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High Sulfur Content in Distillers Grains Alters Ruminal Fermentation and Diet Digestibility in Beef Steers

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Introduction

Requirements for elemental sulfur in feedlot diets have been established to be approximately 0.15% with a maximum upper threshold of 0.40% of diet dry matter. Feeding ethanol fermentation by-products, such as distillers grains with solubles, that are high in sulfur can result in dietary sulfur levels that exceed the recommended maximum. Previous studies indicated that dietary sulfur influenced the site and extent of fiber and protein digestion. The objective of this study was to evaluate ruminal fermentation characteristics and diet digestibility when 30% (dry matter basis) dried distillers grains with solubles with various levels of sulfur was incorporated into finishing diets based on steam-flaked corn or dry-rolled corn.

Experimental Procedures

Twelve ruminally cannulated crossbred steers were used in a metabolism study and fed one of four experimental diets: (1) dry-rolled corn with high sulfur (0.65%), (2) dry-rolled corn with moderate sulfur (0.42), (3) steam-flaked corn with high sulfur (0.65%), or (4) steam-flaked corn with moderate sulfur (0.42). The moderate sulfur level was achieved by using individual ration ingredients, whereas the high sulfur level was attained by mixing sulfuric acid with dried distillers grains with solubles.

Steers were assigned randomly to experimental diets. Diets were fed free choice and formulated to contain similar amounts of crude protein (Table 1). Weights of fresh feed offered to steers and feed refusals were recorded daily. Steers were housed in individual slatted-floor pens with a total area of 60 ft^2. Pens were equipped with individual feed bunks and water fountains.

Two 15-day experimental periods, each consisting of a 12-day diet adaptation phase and a 3-day sample collection phase, were used to assess intake and diet digestion. Beginning 7 days before sample collection, steers were dosed daily via ruminal cannulae with 10 g of chromic oxide, which was used as an indigestible marker to estimate total fecal output. Collection times for fecal and ruminal digesta samples were 0, 6, 12, and 18 hours after feeding on day 1; 2, 8, 14, and 20 hours after feeding on day 2; and 4, 10, 16, and 22 hours after feeding on day 3.

Ruminal pH was measured immediately after samples were collected from the rumen. Concentrations of ruminal ammonia, volatile fatty acids, and lactate in digesta samples were measured. Fecal samples were composited for each animal and period and used to

[1] Dakota Gold Research Association, Sioux Falls, SD.

estimate total fecal output and total tract digestibilities of dry matter, organic matter, neutral detergent fiber, crude protein, starch, and crude fat.

Animal health was monitored daily. One animal on the steam-flaked corn with high sulfur treatment exhibited symptoms related to polioencephalomalacia during the experiment and was removed from all analyses.

Results and Discussion

There were no interactions ($P>0.10$) between grain processing method and dietary sulfur level with respect to feed intake or diet digestibility (Table 2). Feeding high dietary sulfur decreased ($P=0.04$) neutral detergent fiber intake and tended to be associated with lower intake of dry matter and organic matter ($P=0.08$), crude protein ($P=0.06$), crude fat ($P=0.08$), and starch ($P=0.09$).

Steers fed high dietary sulfur had greater apparent total tract digestibility of dry matter ($P=0.04$) and fat ($P=0.03$) than steers fed diets containing moderate dietary sulfur, but dietary sulfur level had no effect on digestibility of other nutrients (Table 2). Conversely, dietary sulfur level did not affect ($P\geq0.17$) the actual amount digested (lb/day), suggesting that differences in the percentage of total tract digestibility were related to feed intake rather than sulfur level. Steers fed diets with high dietary sulfur consumed less feed and, consequently, had a greater percentage of diet digestibility than steers fed diets with moderate dietary sulfur.

Ruminal pH was greater ($P<0.01$) in cattle fed high dietary sulfur than in those fed moderate dietary sulfur (Figure 1). This may be attributable to two factors: lower ($P<0.05$) volatile fatty acid concentrations (Figure 2) resulting from less feed intake and greater ($P<0.01$) ruminal ammonia concentrations (Figure 3).

There were interactions ($P<0.05$) between grain processing method and dietary sulfur levels with respect to acetate and propionate concentrations. Steers fed dry-rolled corn with high dietary sulfur had the least acetate concentration, but sulfur level did not affect acetate concentration when steam-flaked corn was fed. Conversely, propionate concentration was least in cattle fed steam-flaked corn with high sulfur but greatest in cattle fed steam-flaked corn with low sulfur. Despite this interaction, there was also a substantial impact of sulfur level ($P<0.01$) on propionate concentration. Steers fed high-sulfur diets had a lower ($P=0.02$) propionate concentration than steers fed moderate-sulfur diets.

Data from a finishing study in which animals were fed the same diets used this study (Table 1) indicated that cattle fed high-sulfur diets had greater ruminal concentrations of hydrogen sulfide than cattle fed moderate-sulfur diets. High dietary sulfur level negatively affected propionate concentration. Thus, it is conceivable that some free hydrogen ions that could be used to produce propionate were shifted to production of hydrogen sulfide.

Steers fed high-sulfur diets had greater ($P<0.01$) ruminal ammonia concentrations than steers fed low-sulfur diets, especially when dry-rolled corn was fed (interaction, $P<0.01$). Protein-digesting bacteria likely grew better at greater pH. Previous studies

showed that cattle fed dry-rolled corn had greater ruminal pH than cattle fed steam-flaked corn. It is probable that feeding high dietary sulfur either enhanced ruminal protein degradation or reduced bacterial uptake of recycled urea nitrogen.

Implications

Feeding distillers grains containing high levels of dietary sulfur decreased intake and altered ruminal fermentation and diet digestibility. This may have reduced energetic efficiency of the diet by producing more undesirable hydrogen sulfide and less propionate. Overall, this could have compromised growth performance of feedlot cattle.

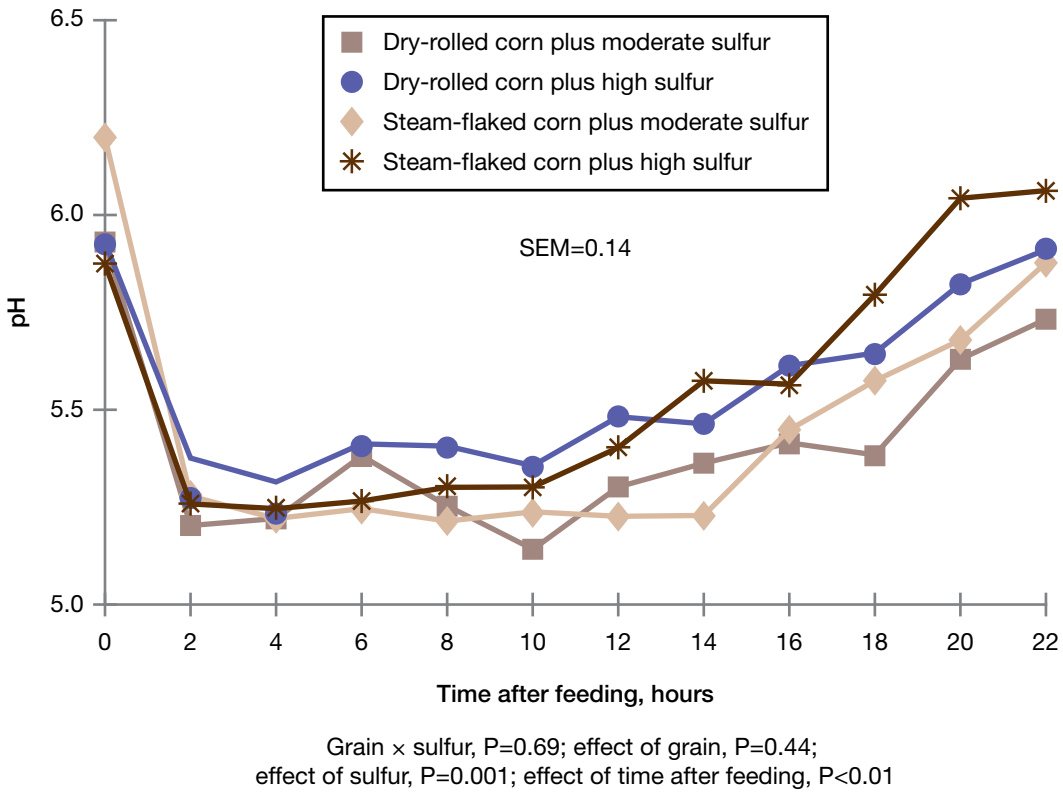
Table 1. Composition of finishing diets based on steam-flaked corn or dry-rolled corn containing dried distillers grains with moderate or high sulfur concentrations

	Dry-rolled corn		Steam-flaked corn	
Item	Moderate sulfur	High sulfur	Moderate sulfur	High sulfur
Ingredients, % dry matter				
Steam-flaked corn	---	---	51.1	50.6
Dry-rolled corn	51.3	50.8	---	---
Dried distillers grains with high sulfur	---	30.4	---	30.6
Dried distillers grains with low sulfur	29.9	---	30.1	---
Alfalfa hay	8.6	8.6	8.6	8.6
Cane molasses	6.2	6.2	6.2	6.2
Supplement[1]	4.0	4.0	4.0	4.0
Analyzed composition, %				
Dry matter	87.2	86.6	84.1	83.4
Starch	38.3	38.4	38.8	38.9
Crude protein	15.6	15.4	15.2	15.0
Crude fat	5.8	5.8	5.8	5.8
Neutral detergent fiber	12.6	12.2	12.5	12.1
Calcium	0.7	0.7	0.7	0.7
Phosphorus	0.4	0.4	0.4	0.4
Potassium	0.7	0.7	0.7	0.7
Sulfur	0.42	0.65	0.42	0.65

[1] Formulated to provide 300 mg/day Rumensin and 90 mg/day Tylan (Elanco Animal Health, Greenfield, IN); 1,000 IU/lb vitamin A; 10 IU/lb vitamin E; 10 ppm copper; 60 ppm zinc; 60 ppm manganese; 0.5 ppm iodine; 0.25 ppm selenium; and 0.15 ppm cobalt.

Table 2. Digestion characteristics in ruminally cannulated crossbred steers fed steam-flaked corn or dry-rolled corn diets containing dried distillers grains with moderate or high sulfur concentrations

	Dry-rolled corn		Steam-flaked corn			P-values		
Item	Moderate sulfur	High sulfur	Moderate sulfur	High sulfur	SEM	Grain processing	Sulfur level	Grain × Sulfur level
No. of steers	6	5	6	5				
Feed intake, lb/day								
Dry matter	14.82	13.07	15.11	13.71	2.00	0.59	0.08	0.85
Organic matter	13.97	12.32	14.30	12.96	1.89	0.55	0.08	0.85
Starch	5.68	5.02	5.87	5.34	0.77	0.46	0.08	0.85
Neutral detergent fiber	1.99	1.63	1.91	1.62	0.28	0.77	0.04	0.77
Crude protein	2.31	2.01	2.30	2.06	0.31	0.95	0.06	0.85
Crude fat	0.86	0.76	0.88	0.80	0.12	0.59	0.08	0.86
Apparent total tract digestibility, %								
Dry matter	70.1	76.1	76.6	79.9	2.1	0.03	0.04	0.59
Organic matter	73.5	78.5	78.8	81.8	2.1	0.06	0.08	0.61
Starch	90.2	96.4	99.2	99.6	2.1	0.02	0.14	0.19
Neutral detergent fiber	15.3	21.3	18.4	27.3	6.1	0.37	0.16	0.75
Crude protein	76.4	77.1	77.6	81.9	2.0	0.13	0.18	0.32
Crude fat	91.6	92.4	90.6	94.3	0.8	0.08	0.03	0.14



Grain × sulfur, P=0.69; effect of grain, P=0.44;
effect of sulfur, P=0.001; effect of time after feeding, P<0.01

Figure 1. Ruminal pH in cannulated crossbred steers fed finishing diets based on steam-flaked corn or dry-rolled corn containing dried distillers grains with moderate or high sulfur concentrations.

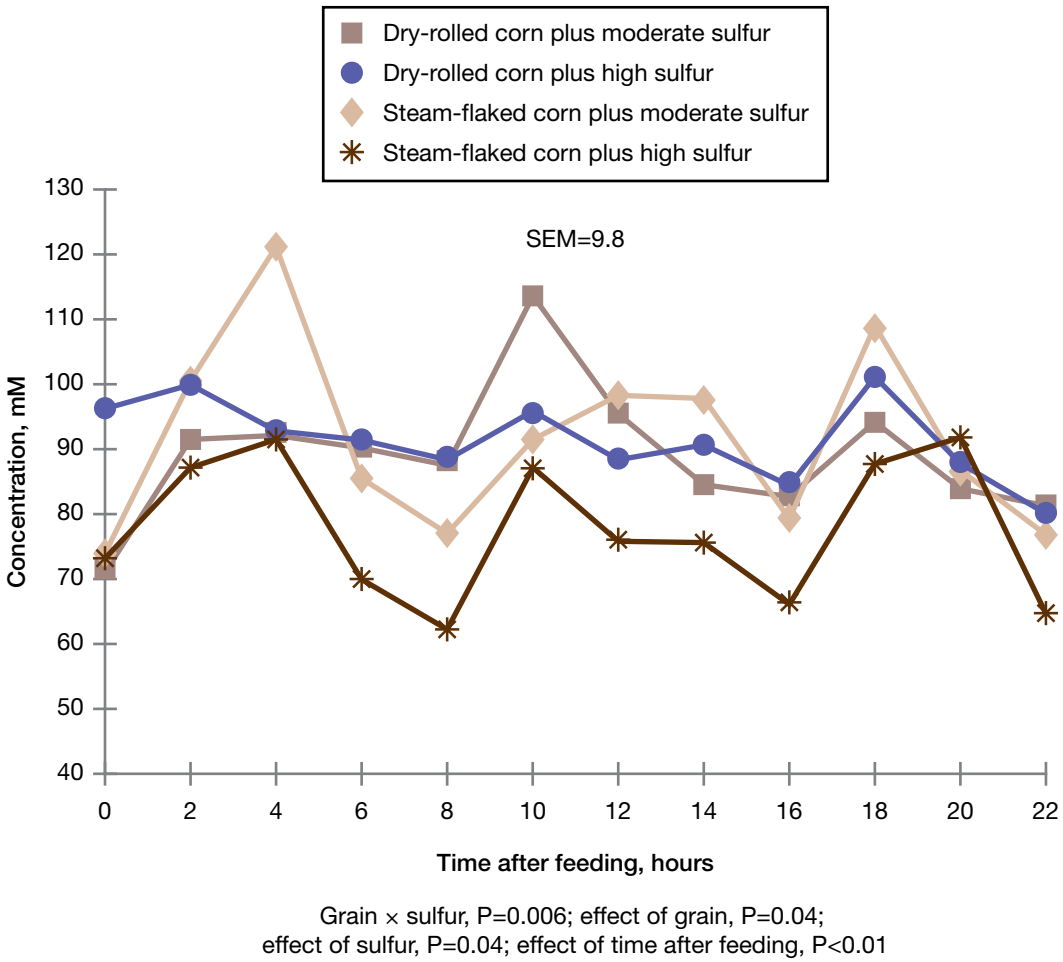


Figure 2. Total volatile fatty acid concentrations in cannulated crossbred steers fed finishing diets based on steam-flaked corn or dry-rolled corn containing dried distillers grains with moderate or high sulfur concentrations.

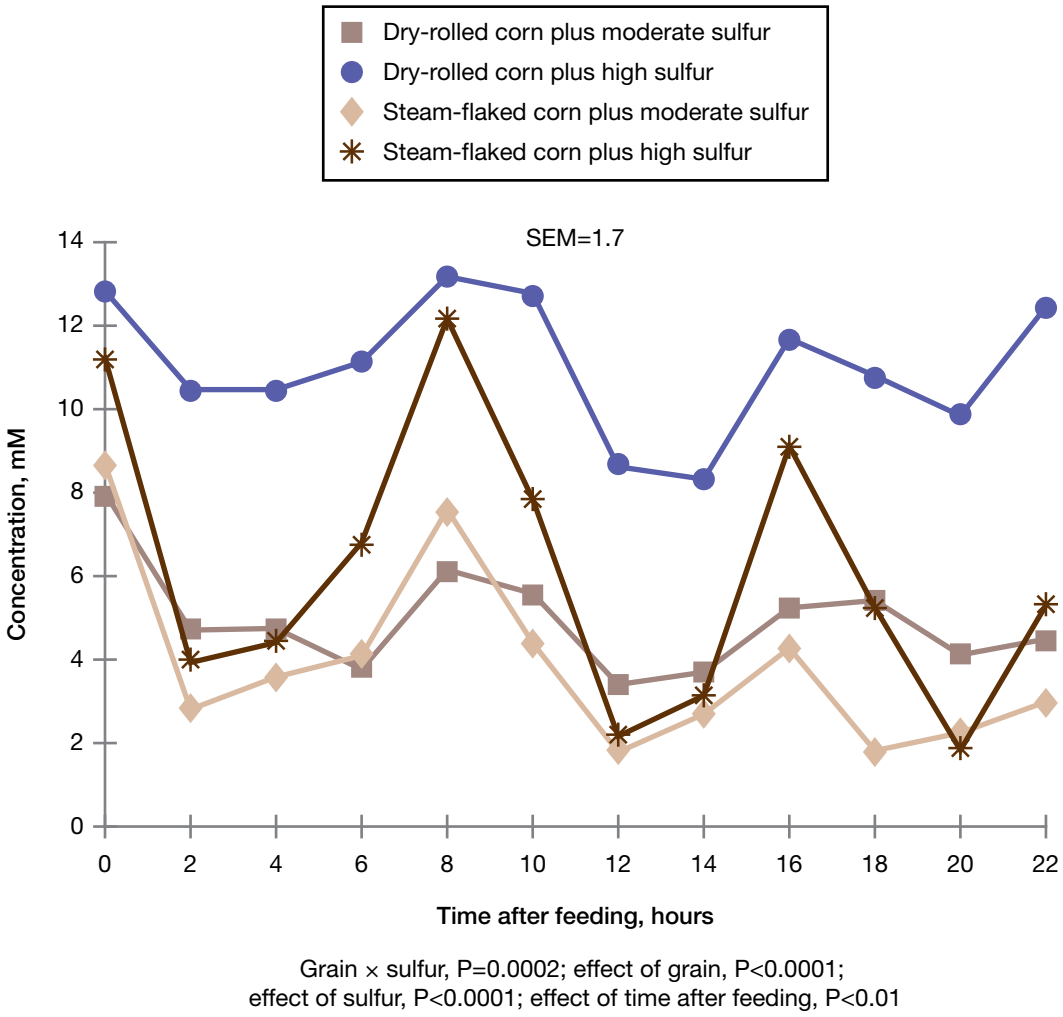


Figure 3. Ammonia concentrations in cannulated crossbred steers fed finishing diets based on steam-flaked corn or dry-rolled corn containing dried distillers grains with moderate or high sulfur concentrations.