Obtaining Optimum Utilization of Distillers Grains in Feedlot Diets

G. Crawford
University of Minnesota Extension, Hutchinson, MN

Take Home Message

- Distillers grains usage in beef cattle feedlot rations has drastically increased in recent years, with the potential for further increases.
- Sulfur content of distillers grains is likely the primary factor limiting increased inclusion in feedlot rations.
- Extreme dietary sulfur concentrations of 0.60% decreased DMI by 19%, ADG by 25%, and feed efficiency by 5% when compared to a diet with 0.35% dietary sulfur.
- Manganese oxide appears to improve ADG and feed conversion in high S diets during the first 28 days on feed.
- Increasing dietary roughage increases intake and decreases feed efficiency, but so far does not appear to affect feedlot performance when included in high S rations.
- Increasing dietary distillers grains inclusion from 20 to 40 and 60% can drastically reduce ration costs, and can reduce cost of gain with current feed costs as long as feed conversion losses are not more than 4% with 40% distillers grains and 9.4% with 60% distillers grains.
- Questions remain that limit distillers grains inclusion in feedlot rations, and these questions deserve attention in order to increase distillers grains usage.

Introduction

With the rapid increase in ethanol production over the last ten years, livestock producers are feeding more distillers grains (DG) than ever before. According to the Renewable Fuels Association, production of DG, the most common corn milling byproduct, increased from 2.5 million tons in 1999 to nearly 36 million tons in 2010. Beef cattle utilize about 39% of all the DG produced, and most of this goes into feedlot rations. For cattle feeders in the upper Midwest, DG are readily available, and are used extensively, particularly in with the current high corn prices.

Research has shown DG inclusions of 30-40% of dietary DM can be used in replacement of corn without negatively affecting feedlot cattle weight gains and efficiency (Vander Pol et al., 2006). Most feedlots in the upper Midwest are feeding lesser amounts of DG, but with rising corn prices there is interest among feeders in increasing DG inclusion. Questions remain, however, regarding the factors limiting DG inclusion. The University of Minnesota Beef Team conducted an informal survey of consulting feedlot nutritionists in late 2009 to determine use of DG in feedlot rations and the factors limiting greater inclusions (G. Crawford, unpublished data). The responses to the survey indicated a high proportion (mean = 88%, median = 96.5%) of the consultants' clients were utilizing DG in their rations. In terms of inclusion, the mean and median dietary inclusions were 23 and 25%, respectively. The most telling response from the survey may have been to a question regarding the biggest constraints to feeding increased dietary concentrations of DG. A total of 12 consultants responded to this question, with seven of the respondents (58%) indicating that sulfur (S) concentration was the greatest constraint. Other constraints indicated by the respondents: fat content (5 responses, 42%), price (5 responses, 42%), and DG consistency (3 responses, 25%; Table 1).

Table 1. Responses by consulting feedlot nutritionists to the question "In your opinion, what is the biggest constraint to feeding more distillers grains in feedlot rations?".[1]

Response	Frequency	Percentage of Respondents
Sulfur concentration	7	58.3
Fat concentration	5	41.7
Price	5	41.7
Product consistency	3	25.0
Animal performance	2	16.7
Protein concentration	2	16.7
Moisture content	2	16.7
Availability	2	16.7
Shrink	1	8.3
True cost	1	8.3

[1] Survey conducted in October 2009. Survey initially emailed to 24 consulting feedlot nutritionists in the upper Midwest. Twelve responded. Some respondents included more than one response.

These responses confirmed what many had previously suggested, that S concentration of DG was the major constraint to feeding increased dietary DG concentrations, while fat concentration and price were also major constraints. Detailed reviews of the effect of dietary S concentration of feedlot cattle health and performance are available (Crawford, 2007). In recent years, many universities have tackled the issue of maximizing dietary DG inclusion, and by extension maximizing dietary S concentration, with varying degrees of success. Beyond the university research, many feedlot operators and nutritionists have increased DG inclusion in feedlot rations to combat high corn prices, and in many cases have gone well beyond the NRC (2005) maximum tolerable concentration of S of 0.30% of dietary DM.

With these issues in mind, the University of Minnesota Beef Team has received generous funding from the Minnesota Corn Research and Promotion Council and the Agricultural Utilization Research Institute to conduct research on different methods of maximizing DG use in beef cattle feedlot diets. Our DG research has generally fallen into four categories: utilization of novel corn co-products in beef cattle feedlot rations (Kelzer et al., 2011); the effect of DG on meat quality (Popowski et al., 2011 b,c,d); the effect of DG on shedding of E. coli O157:H7, which will be presented in depth at this conference (Fink, 2011) and has been reported elsewhere (Fink et al., 2011; Jaderborg et al., 2011; Paulus et al., 2011; Popowski et al., 2011a); and methods to attenuate high S concentrations in distillers grains to maximize DG use, which will be the focus of this report.

Methods to Reduce Negative Effects of High-S Feedlot Rations

I. Supplementation of manganese

Manganese oxide (MnO) is commonly supplemented to feedlot cattle as a source of manganese and is also a powerful oxidizing agent. Manganese oxides may effectively oxidize hydrogen sulfide (H_2S) into sulfate, S, and small amounts of thiosulfate (Herszage and Afonso, 2003). At low pH, sulfates are the primary products of this oxidation, and elemental S is the primary product with pH values at or above neutral (Herszage and Afonso, 2003). At pH of 5, aqueous MnO oxidized H_2S to sulfate and elemental S at a rate of 1.49 g of MnO to 1 g of H_2S (Herszage and Afonso, 2003).

Ruminal pH of feedlot cattle consuming finishing rations commonly ranges from 5.2 to 6.0. Therefore, supplementing MnO to feedlot cattle consuming rations high in dietary S may result in lower ruminal concentrations of H_2S due to increased ruminal oxidation of H_2S into sulfates.. The sulfates should then be eliminated in the small intestine; thus reducing the potential negative effects of S toxicity on health and performance of feedlot cattle.

To assess the effects of MnO inclusion on ruminal fermentation and beef cattle feedlot performance, we have conducted numerous *in vitro,* metabolism, and feedlot experiments. The results of the *in vitro* and metabolism experiments are detailed by Kelzer et al., 2010 and Kelzer, 2011. In these preliminary experiments, we assessed various dietary concentrations of MnO, ranging from 0 to 2,500 ppm *in vitro* and 0 to 1,000 ppm *in vivo.* The results of these experiments identified a positive response to MnO up to 1,000 ppm.

The results showing a positive response to 1,000 ppm MnO supplementation in high-S (approximately 0.65%) feedlot diets led to a feedlot experiment assessing the performance and carcass responses to supplementing MnO in moderate and high S feedlot diets. The feedlot experiment consisted of 182 head (107 crossbred heifers and 75 crossbred steers, initial BW = 728 ± 62 lb) blocked by weight and sex and arranged into 16 pens. Steer pens (n=8) contained 9-10 head/pen, while heifer pens (n=8) contained 13-14 head/pen. Cattle were fed one of four dietary treatments arranged in a 2 x 2 factorial. The two factors were dietary S concentration of 0.35 or 0.60% (DM basis), and dietary MnO supplementation of 0 or 1,000 ppm. The basal diet contained 44% high moisture corn, 35% wet DG, 9% corn silage, 3% straw, and 9% supplement. Wet DG were sourced from Otter Tail Ag Enterprises in Fergus Falls, MN, and contained approximately 34% DM, 29.5% CP, and 0.85% S. Sulfur concentration of wet DG ranged from 0.80 to 0.91% during the experiment. High S concentrations in the 0.60% S treatments were achieved through supplementation of a gypsum premix.

Cattle were fed for *ad libitum* intake once daily at 0800 and were weighed every 28 d. Cattle were marketed upon visual appraisal of approximately 0.40 in. of backfat. This resulted in the heavy block of steers and heifers being on feed for 173 d and the light block on feed for 201 d. Heavy block cattle were harvested at Tyson Fresh Meats in Dakota City, NE, and light block cattle were harvested at JBS Swift in Grand Island, NE.

Live performance data are shown in Table 2. After 28 d on feed, cattle consuming low-S treatments had a 12% greater DMI ($P < 0.01$) and a 25% greater ADG ($P < 0.01$) than those consuming high-S treatments. Though MnO supplementation did not affect DMI ($P = 0.31$), there was a trend ($P = 0.09$) for greater ADG with MnO supplementation through the first 28 d on feed. There was also a S x MnO interaction for feed conversion, where the high-S, no MnO treatment had a poorer feed conversion than all other treatments ($P < 0.01$; Figure 1).

Table 2. Main effects of manganese oxide inclusion in low and high-S feedlot diets on beef cattle feedlot performance.

	Sulfur Concentration, %		Manganese Oxide, ppm			*P*-values		
Item	**0.35**	**0.60**	**0**	**1,000**	**SEM[1]**	**Sulfur**	**MnO**	**SxMnO**
Initial BW, lb	728	727	727	728	27	0.76	0.40	0.43
Day 28 BW, lb	829	808	812	824	25	<0.01	0.04	0.19
DMI d 0-28, lb/d	18.7	17.3	17.8	18.1	0.2	<0.01	0.31	0.63
ADG d 0-28, lb	3.60	2.88	3.05	3.43	0.20	<0.01	0.09	0.15
F:G[2] d 0-28	5.19	6.01	5.84	5.28	0.33	0.01	0.03	0.03
Final BW, lb	1,357	1,230	1,295	1,292	17	<0.01	0.80	0.31
Final DMI, lb/d	22.7	19.1	20.7	21.0	0.2	<0.01	0.35	0.31
Final ADG, lb	3.37	2.69	3.05	3.02	0.09	<0.01	0.65	0.28
Final F:G[2]	6.73	7.10	6.79	6.95	0.17	0.02	0.35	0.10

[1] Standard error.

[2] Feed:Gain ratio.

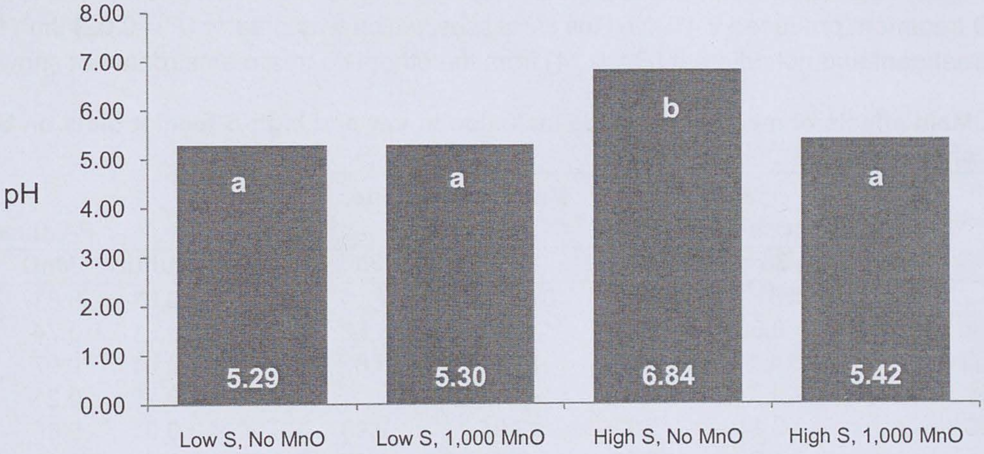

Figure 1. Simple effects of dietary S and MnO concentration on feed conversion during the first 28 days on feed.

[ab] Uncommon scripts indicate difference ($P < 0.05$). Standard error = 0.38.

These results suggest that MnO had an effect on feedlot performance when supplemented to high-S diets through 28 d. McAllister et al. (1997) reported the incidence of polioencephalomalacia (PEM) cases peaked between 15-30 days on feed. The relationship to days on feed could be due to the changes in the ruminal environment that are associated with adapting cattle to a high-concentrate diet. Sager et al. (1990) and Low et al. (1996) both observed clinical signs of PEM beginning on day 15 after adaptation to a high-concentrate diet with excess S. During this time, ruminal pH becomes increasingly more acidic. The pKa for hydrogen sulfide is 7.2 (Kung et al., 1998), which indicates that as ruminal pH decreases, more hydrogen sulfide will be in the more toxic protonated form. At a ruminal pH in the 5.0-5.5 range, which will occur with high-concentrate rations, nearly 100% of the hydrogen sulfide would be in the protonated form.

Beyond the MnO results observed at d 28, we did not observe any MnO effects or S x MnO interactions throughout the experiment, and by the end of the experiment the cattle consuming the 0 and 1,000 ppm MnO treatments had similar ($P \geq 0.35$) final BW, DMI, ADG, and feed conversion. This suggests that the inclusion of MnO may be useful when cattle are adapting to a high-S and high-concentrate diet, but loses its usefulness beyond that time.

Though no MnO effects were observed beyond d 28, high dietary S concentrations continued to suppress feedlot performance. Cattle consuming the low-S treatments had 10% greater final BW ($P < 0.01$), 19% greater DMI ($P < 0.01$), 25% greater ADG ($P < 0.01$), and a 5% improvement in feed conversion ($P = 0.02$).

Carcass characteristics are shown in Table 3. A S x MnO interaction ($P = 0.01$) was present for frequency of carcasses grading Choice or greater. Cattle that consumed the high-S, no MnO treatment had lower percentage Choice or greater carcasses than all other treatments (Figure 2). A S x MnO interaction ($P = 0.01$) was present for frequency of No Roll carcasses, where the high-S, no MnO treatment produced 12.2% No Roll carcasses, which was greater ($P < 0.04$) than either the low-S, no MnO treatment (0.0%) or the high-S, 1,000 ppm MnO treatment (3.6%). The low-S, 1,000 ppm MnO treatment produced 9.4% No Roll carcasses, which was greater ($P = 0.02$) than the low-S, no MnO treatment and not different ($P > 0.14$) from the other two treatments (data not shown).

Table 3. Main effects of manganese oxide inclusion in low and high-S feedlot diets on beef cattle carcass characteristics.

	Sulfur Concentration, %		Manganese Oxide, ppm			*P*-values		
Item	**0.35**	**0.60**	**0**	**1,000**	**SEM[1]**	**Sulfur**	**MnO**	**SxMnO**
HCW, lb	858	777	818	817	10	<0.01	0.81	0.31
Backfat, in	0.58	0.47	0.52	0.52	0.04	<0.01	0.74	0.91
REA[2], sq in	14.1	13.5	13.8	13.8	0.4	<0.01	0.97	<0.01
Marbling[3]	521	492	492	520	18	0.19	0.21	0.49
USDA YG[4]	3.14	2.79	2.94	2.98	0.20	<0.01	0.66	0.26
YG 1, %	1.39	8.39	6.11	2.67	1.57	0.01	0.28	0.03
YG 2, %	14.0	19.4	18.7	14.7	3.0	0.22	0.36	0.23
YG 3, %	28.2	22.1	22.8	27.5	3.4	0.22	0.33	0.33
YG 4, %	8.81	8.84	7.45	9.52	2.32	0.83	0.53	0.65
YG 5, %	1.00	0.00	1.00	0.00	0.51	0.19	0.19	0.19
Prime QG[5], %	6.46	5.10	4.89	6.66	2.30	0.67	0.59	0.90
Choice QG, %	80.0	74.1	75.7	78.4	2.6	0.12	0.47	0.01
Prime+Choice, %	86.5	79.2	80.6	85.1	2.5	0.06	0.23	0.01
Select QG, %	8.9	12.9	13.3	8.5	2.4	0.25	0.17	0.84
No Roll QG, %	4.70	7.90	6.11	6.49	2.01	0.27	0.90	0.01

[1] Standard error.

[2] Ribeye (longissimus muscle) area measured at the 12th rib.

[3] Marbling score assessed by USDA grader where 400 = Small^0, 500 = Modest^0, etc.

[4] USDA yield grade assessed by USDA grader.

[5] USDA quality grade assessed by USDA grader.

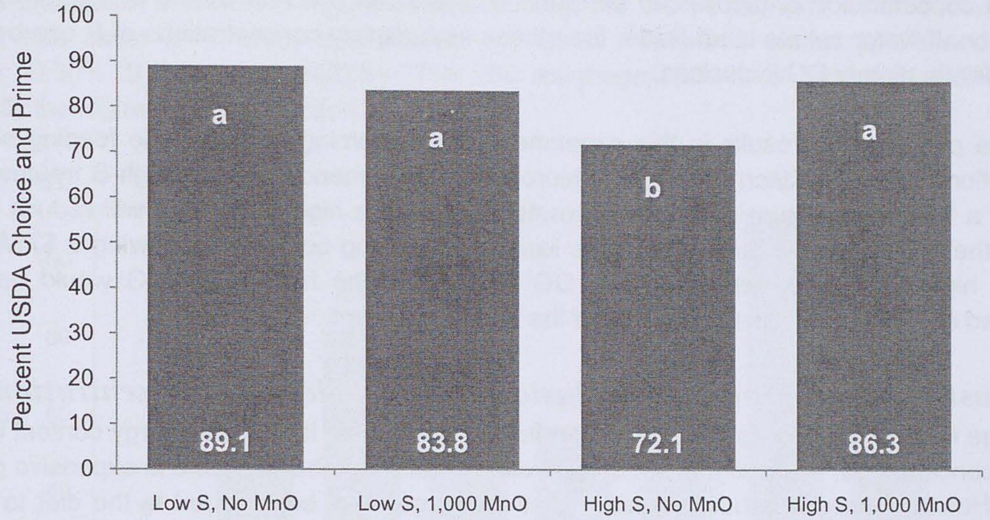

Figure 2. Simple effects of dietary S and MnO concentration on percentage of carcasses grading USDA Choice and Prime.

^{ab} Uncommon scripts indicate difference ($P < 0.05$). Standard error = 3.9.

A S x MnO interaction ($P = 0.03$) was also present for frequency of USDA yield grade (YG) 1 carcasses. The high-S, no MnO treatment produced 12.2% YG 1 carcasses, which was greater ($P < 0.02$) than all other treatments (data not shown). This result corresponds with the Choice and higher and No Roll results, which generally show the high-S, no MnO treatment to have produced a lower quality, less-finished carcass.

A surprising S x MnO interaction ($P < 0.01$) occurred for ribeye area, where the low-S, no MnO treatment produced a 14.3 sq in ribeye area, which was greater ($P < 0.02$) than all other treatments. The low-S, 1,000 ppm MnO and high-S, 1,000 ppm MnO treatments each produced 13.8 sq in ribeye areas, which were greater ($P < 0.02$) than the high-S, no MnO treatment (13.3 sq in; data not shown).

No other S x MnO interactions were present for any carcass characteristic ($P > 0.18$). Manganese oxide inclusion did not affect ($P > 0.17$) any measured carcass characteristic.

Overall, it appears that MnO may have a positive impact on beef cattle feedlot performance, particularly when supplemented to high-S feedlot diets during the first 28 d on feed. The effects of dietary S concentration were present throughout the experiment, and appeared to accumulate over time.

Though the S content of the high-S treatments may be extreme, it is attainable and may be seen in the industry with increased DG use and instances with extreme DG S concentrations. To reach a 0.60% S concentration in a diet similar to that fed in this experiment, it would require a DG S concentration of between 1.40 and 1.50%, assuming that water sulfate concentrations are negligible. These DG S concentrations are not common, but may occur in extreme cases. However, if a producer decides to maximize DG use by feeding, for example, 50% DG on a DM basis, then a dietary S concentration of 0.60% can be reached with a DG S concentration of 1.0%, which is not uncommon. If water sulfate is an issue, then these high dietary concentrations of S can be reached with moderate dietary DG inclusions.

Using the performance results in this experiment, and assuming current cattle feeding economics and a ration cost of $230/ton of DM, the decrease in performance with the high-S treatment would result in a $77 lower return per head. Therefore, to feed a high-S DG that will reduce per head returns, the DG should be purchased for a lower price. Using our results showing a $77/head loss with the high-S diet, and assuming wet DG at $65/ton, the high-S wet DG would have to be purchased at $19/ton to match the return of the low-S treatment.

II. Adjusting dietary roughage inclusion based on dietary S concentration

Roughage is often the "necessary evil" of the feedlot enterprise. It has low energy content compared to most concentrates, it is bulky, it can spoil, it can be difficult to harvest, and is expensive per unit of energy. However, feedlot producers know that roughage must be included in the diet to keep the rumen healthy and keep cattle on feed. With the availability of DG, many feedlot operators and nutritionists initially thought that they might be able to decrease dietary roughage concentrations. However, research has shown dietary DG inclusion may actually lower rumen pH (Vander Pol et al., 2009). In addition, because conversion of sulfur to hydrogen sulfide is pH-dependant, and dietary increased roughage concentrations have been shown to increase ruminal pH (Crawford et al., 2007; Vanness et al., 2009b), one could argue that dietary roughage concentration should be increased when feeding high-S DG.

To address this issue, we have conducted a series of experiments to determine the interaction between dietary roughage and S concentrations. The first experiment focused on the effect of dietary roughage and S concentration on H_2S production in batch culture (Seitz et al, 2011). The objective of this experiment was to assess the production of H_2S and NH_3N as well as measure final pH of batch cultures resulting from eight different dietary concentrations of dietary roughage and S. The eight diets consisted of a corn-based control containing no DG, 9% roughage (DM basis), and 0.18% S (CON); a high roughage treatment with 27% roughage, 40% DG, and 0.50% S (HRHS); and six treatments arranged in a 3 x 2 factorial with three dietary S concentrations (0.30, 0.40, and 0.50%) and two dietary roughage concentrations (3 and 9%). Grass hay served as the roughage source for all treatments, and dietary S concentrations were achieved through combinations of two different dried DG with S concentrations of 0.35 and 0.98% (sourced from Western Wisconsin Energy, Boyceville, WI and POET Energy, Sioux Falls, SD, respectively). Dietary treatments were formulated to be isonitrogenous. Batch cultures were incubated for 24 h, and final pH, NH_3N concentration, and H_2S and total gas production measurements were taken at that time.

Results for final batch culture pH and NH_3N concentration are listed in Table 4. In general, DG inclusion increased batch culture pH compared with the control, and increased roughage concentration further increased batch culture pH. Final pH for the HRHS treatment was 5.95, which was higher than all other treatments ($P < 0.05$). The CON treatment had a final batch culture pH of 5.44, which was lower ($P < 0.05$) than all other treatments other than the 3% roughage, 0.30% S treatment (LRLS). Concentration of NH_3N was not affected by treatment ($P = 0.52$).

Total H_2S production is shown in Figure 3. As expected, the CON treatment, which contained only 0.18% S, had lower ($P < 0.05$) H_2S production that all treatments except LRLS and the 9% roughage, 0.30% S treatment (MRLS). The 9% roughage, 0.50% S treatment (MRHS) had numerically the highest H_2S production.

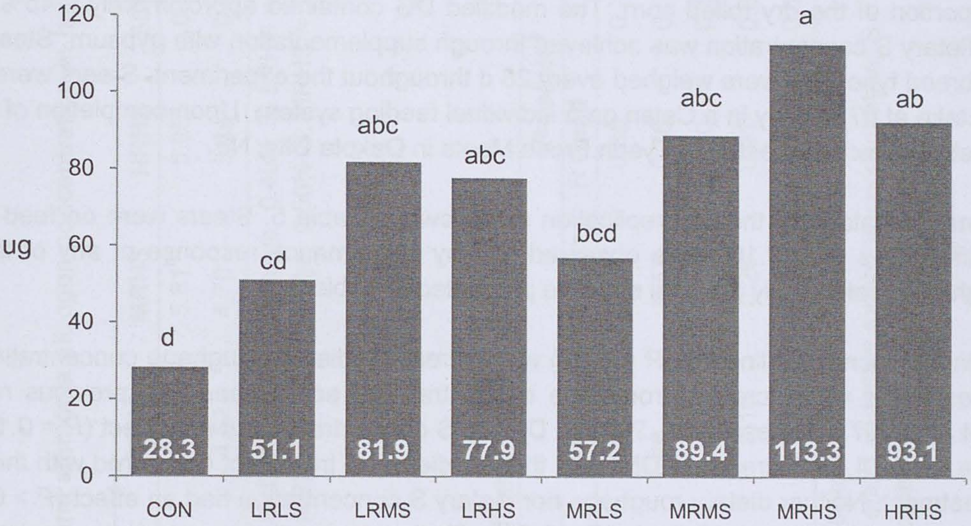

Figure 3. Total 24-h hydrogen sulfide production from batch cultures of rumen contents. CON = Control, no DG, 9% roughage, 0.18% S; LRLS = 3% roughage, 0.30% S; LRMS = 3% roughage, 0.40% S; LRHS = 3% roughage, 0.50% S; MRLS = 9% roughage, 0.30% S; MRMS = 9% roughage, 0.40% S; MRHS = 9% roughage, 0.50% S; HRHS = 27% roughage, 0.50% S. All treatments other than CON contained 40% dried DG.

^{abcd} Uncommon scripts indicate difference ($P < 0.05$). Standard error = 16.3.

The data from the batch culture basically confirmed what we hypothesized, that roughage concentration will increase pH, and that addition of DG to corn-based feedlot diets will increase H_2S production. We did not, however, see an interaction between dietary S and roughage concentrations to suggest that H_2S production is reduced when high dietary S concentrations are fed with increased dietary roughage. Even the HRHS ration, which contained 27% roughage, produced a similar amount of H_2S as the lower roughage, DG-containing rations.

A follow-up experiment evaluating these eight treatments in a continuous culture fermentation system has been completed and the data are currently being compiled. This continuous culture results will allow us to further assess the effect of these treatments on pH, NH_3N, and H_2S production, and will also allow us to assess the effect on microbial protein production and efficiency and volatile fatty acid production.

We are currently conducting a feedlot finishing experiment to assess the interaction of dietary roughage and sulfur concentrations on feedlot performance and carcass characteristics. As of early August 2011, the first replication of the experiment has been completed, and an additional replication is currently underway.

The completed replication consisted of 48 steers (initial BW = 938 ± 75 lb), 30 of which were Limousin and 18 Angus. Six treatments were arranged in a 3 x 2 factorial, with factors consisting of dietary S concentration (0.28 and 0.56%) and dietary roughage concentration (5, 10, and 15%). Diets consisted of dry-rolled corn, 35% modified DG (Western Wisconsin Energy, Boyceville, WI), mineral supplement, and roughage supplied as grass hay. Increasing roughage concentrations replaced a portion of the dry rolled corn. The modified DG contained approximately 0.45% S, and the 0.56% dietary S concentration was achieved through supplementation with gypsum. Steers were blocked by breed type, and were weighed every 28 d throughout the experiment. Steers were fed for *ad libitum* intake at 0730 daily in a Calan gate individual feeding system. Upon completion of the first replication, steers were harvested at Tyson Fresh Meats in Dakota City, NE.

Live performance data from the first replication are shown in Table 5. Steers were on feed for 134 days. No differences ($P > 0.10$) were observed for any performance response at any of the 28 d interim weights, therefore only the final data are presented in Table 5.

Dry matter intake increased linearly ($P = 0.03$) with increasing dietary roughage concentration. This was to be expected with increased roughage concentrations, and agrees with previous research (Crawford et al., 2007; Vanness et al., 2009b). Dietary S concentration did not affect ($P = 0.12$) DMI, though there was a 4.5% increase in DMI with the low dietary S treatment compared with the higher dietary S treatment. Neither dietary roughage nor dietary S concentration had an effect ($P > 0.26$) on ADG. Feed conversion improved linearly ($P = 0.01$) with decreasing dietary roughage concentration. Dietary S concentration had no effect ($P = 0.60$) on feed conversion.

Carcass characteristics are shown in Table 6. No differences ($P > 0.37$) were present for hot carcass weight, marbling, backfat, ribeye area, or average USDA YG. There were also no differences ($P > 0.12$) present for frequency of any of the USDA quality grades. No differences were present for frequency of USDA YG 1 carcasses ($P > 0.15$). There was a quadratic roughage effect for frequency of USDA YG 2 carcasses. Roughage x S interactions occurred for USDA YG 3 ($P = 0.01$) and 4 ($P = 0.04$) carcasses. The 10% roughage, 0.28% S treatment and the 5% roughage, 0.56% S treatments each averaged 55.7% USDA YG 3 carcasses, which was greater ($P < 0.05$) than the 15% roughage, 0.28% S treatment (18.2% USDA YG 3 carcasses) and the 5% roughage, 0.28% S treatment (5.7% USDA YG 3 carcasses; data not shown). There was a trend ($P = 0.07$) for a decrease in USDA YG 4 carcasses with the 10% roughage, 0.28% S treatment and the 10% roughage, 0.56% S treatment (4.9% USDA YG 4 carcasses each) compared with the 5% roughage, 0.28% S, 15% roughage, 0.28% S, and 10% roughage, 0.56% S treatments (29.9% USDA YG 4 carcasses each; data not shown). The biological basis for these responses is unknown, and it is anticipated that these differences may disappear when the second replication is completed.

Table 4. Effects of dietary roughage and sulfur concentrations on final pH and ammonia nitrogen concentration in batch cultures of rumen contents[1].

Item	CON	LRLS	LRMS	LRHS	MRLS	MRMS	MRHS	HRHS	SEM[2]	*P*-value
Final pH	5.44^{e}	5.55^{de}	5.65^{cd}	5.62^{cd}	5.67^{c}	5.66^{cd}	5.81^{b}	5.95^{a}	0.05	<0.01
NH_3N (mg/100 ml)	4.21	3.95	3.83	5.14	3.76	4.52	4.70	5.09	0.65	0.52

[1] CON = Control, no DG, 9% roughage, 0.18% S; LRLS = 3% roughage, 0.30% S; LRMS = 3% roughage, 0.40% S; LRHS = 3% roughage, 0.50% S; MRLS = 9% roughage, 0.30% S; MRMS = 9% roughage, 0.40% S; MRHS = 9% roughage, 0.50% S; HRHS = 27% roughage, 0.50% S. All treatments other than CON contained 40% dried DG.

[2] Standard error.

Table 5. Effects of dietary roughage and sulfur concentrations on feedlot performance of beef steers[1].

	Roughage Concentration			S Concentration			*P*-values[2]			
Item	5%	10%	15%	0.28%	0.56%	SEM[3]	R Linear	R Quad	S	R x S
Initial BW, lb	931	941	942	941	935	27	0.70	0.85	0.79	1.00
Final BW, lb	1,409	1,400	1,387	1,407	1,390	29	0.57	0.76	0.60	0.81
DMI, lb/d	21.7	23.3	23.5	23.3	22.3	1.5	0.03	0.30	0.12	1.00
ADG, lb	3.58	3.44	3.34	3.50	3.42	0.15	0.26	0.91	0.64	0.73
Feed:Gain	6.06	6.77	7.04	6.66	6.52	0.30	0.01	0.47	0.60	0.68

[1] Data are from first replication of experiment. This includes eight observations per treatment.

[2] R Linear = Linear effect of dietary roughage concentration; R Quad = quadratic effect of dietary roughage concentration; S = main effect of dietary S concentration; R x S = interaction between dietary roughage and S concentrations.

[3] Standard error.

Table 6. Effects of dietary roughage and sulfur concentrations on carcass characteristics of beef feedlot steers[1].

	Roughage Concentration			S Concentration			*P*-values[2]			
Item	5%	10%	15%	0.28%	0.56%	SEM[3]	R Linear	R Quad	S	R x S
HCW, lb	913	907	899	911	901	17	0.57	0.76	0.60	0.81
Backfat, in	0.49	0.48	0.45	0.48	0.46	0.19	0.41	0.73	0.56	0.76
REA[4], sq in	15.8	16.2	16.2	16.2	15.9	1.4	0.43	0.70	0.45	0.92
Marbling[5]	492	509	464	491	486	138	0.47	0.37	0.88	0.21
USDA YG[6]	2.58	2.46	2.46	2.50	2.50	0.84	0.60	0.76	1.00	1.00
YG 1, %	7.1	32.1	25.8	19.6	23.8	9.3	0.15	0.17	0.70	0.35
YG 2, %	44.9	7.4	26.1	32.4	19.9	9.5	0.16	0.02	0.25	0.27
YG 3, %	30.7	43.2	24.4	26.5	39.0	8.6	0.60	0.14	0.21	0.01
YG 4, %	17.4	17.4	23.6	21.5	17.4	7.0	0.52	0.71	0.60	0.04
Prime QG[7], %	9.7	22.2	9.7	16.0	11.8	6.6	1.00	0.12	0.58	0.30
Choice QG, %	50.7	38.2	44.4	40.3	48.6	9.8	0.65	0.43	0.46	0.39
Prime+Choice, %	60.4	60.4	54.2	56.3	60.4	7.4	0.54	0.73	0.62	0.78
Select QG, %	40.4	34.2	40.4	36.3	40.4	8.4	1.00	0.54	0.66	0.83
No Roll QG, %	0.00	5.42	5.42	7.50	0.00	4.76	0.35	0.59	0.13	0.56

[1] Data are from first replication of experiment. This includes eight observations per treatment.

[2] R Linear = Linear effect of dietary roughage concentration; R Quad = quadratic effect of dietary roughage concentration; S = main effect of dietary S concentration; R x S = interaction between dietary roughage and S concentrations.

[3] Standard error.

[4] Ribeye (longissimus muscle) area measured at the 12th rib.

[5] Marbling score assessed by USDA grader where 400 = Small^0, 500 = Modest^0, etc.

[6] USDA yield grade assessed by USDA grader.

[7] USDA quality grade assessed by USDA grader.

Our hypothesis was that increased dietary roughage concentrations may result in improvements in performance within dietary S concentrations. However, no significant interactions were present for any performance variable. Through the first replication, it is clear that dietary roughage concentration increases DMI and decreases feed efficiency, and it also appears that high dietary S concentrations may reduce DMI.

Discussion on Methods to Maximize DG Utilization

Our data have illustrated the negative effect that high dietary S concentrations can have on feedlot performance and carcass characteristics. In addition to our research, a number of universities have conducted experiments to determine the optimum level of DG, and in many cases dietary S, that can be fed without impacting animal performance. University of Nebraska research has reported that up to 0.46% S can be fed in feedlot diets before S toxicity occurs (Vanness et al., 2009a). Further University of Nebraska research (Wilken et al., 2009) evaluated the effects of feeding feedlot rations with little to no corn, and found that a diet with 66% wet DG, 22% grass hay, 7.5% alfalfa hay, and 5% supplement produced a similar DMI, ADG, and feed conversion as a corn-based diet with no DG. In the same study, the authors fed a diet with 33% wet DG, 33% wet corn gluten feed, 22% dry-rolled corn, 7.5% alfalfa hay, and 5% supplement and reported an ADG, DMI, and reported feed conversions similar to that of the corn-based control.

The types of diets fed in the Wilken et al. (2009) study could become more common if high corn prices persist. Current corn futures show greater than $7.00/bu prices through July 2012, and greater than $6.00/bu prices through December 2014. With these prices, it is imperative for feedlot operators and nutritionists to focus on cost of gain, even if it means decreased performance. For instance, assuming feedstuff prices of $7.00/bu for corn, $70/ton for corn silage, $95/ton for modified DG, $130/ton for alfalfa hay, and $300/ton for supplement, a conventional corn-based diet with no distillers, 10% corn silage, 5% alfalfa hay and 5% supplement would cost $277/ton of DM. When corn is partially replaced by modified DG at 20, 40, and 60% of the ration, the ration cost drops to $262, $248, and $233/ton, respectively. If DMI, ADG, and feed conversion are not affected by ration, the costs of gain are $1.10, 1.05, 1.00, and 0.95/lb for the 0, 20, 40, and 60% DG rations, respectively.

However, field and research data have shown reduced performance when dietary DG concentrations exceed 40%. Therefore, we need to determine how much performance we can sacrifice and still see a positive return to increased DG inclusion. If we consider the typical upper Midwest feedlot operator includes 25% modified DG in their ration, and that ration costs $258/ton and they expect DMI, ADG, and feed conversions of 22 lb/d, 3.3 lb, and 6.67, respectively, their cost of gain would be $1.04/lb. If they increase modified DG inclusion to 40% of their ration, they could afford a 4% drop in feed efficiency and still realize the same cost of gain as with the 20% modified DG ration. If they increase their dietary modified DG inclusion to 60%, they could afford a 9.5% drop in feed efficiency and still realize the same profit as with 20% modified DG inclusion. A 9.5% drop in feed efficiency would be equivalent to going from a 6.67 feed conversion to a 7.31 feed conversion. Inclusion of modified DG up to 50% of dietary DM resulted in a linear improvement in feed conversion (Huls et al., 2008); though DMI and ADG were maximized at 20% inclusion.

Remaining Questions and Research Needs

Over the years, feedlot operators and nutritionists have become more comfortable feeding increased dietary concentrations of DG. Part of this is likely due to comfort and experience, part is likely due to increased field and research data available, and a large part of it may be due to the need to manage cost of gain with increasing feedstuff prices. Despite increased inclusions and increased comfort, many questions still remain that limit further increases in DG inclusion in feedlot diets. Sulfur has been addressed at length in this report and many others, but by no means has the issue of S in feedlot diets been solved. Fat content of DG was a major concern before the realization that S was an issue, and still remains. Other questions, such as required mineral content, required roughage content, required degradable protein content, and ionophore levels remain unanswered. Roughage, for instance, could in theory be reduced at high DG inclusions due to the reduced starch load. However, anecdotal data from our U of M research feedlot, as well as anecdotes from consulting feedlot nutritionists, have indicated that increased dietary roughage may be needed at high dietary DG concentrations, even when dietary S content may not be an issue.

These questions exist, and need to be addressed to further increase the amount of DG that are utilized in feedlot rations.

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Notes