2
Feed N	37.2	36.1	37.5	4.5
Ruminal digestion, % of intake				
OM	62.7	60.9	60.2	2.6
ADF[b]	36.9	27.5	31.1	7.3
Starch[a]	83.0	81.0	80.6	2.0
Feed N	57.4	58.6	57.0	5.3
MN efficiency[c]	20.2	19.6	21.3	2.6
N efficiency[d]	1.05	1.01	1.06	.09
Fecal excretion, g/d				
OM	752.5	719.5	758.4	90.0
ADF	170.3	152.7	169.8	27.6
Starch[b]	30.2	20.1	25.9	8.0
N	21.7	23.2	22.7	2.3
Postruminal digestion, % of that leaving abomasum				
OM	65.3	67.6	67.2	2.8
ADF[e]	12.0	32.6	22.2	12.0
Starch[ae]	92.7	95.8	94.6	1.7
N	77.2	74.6	76.4	3.1
Total-tract digestion, % of intake				

OM	82.7	83.4	82.5	2.1
ADF	45.8	51.3	45.8	8.8
Starch	98.7	99.1	98.9	.3
N	75.1	73.4	73.9	2.7

[a]Linear effect (P < .10).
[b]Quadratic effect (P < .10).
[c]Grams microbial N/kg OM fermented.
[d]Nonammonia N leaving the abomasum/N intake.
[e]Quadratic effect (P < .05).

Table 5. Influence of sulfur level on ruminal pH, lactic acid, VFA profiles, and estimated methane production 4 hours after feeding (Trial 2)

	Dietary sulfur, %			
Item	.15	.20	.25	SD
pH	6.05	5.90	5.96	.15
D-Lactic acid, mg/dL	10.59	10.38	10.30	1.81
L-Lactic acid, mg/dL	7.42	7.40	7.27	.92
Ruminal VFA, mM	82.6	82.1	84.5	9.5
Ruminal VFA, mol/100 mol				
Acetate[ab]	50.7	51.3	47.4	2.5
Propionate[a]	30.8	30.5	35.5	4.2
Butyrate	13.0	12.7	12.2	2.0
Methane, mol/d[cd]	6.81	6.59	5.66	.23

[a]Linear effect ($P < .10$).
[b]Quadratic effect ($P < .10$).
[c]Linear effect ($P < .01$).
[d]Quadratic effect ($P < .05$).