Interaction of corn processing and distillers dried grains with solubles on health and performance of steers

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Introduction

One challenge with using ethanol co-products is the potential for sulfur-induced polioencephalomalacia (PEM) in ruminants (Gould, 1998). Research has demonstrated that lambs fed diets containing 60 percent dried distillers grains with solubles (DDGS) did not develop PEM (Neville et al., 2010) and performed similar to those fed lesser concentrations of DDGS (Schauer et al., 2008). Schauer et al. (2008) and Neville et al. (2010) provide evidence that use of DDGS can be increased in lamb finishing rations. Differences in lamb and beef cattle responses to high sulfur (S) diets require additional research.

Average utilization of DDGS in the beef feedlot industry is 16.5 percent (Vasconcelos and Galyean, 2007); this is lower than the 20-30 percent inclusion rate suggested to optimize ADG and G:F (Klopfenstein et al., 2008). The reason for the low DDGS inclusion rate in beef feedlot diets could be economic or, more likely, a result of negative connotations with feeding co-products (i.e. sulfur content). Feeding 60 percent DDGS results in exceeding the maximum tolerable level of dietary S (0.3%; NRC, 2005).

Neville et al. (2010) demonstrated that lambs can be fed a greater S concentration than recommended by NRC (2005). Our hypothesis was that feeding combinations of DDGS and either dry-rolled corn (DRC) or high-moisture corn (HMC) with dietary S content exceeding 0.3 percent S will not result in incidence of PEM. We further hypothesized that feeding high-moisture corn in combination with DDGS will increase ruminal hydrogen sulfide (H_2S) gas concentrations over those found when feeding DDGS with dry-rolled corn. Admittedly, animal performance may suffer due to decreased palatability and intake as the concentration of DDGS increases. However, the economic benefit from decreased feed costs may warrant such feeding practices.

The objective of this study was to evaluate the influence of feeding increasing concentrations of DDGS and corn processing method (high-moisture vs. dry-rolled corn) on animal performance, incidence of PEM, and concentration of ruminal H_2S in feedlot steers.

Materials and Methods

All animal care and handling procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee prior to the initiation of the research. Seventy-two mixed breed steer calves (750 ± 27 lbs) were utilized in a completely random design with a 3 x 2 factorial arrangement of treatments to evaluate the outlined objective. Animals were assigned to treatment at the time of arrival. Main effects included concentration of DDGS (20, 40, or 60% DM basis) and corn processing method [high-moisture (HMC) vs. dry-rolled corn (DRC)] resulting in treatments of (1) 20 percent DDGS with DRC, (2) 40 percent DDGS with DRC, (3) 60 percent DDGS with DRC, (4) 20 percent DDGS with HMC, (5) 40 percent DDGS with HMC, and (6) 60 percent DDGS with HMC.

Treatment diets were formulated to meet or exceed dietary nutrient requirements for steers weighing 715 pounds and gaining 3.2 pounds daily (NRC, 2000; Table 1). The dietary treatments were formulated to have minimum Ca to P ratio of 1:1. Diets were formulated to provide 150 mg/hd/d thiamin based on an estimated DMI of 22 pounds; actual thiamin provided was 135.5 mg/hd/d. Prior to initiation of this study steers were vaccinated for clostridial and respiratory diseases and dewormed.

Table 1. Ingredient and nutritional composition of final finishing diets fed to steers.

	Dry-rolled Corn			High-moisture Corn		
Item	20% DDGS	40% DDGS	60% DDGS	20% DDGS	40% DDGS	60% DDGS
Ingredient %						
Alfalfa Hay	5.0	5.0	5.0	5.0	5.0	5.0
Corn Silage	10.0	10.0	10.0	10.0	10.0	10.0
Corn[1]	58.2	38.2	18.2	58.2	38.2	18.2
DDGS[2]	20.0	40.0	60.0	20.0	40.0	60.0
CSB[3]	5.0	5.0	5.0	5.0	5.0	5.0
Supplement[4]	1.8	1.8	1.8	1.8	1.8	1.8
Nutrient composition % (analyzed)						
CP	15.9	20.8	22.6	16.1	19.6	23.0
NDF	25.5	30.1	31.7	24.6	27.6	30.9
ADF	7.7	8.8	8.6	7.8	8.5	8.5
Ca	1.1	0.9	0.7	0.9	0.9	0.7
P	0.6	0.7	0.9	0.5	0.7	0.8
S	0.6	0.7	0.9	0.6	0.7	0.9
Cu	0.003	0.003	0.002	0.003	0.003	0.003
Zn	0.01	0.1	0.1	0.1	0.1	0.1

[1]Corn fed either as dry-rolled corn or high-moisture corn.
[2]DDGS = distillers dried grains plus solubles.
[3]CSB = concentrated separator byproduct.
[4]Supplement contained (%, total ration, DM basis): limestone 1.7%; vitamin A, D, and E premix 0.02% [Trouw Nutrition, Highland, IL (1,500,000 IU vitamin A, 500,000 IU vitamin D, and 500 IU vitamin E)]; Rumensin 0.02% (176 g/kg monensin, Elanco Animal Health, Indianapolis, IN); Trace mineral premix 0.05% [Hubbard Feeds Inc., Mankato, MN (3.95% Ca, 2.56% Cu, 16.0% Zn, 4.0% Mn, 1,050 mg/kg I, and 250 mg/kg Co)]; 0.002% thiamin (analyzed concentration 13.55 mg/kg dietary DM).

Steers were trained to use the Calan Broadbent Feeding System (American Calan, Northwood, NH) prior to adaptation to finishing diets. During this training phase steers were fed a diet consisting of 50 percent corn silage, 25 percent alfalfa hay, 25 percent dry-rolled corn (DM basis). Steers were maintained on this diet until day 0 at which time adaptation to final finishing diets began. Neither the receiving diet nor the training diet contained DDGS.

Ruminal H_2S gas concentrations were measured via rumen puncture during the adaptation to the finishing diets and throughout the finishing phase. Collection of rumen gasses occurred 5 hours after feed was offered. Hydrogen sulfide measurements were collected on day 0, 7, 14, 21, 28, 35, 49, 63, and 91; final finishing diets were provided on day 28. On day 0, steers began the dietary adaptation period which increased the concentrate portion of the diet to 85 percent over 28 days (Table 2). Adaptation diets increased the amount of concentrate (corn and DDGS) while reducing the amount of corn silage and alfalfa hay. Steers were then given a single 10 ml injection of penicillin to prevent infection after conclusion of the gas sampling procedure.

Table 2. Final finishing ration and adaptation diets (%, DM basis) fed to steers.

	Stage of Adaptation				
Diet	Step 1	Step 2	Step 3	Step 4	Step 5
Day	0	7	14	21	28
20% DDGS					
Alfalfa Hay	20.0	16.3	12.5	8.8	5.0
Corn Silage	40.0	32.5	25.0	17.5	10.0
DDGS[1]	--	5.0	10.0	15.0	20.0
Corn[2]	33.2	39.4	45.7	51.9	58.2
CSB[3]	5.0	5.0	5.0	5.0	5.0
Supplement[4]	1.8	1.8	1.8	1.8	1.8
40% DDGS					
Alfalfa Hay	20.0	16.3	12.5	8.8	5.0
Corn Silage	40.0	32.5	25.0	17.5	10.0
DDGS[1]	--	10.0	20.0	30.0	40.0
Corn[2]	33.2	34.4	35.7	36.9	38.2
CSB[3]	5.0	5.0	5.0	5.0	5.0
Supplement[4]	1.8	1.8	1.8	1.8	1.8
60% DDGS					
Alfalfa Hay	20.0	16.3	12.5	8.8	5.0
Corn Silage	40.0	32.5	25.0	17.5	10.0
DDGS[1]	--	15.0	30.0	45.0	60.0
Corn[2]	33.2	29.4	25.7	21.9	18.2
CSB[3]	5.0	5.0	5.0	5.0	5.0
Supplement[4]	1.8	1.8	1.8	1.8	1.8

[1]DDGS = distillers dried grains plus solubles.
[2]Corn fed either as dry-rolled corn or high-moisture corn.
[3]CSB = concentrated separator byproduct.
[4]Supplement contained (%, total ration DM basis): limestone 1.7%; vitamin A, D, and E premix 0.02% [Trouw Nutrition, Highland, IL (1,500,000 IU vitamin A, 500,000 IU vitamin D, and 500 IU vitamin E)]; Rumensin 0.02% (176 g/kg Monensin, Elanco Animal Health, Indianapolis, IN); Trace mineral premix 0.05% [Hubbard Feeds Inc., Mankato, MN (3.95% Ca, 2.56% Cu, 16.0% Zn, 4.0% Mn, 1,050 mg/kg I, and 250 mg/kg Co)]; 0.002% thiamin (analyzed concentration 13.55 mg/kg dietary DM).

Two-day body weights were collected at arrival (day -28), beginning of dietary adaptation (day 0), beginning of the finishing phase (day 28), and the conclusion of the study. Intermediate weights were collected every 28 days as single-day weights to monitor animal performance (data not presented). Steers received a single implant containing 80 mg trenbolone acetate and 16 mg estradiol (Revalor-IS, Intervet Inc., Millsboro, DE) on day 28. Feed offered was recorded daily with feed refusals collected, weighed, and sampled weekly. Weekly feed samples were collected to determine dietary DM and nutrient composition. Average daily gain and G:F were calculated based on these data. Carcass characteristics were collected by trained personnel 24 hours after slaughter. Liver scores were recorded with evaluation based on procedures outlined by Brink et al. (1990).

Results

The day × corn processing × DDGS concentration interaction for hydrogen sulfide gas concentrations was not significant ($P = 0.91$). Ruminal H_2S concentration was affected by increasing DDGS concentration in the diet ($P < 0.001$) and day ($P < 0.001$), but not by corn processing method ($P = 0.94$). No differences in H_2S concentration among treatments were observed on days 0, 7, 14, or 21 ($P \geq 0.14$; Figure 1). On day 28, steers fed 60 percent DDGS had greater ($P \leq 0.006$) H_2S concentrations than those fed either 20 or 40 percent DDGS. Hydrogen sulfide concentration increased ($P < 0.001$) from day 28 to day 91 for steers fed 60 percent DDGS. Steers fed 60 percent DDGS had the greatest concentrations of H_2S on day 91 ($P \leq 0.01$). Hydrogen sulfide concentrations were either static ($P = 0.68$) or tended to decrease ($P = 0.08$) for steers fed 20 or 40 percent DDGS, respectively, from day 49 to day 91.

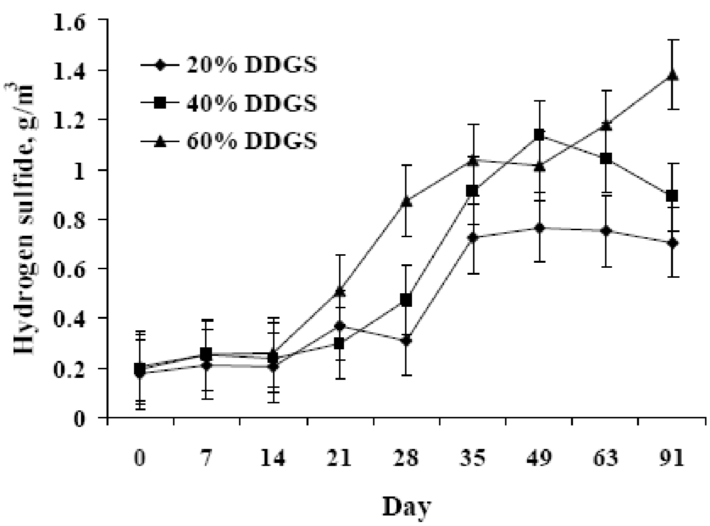

Figure 1. Change in hydrogen sulfide concentration (g/m^3) caused by increasing dietary DDGS (DDGS) concentration in steers over adaptation from a medium-concentrate to high-concentrate finishing ration. Treatments were based concentrations of DDGS (20, 40, and 60% DM basis) as well as corn processing (high-moisture vs. dry-rolled corn). P values: corn processing ($P = 0.94$), DDGS ($P < 0.001$), and corn processing by DDGS ($P = 0.36$). Concentrations of hydrogen sulfide gas measured via rumenocentesis on hydrogen sulfide detector tubes (Gastec©, Kanawaga, Japan).

Results for steer performance are reported in Table 3. There were no corn processing and DDGS concentration interactions ($P \geq 0.12$). Furthermore, there was no effect of corn processing ($P \geq 0.14$). Therefore the effects will be discussed as either linear or quadratic responses to increasing DDGS concentration. There were no differences in initial BW ($P \geq 0.82$) due to DDGS inclusion with steers averaging 748 ± 26.4 pounds. Performance data was partitioned into adaptation (day 0 - 28) and finishing (day 29 - end). During the adaptation phase there were no differences in ADG, DMI, or G:F for DDGS concentration ($P \geq 0.35$). During the finishing phase ADG and DMI decreased quadratically ($P \leq 0.02$) while G:F decreased linearly ($P = 0.01$) with increasing concentration of DDGS in the diet. As a result of decreased ADG, final BW decreased linearly ($P = 0.002$) with increasing DDGS inclusion.

Table 3. Influence of corn processing and concentration of distillers dried grains plus solubles (DDGS) on animal performance of steers.

	Dry-rolled Corn			High-moisture Corn				P value[1,2]			
Item	20% DDGS	40% DDGS	60% DDGS	20% DDGS	40% DDGS	60% DDGS	SEM[3]	Corn	DDGS	L	Q
Initial BW, lb	761	750	761	750	752	750	28.6	0.76	0.97	0.96	0.82
Final BW, lb	1372	1336	1289	1358	1396	1233	31.1	0.52	0.004	0.002	0.16
Adaptation[4]											
ADG, lb	4.0	4.0	3.8	3.8	4.0	4.0	0.22	0.87	0.64	0.91	0.35
DMI, lb	24.5	26.0	25.6	25.1	25.4	25.6	0.84	0.97	0.41	0.29	0.42
G:F	0.16	0.16	0.15	0.14	0.16	0.16	0.01	0.70	0.77	0.74	0.51
Finishing[5]											
ADG, lb	4.4	4.2	3.1	4.4	4.0	2.6	0.22	0.14	<0.001	<0.001	0.02
DMI, lb	24.3	23.2	18.7	23.8	22.5	17.2	0.88	0.23	<0.001	<0.001	0.01
G:F	0.18	0.18	0.17	0.18	0.17	0.15	0.01	0.35	0.03	0.01	0.36

[1]P values for effect of corn processing, concentration of DDGS, and linear or quadratic effect of DDGS.
[2]DDGS x corn processing interaction (P ≥ 0.17); thus main effects of corn processing and DDGS inclusion are presented.
[3]n = 11, 12, 10, 12, 11, and 12, respectively.
[4] Adaptation measured from day 0 through day 28.
[5] Finishing measured from day 29 through slaughter.

Similar to steer performance, corn processing and DDGS concentration interactions were not affected (P ≥ 0.12) and corn processing had no affect (P ≥ 0.35) on carcass characteristics of steers. Carcass composition reflected the decrease in final BW with a linear decrease in hot carcass weight (HCW) (P = 0.006) as well as a linear decrease in fat depth (P = 0.005) with increasing concentration of DDGS in the diet. As a result of decreased backfat thickness, yield grade decreased linearly (P = 0.01) with increasing DDGS inclusion. Marbling score was unaffected by corn processing (P = 0.46) and DDGS concentration (P = 0.82) with an average marbling score of 477 ± 33.6 (Small^0 = 400). Further, KPH, ribeye area, and quality grade were unaffected by corn processing (P ≥ 0.35) and DDGS concentration (P ≥ 0.18). Liver abscess evaluation resulted in all scores of 0 (no abscesses).

Table 4. Influence of corn processing and concentration of distillers dried grains plus solubles (DDGS) on carcass quality of steers.

	Dry-rolled Corn			High-moisture Corn				P value [1,2]			
Item	20% DDGS	40% DDGS	60% DDGS	20% DDGS	40% DDGS	60% DDGS	SEM[3]	Corn	DDGS	L	Q
HCW, lb	847.4	826.4	804.6	835.7	845.8	768.4	20.5	0.56	0.01	0.006	0.18
Fat depth, in	0.4	0.5	0.4	0.5	0.4	0.4	0.05	0.78	0.01	0.005	0.29
KPH, %	1.9	2.0	2.0	1.8	2.0	1.7	0.14	0.35	0.18	0.99	0.07
Ribeye area, in^2	13.2	12.8	13.1	13.0	14.0	12.9	0.38	0.40	0.56	0.86	0.29
Marbling score[4]	466	488	505	478	489	436	33.6	0.46	0.82	0.95	0.53
Quality Grade[5]	10.1	9.9	10.7	10.3	10.5	10.1	0.45	0.87	0.87	0.61	0.89
Yield Grade	3.0	3.0	2.6	3.0	2.8	2.4	0.19	0.45	0.03	0.01	0.48

[1]P values for effect of corn processing, concentration of DDGS, and linear or quadratic effect of DDGS.
[2]DDGS x corn processing interaction ($P \geq 0.12$); thus main effects of corn processing and DDGS inclusion are presented.
[3]n = 11, 12, 10, 12, 11, and 12, respectively.
[4] Marbling score based on 400 = $Small^0$.
[5]Quality Grade based on Low Choice (Ch^-) = 10, High Prime (Pr^+) = 15.

Discussion

Previous research (Leibovich et al., 2009) has reported that corn processing did not affect in vitro H_2S production. The present study demonstrates that corn processing does not affect in vivo H_2S concentrations. Unlike previous reports (Gould et al., 1997) the present study indicates that H_2S concentrations do not decrease immediately after adaptation to high-concentrate rations. One possible explanation for this is differences in acute versus chronic exposure to sulfur. Further, the results from the present study indicate that rumen microorganisms may not adapt in a way that decreases the concentration of H_2S in the rumen gases. Other work (Niles et al., 2002; Neville et al., 2010) feeding various concentrations of DDGS agree with the present study in that increasing DDGS concentration in the diet results in increased H_2S concentration in the rumen gas cap.

Corrigan et al. (2009) reported that corn processing resulted in changes in DMI, however these changes were not observed in the present study. Similar to Corrigan et al. (2009), the present study demonstrated a quadratic decrease in DMI with increasing inclusion of DDGS. It is unknown if the decreases in intake and performance in the present study are a function of decreased gut motility or sub-clinical PEM. Interestingly, Loneragan et al. (2001) concluded that while H_2S levels may not be great enough to cause toxicity they may be great enough to decrease animal growth. The results of the present study appear to support this conclusion as steer performance was impacted when greater concentrations of DDGS were fed resulting in greater H_2S concentrations. The decrease in HCW, backfat thickness, as well as yield grade for the steers fed 60 percent DDGS are understandable given the decreased performance of those animals.

During the course of this study there were no confirmed cases of PEM even though dietary S concentrations ranged from 0.6 to 0.9 percent S, which exceeds the recommended maximum tolerable level (0.3% S; NRC, 2005). These results stand in stark contrast to the recommendations of NRC (2005) and previous research (Loza et al., 2010). In the present study, one steer from the HMC with 60 percent DDGS treatment did exhibit signs of sulfur toxicity (blind staggers, lack of appetite, and lethargy: McDowell, 2000). This steer responded to treatment with thiamin injections (1 g/d thiamin hydrochloride) and recovered completely within three days; histological analysis was not conducted thus a diagnosis of PEM cannot be confirmed. Although only one case of PEM was suspected, sub-clinical cases of PEM could be one explanation for the decreased animal performance of those steers fed 60 percent DDGS. The lack of confirmed clinical PEM incidence points to a need to clearly distinguish between the maximum tolerable level and toxicity within the scientific literature.

Conclusions

The present study along with Neville et al. (2010) and Schauer et al. (2008) have consistently demonstrated that S from DDGS can be fed in excess of maximum tolerable level in both lambs and steers fed high-concentrate diets. It is possible the maximum tolerable level of sulfur (NRC, 2005) needs to be reevaluated. In addition, from a practical application standpoint, factors which may alter fermentation such as grain source, digestibility, and rate of adaptation must be considered as variables influencing sulfur toxicity in the ruminant animal and should be considered when formulating high-concentrate rations which include dried distillers grains plus solubles.

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