Determining the Influence of Dietary Roughage Concentration and Source on Rumen Parameters related to Sulfur Toxicity

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Summary and Implications

Producers are looking for a way to prevent the negative effects associated with feeding large amounts of ethanol co-products that are high in sulfur (S). High levels of S in the diet result in increased ruminal concentrations of hydrogen sulfide (H_2S). Elevated levels of ruminal H_2S have been correlated to increased incidences of the neurological disorder polioencephalomalcia.

The results of these studies suggest that when balanced for NDF levels, chopped cornstalks and chopped bromegrass grass hay did not differ in their effects on rumen H_2S concentrations and ruminal pH, and that increasing inclusion of roughage resulted in increased ruminal pH and decreased ruminal H_2S.

Although increasing roughage levels in the diet results in reduced energy density of the diet, steers in this study increased intake to compensate and thus gains were not affected. Increasing hay inclusion in the diet from 5% to 12% (DM basis) decreased H_2S concentrations by approximately 2,000 ppm, and thus appears to be a practical way to increase inclusion of high S ingredients such as ethanol co-products while reducing the risk of S toxicity.

Introduction

The co-products left after ethanol production are an economical feedstuff; however, they are high in sulfur (**S**) because sulfuric acid is used during the ethanol production process. The residual S limits the use of these co-products in ruminant diets. Increased intake of S has been shown to decrease intake, reduce gain and can lead to a neurological disorder called polioencepahlamalcia. Sulfate, when fed to ruminants is reduced to sulfide by ruminal bacteria. Then sulfide in the rumen can be converted to its gaseous form hydrogen sulfide (**H_2S**) in a pH dependent process. As ruminal pH decreases the proportion of sulfide that will be present as H_2S increases. The ruminal accumulation, eructation and inhalation of large amounts of H_2S are thought to be the cause of the negative effects of excess S. Recent research suggests that risk for S toxicity may be less when forage levels in feedlot diets are increased above the typical 5-7 %. However, little research has been conducted to determine the exact amount of forage needed. Increasing the amount of forage in the diet may reduce potential for S toxicity by modulating ruminal pH. Time spent chewing increases with the increased proportion of roughage in the diet and chewing stimulates saliva secretion. Saliva contributes approximately half the bicarbonate entering the rumen, which helps buffer the acids produced during fermentation as well as acidic feed stuffs such as ethanol co-products. In addition, increasing the amount of forage in feedlot diets has been shown to decrease consumption rate and help to maintain a more steady ruminal pH. The objective of experiment 1 was to compare two sources of roughage, chopped cornstalks and chopped bromegrass hay, in their effects on rumen parameters related to S toxicity when included at three concentrations of added NDF (4, 7 and 10%). The objective of experiment 2 was to investigate the effects of increasing inclusion of bromegrass hay in high S finishing diets on cattle performance, rumen pH, and H_2S concentration.

Materials and Methods

Experiment 1

Six ruminally-fistulated steers were used in a 6 x 6 Latin square design with 14 day periods, and were fed diets containing 0.5 % S, from a combination of distillers grains and condensed corn distillers solubles. The Latin square design takes into account individual steer variation as each steer will have received all diets by the end of the trial. The experimental design was a 2 x 3 factorial with two roughage sources: cornstalks or bromegrass hay, at 1 of 3 levels of added roughage NDF of 4, 7, or 10 % on a DM basis. Cornstalks and hay were both chopped in a tub grinder with a 6 inch screen using a jackknife. Cornstalks (75 % NDF) and hay (68 % NDF) differed in NDF thus diets were formulated on a balanced NDF level, resulting in roughage inclusions of 5, 9, and 13% for cornstalks and 6, 10, and 15% for hay (Table 1).

Diet adaptation occurred over the first 13 days of each period, followed by measurements of rumen H_2S concentration and ruminal pH on day 14 at 6 hours after feeding. Data were analyzed using the MIXED Procedure of SAS (SAS Institute Inc, Cary, NC).

Experiment 2

One hundred and fifty steers were fed one of five diets with varying roughage NDF inclusion. Diets were formulated to contain 4, 6.5, 9, 11.5, or 13 % NDF from bromegrass hay. All diets contained 0.5 % dietary S, which came from a combination of distillers grains and condensed corn solubles. Six replicate pens (5 steers per pen) were randomly assigned to each of the 5 treatments. Steers were transitioned to a high concentrate diet via 2 step up diets (Table 2). They were fed Step up 1 for 6 days, then they were fed Step up 2 for 7 days. Their finishing diet (Table 2) was then limit fed at 1.5 % BW and increased 0.25 % BW daily until cattle reached ad-libum intake.

Gains were calculated using two day consecutive weights, taken after cattle had been limit-fed their finishing diets for one week and weights taken 84 days later. During the study rumen H_2S concentration and ruminal pH was measured on d 7, 14, 21, 28, and 84 at 6 hours after feeding..

Data were analyzed using the MIXED Procedure of SAS (SAS Institute Inc, Cary, NC). Repeated measures were used for H_2S and pH data.

Results and Discussion

Experiment 1

The source of roughage did not differ in the affect on dry matter intake (*P* = 0.08), ruminal pH (*P* = 0.17), or H_2S concentration (*P* = 0.63; Table 3). Ruminal pH was increased (*P* = 0.03) as roughage NDF (**rNDF**) was increased from 4 to 7 %. However, ruminal pH did not differ (*P* = 0.98) between 7 and 10% rNDF. Concentration of H_2S was greater (*P* < 0.01) in 4% than 7 or 10% rNDF, which did not differ (*P* = 0.5; Table 3). Additionally, the study showed a strong negative correlation (R = -0.65; *P* < 0.01) between ruminal pH and H_2S data.

Experiment 2

The addition of roughage did not appear to negatively affect cattle performance. Cattle intake linearly increased (*P* > 0.01) with the increased inclusion of rNDF. The diets with a lower amount of roughage contained a greater level of energy when compared to the diets with the higher amount of roughage, resulting in differences in cattle intake between treatments. Cattle gains tended to have a quadratic relationship (*P* = 0.09) to rNDF (Table 4). The low level of of roughage (4% NDF) and high (13% NDF) of roughage did not differ in average daily gain. The middle level of roughage inclusion (9% NDF) resulted in the lowest gain, causing the trend for a quadratic effect. Feed to gain tended to linearly increase (*P* = 0.08) with the increased inclusion of rNDF. Ruminal H_2S concentrations linearly decreased and ruminal pH linearly increased (*P* > 0.01) with the increased inclusion of rNDF. There was a dramatic increase from 4 % NDF to 9 % NDF in both H_2S and ruminal pH. Athough H2S continued to decrase as roughage level increased there appeared to be a reduced level of benefit to increasing the inclusion of roughage from 9 to 13 % NDF compared to increasing roughage NDF from 4 to 9%.

In conclusion, when balanced for NDF levels, chopped cornstalks and bromegrass hay did not in their effects on rumen H_2S concentration and ruminal pH. The inclusion of bromegrass hay up to 17% of the diet did not decrease average daily gain and appears to increase ruminal pH and decrease H_2S concentrations, thus reducing the risk of S toxicity.

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Table 1. **Diets fed to cannulated steers in experiment 1.**

	Hay			Cornstalks		
	4% NDF	7% NDF	10% NDF	4% NDF	7% NDF	10% NDF
	% of diet (DM basis)					
Chopped bromegrass hay	5.9	10.3	14.7	--	--	--
Chopped cornstalks	--	--	--	5.3	9.3	13.3
DDGS	30.2	30.2	30.2	30.2	30.2	30.2
CCDS	6.0	6.0	6.0	6.0	6.0	6.0
Basal diet[1]	5.0	5.0	5.0	5.0	5.0	5.0
Corn	52.9	48.5	44.1	53.5	49.5	45.5

[1] Salt, Rumensin, trace minerals, and vitamin A, and DDGS as a carrier.

Table 2. Diets fed to steers in experiment 2.

			Finishing diet, % NDF from roughage				
	Step Up 1	Step Up 2	4%	6.5%	9%	11.5%	13%
	% of diet (DM basis)						
Chopped bromegrass hay	30.0	17.3	5.3	8.6	11.9	15.3	17.3
DDGS	20.8	22.8	32.0	32.0	32.0	32.0	32.0
CCDS	14.0	12.5	7.0	7.0	7.0	7.0	7.0
Corn	33.0	45.2	53.5	50.2	46.9	43.5	41.5
Limestone	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Micro-ingredients[1]	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Ne_m Mcal/cwt	79.3	85.8	91.9	90.2	88.5	86.8	85.8
Ne_g Mcal/cwt	51.9	57.6	62.8	61.2	59.7	58.2	57.3

[1] Salt, Rumensin, trace minerals, and vitamin A

Table 3. Dry matter intake, ruminal hydrogen sulfide (H_2S) gas concentration and rumen fluid pH of cannulated steers fed chopped bromegrass hay or corn stalks at three different levels.

	Hay			Corn Stalks				*P*-value		
	4 % NDF	7 % NDF	10 % NDF	4 % NDF	7 % NDF	10 % NDF	SEM	Level	Source	Level by Source
Intake, lbs/hd/d	22.1	20.8	21.8	22.8	23.4	23.5	2.58	0.89	0.08	0.67
Ruminal H_2S, ppm	3383	2597	2377	4173	2183	2983	449	<0.01	0.17	0.15
Rumen pH	5.58	5.63	5.77	5.54	5.68	5.84	0.13	<0.01	0.63	0.66

Table 4. Dry matter intake, average daily gain, feed conversion, ruminal hydrogen sulfide (H_2S) concentrations and ruminal pH of steers fed a finishing diet with 0.5% S and five different levels of hay.

	Roughage NDF in Diet						*P*-value		
	4 %	6.5 %	9 %	11.5 %	13 %	SEM	Trt	Linear	Quad
Intake, lbs/hd/d	23.5	23.5	23.7	24.9	24.9	0.40	<0.01	<0.01	0.25
Gain, lbs/hd/d	4.52	4.39	4.31	4.55	4.51	0.078	0.15	0.55	0.09
Feed to gain	5.20	5.38	5.49	5.40	5.53	0.12	0.36	0.08	0.53
Ruminal H_2S, ppm	7365	6290	5478	5148	4528	276	<0.01	<0.01	0.18
Rumen pH	5.48	5.66	5.75	5.74	5.78	0.047	<0.01	<0.01	0.03