Sulfur balance in lambs fed increasing concentrations of distillers dried grains with solubles[1]

B. W. Neville[*], G. P. Lardy[*], K. K. Karges[‡], L.A. Kirschten[*], and C. S. Schauer[†]

[*]Department of Animal Sciences, North Dakota State University, Fargo, ND 58108

[†]Hettinger Research Extension Center, North Dakota State University, Hettinger, ND 58639

[‡]Dakota Gold Research Association, Sioux Falls, SD 57104

Sulfur balance of lambs fed increasing concentrations of DDGS was evaluated. Lambs fed 60% DDGS consumed 54% more water, excreted 300% more urine, and 480% more S in urine than lambs fed no DDGS. Understanding that S excretion increased with increasing dietary S concentrations explains, in part, why S toxicity did not occur.

[1]Partial support for the research and dried distillers grains plus solubles was provided by Dakota Gold Research Association, Sioux Falls, SD. Additionally, partial support for this research was provided by the North Dakota State Board of Agricultural Research and Education Research Fund – Animal Agriculture and Hay Committee. Any opinions, findings, conclusionts, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of Dakota Gold Research Association.

SUMMARY

Feeding increased concentrations of distillers dried grains with solubles (**DDGS**) has been implicated as a cause of S toxicity in ruminants. Elucidating the mechanism by which dietary S causes polioencephalomalacia (**PEM**) is of importance to the livestock feeding industry. Our hypothesis was that lambs fed increased concentrations of DDGS will increase S excretion to avoid toxicity. The objective of this study was to evaluate the effects of increasing dietary concentration of DDGS on S balance in lambs. Distillers dried grains inclusion did not affect DMI (3.0 ± 0.15 lb/hd/d; $P = 0.25$). Sulfur intake from feed and water, as well as S excretion in feces and urine increased linearly ($P \leq 0.009$) with increasing DDGS inclusion. Sulfur balance increased linearly ($P = 0.02$) with increasing inclusion of DDGS in finishing diets. Increasing concentration of DDGS in the diet increased S intake, excretion, and H_2S concentrations but did not result in the occurrence of PEM. This research suggests that substantial amounts of S contained within DDGS are excreted by the ruminant animal.

INTRODUCTION

Feeding increased concentrations of distillers dried grains with solubles (**DDGS**) to ruminants has been avoided due to risks of S toxicity and concerns about animal performance. High S diets can cause polioencephalomalacia (**PEM**) in ruminants (Gould, 1998). Feeding 60% DDGS can cause dietary S content to exceed the maximum tolerable level (0.3% S; NRC, 2005). However, research has demonstrated that lambs fed 60% DDGS (> 0.55% S) 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 an opportunity for increased utilization of DDGS in lamb finishing rations. Our hypothesis was that lambs fed increased concentrations of DDGS would increase excretion of S to avoid toxicity. The objective of this study was to evaluate the effects of increasing dietary concentration of DDGS on S balance in lambs.

Table 1. Ingredient and nutritional composition of diets fed to lambs

Item	Diet[1]			
	0% DDGS	20% DDGS	40% DDGS	60% DDGS
Ingredient, %	DM basis			
Alfalfa Hay	15.00	15.00	15.00	15.00
Corn	81.38	61.38	41.38	21.38
DDGS[2]	0.00	20.00	40.00	60.00
Ammonium Chloride	0.5	0.5	0.5	0.5
Limestone	2.25	2.25	2.25	2.25
Lasalocid[3]	0.085	0.085	0.085	0.085
TM package[4]	0.78	0.78	0.78	0.78
Copper Sulfate	0.002	0.002	0.002	0.002
Thiamin	0.011	0.011	0.011	0.011
Nutrient composition (analyzed)				
CP, %	14.0	19.4	22.0	24.7
NDF, %	23.7	27.6	30.6	31.8
ADF, %	10.1	11.0	11.1	11.5
S, %	0.22	0.52	0.70	0.84
Ca, %	1.72	1.64	1.35	1.16
P, %	0.50	0.65	0.77	0.81
Cu, ppm	19	19	15	17
Zn, ppm	59	95	90	73
Thiamin[5], ppm	70.8	67.2	55.5	51.5

[1] Diets were balanced to meet or exceed requirements set by (NRC, 2007). Treatments based on distillers dried grains with solubles inclusion: 1) 0% DDGS, 2) 20% DDGS), 3) 40% DDGS, 4) 60%DDGS.
[2] Distillers dried grains with solubles.
[3] Lasalocid (Bovatec 68, Alpharma Inc., Fort Lee, NJ).
[4] Trace Mineral (TM) package contained: 11.7% Ca, 10.0% P, 14% salt, 0.1% K, 0.1% Mg, 20 ppm Co, 100 ppm I, 2,450 ppm Mn, 50 ppm Se, 2,700 ppm Zn, 300,000 IU/lb Vitamin A, 30,000 IU/lb Vitamin D_3, and 600 IU/lb Vitamin E.
[5] Formulated based on estimated feed intake of 3 lb/d, amount of supplemental thiamin provided, and corrected for thiamin contained in remaining feed ingredients.

PROCEDURES

All animal care and handling procedures were approved by the North Dakota State University Animal Care and Use Committee prior to the initiation of the research.

Animals and Treatments. Sixteen western white-faced wether lambs (80.9 ± 5.1 lb) were utilized in a completely random design to evaluate the effects of increasing dietary concentration of DDGS on S balance and ruminal H_2S gas concentrations in lambs. Treatments were based on increasing concentrations of DDGS in the final finishing diet and included: 1) 0% DDGS, 2) 20% DDGS, 3) 40% DDGS, and 4) 60% DDGS. Treatment diets were formulated to meet or exceed CP and Cu requirements; NE was formulated for a lamb gaining 0.88 lb/d (NRC, 2007; Table 1). The dietary treatments were formulated to provide minimum Ca to P ratio of 1.5:1, and ammonium chloride (0.5%, DM basis) was added to all diets to aid in the prevention of urinary calculi. Thiamin was included in all diets at a concentration which would provide 150 mg/hd daily based on 3.0 lb estimated DMI.

Sulfur Balance. Lambs were adapted to stainless steal metabolism crates for 10 d prior to a 10 d collection period. Following adaptation, lambs were fitted with fecal collection bags. Urine was collected in plastic buckets. Feed intake was recorded daily, with daily adjustments made to target ad libitum intake (10% feed remaining daily). Feed refusals were weighed and sub-sampled daily. Water intake was calculated by subtracting any unconsumed water from water offered. Daily water samples were collected and analyzed (Stearns DHIA, Sauk Centre, MN) for sulfate (93 mg/L). Feed, ort, and fecal samples were dried using a forced-air oven (55°C; The Grieve Corporation, Round Lake, IL) for 48 h. Dried samples were ground using a Wiley Mill (Arthur H. Thomas Co., Philadelphia, PA) to pass a 2 mm screen. Samples were composited within lamb across the 10 d collection period. Samples were analyzed for S by a commercial laboratory (Midwest Laboratories, Omaha, NE).

RESULTS AND DISCUSSION

Sulfur Balance. In our study, level of dietary DDGS inclusion did not affect DMI (3.0 ± 0.15 lb/hd daily; $P = 0.25$; Table 2). Sulfur intake from feed and water, as well as S excretion in feces and urine increased linearly ($P \leq 0.009$) with increasing DDGS in the diet. Lambs fed 60% DDGS had water intakes 54% greater than those fed no

Table 2. Intake, excretion, and sulfur balance of lambs fed increasing concentrations of distillers dried grains with solubles

	Treatment[2]						*P*-Value[4]	
Item[1]	0% DDGS	20% DDGS	40% DDGS	60% DDGS	SEM[3]	*P*-value	Linear	Quadratic
Intake								
Feed, kg	1.3	1.5	1.4	1.3	0.07	0.25	0.68	0.06
S, mg	2,487.5	6,076.2	7,429.4	9,029.6	816.6	<0.001	<0.001	0.25
Water, L	3.1	3.5	3.7	4.8	0.28	0.006	<0.001	0.31
S, mg	94.8	109.4	115.7	148.9	8.7	0.006	0.001	0.31
Total S, mg	2,582.4	6,185.6	7,545.1	9,178.4	815.8	<0.001	<0.001	0.25
Excretion								
Fecal, kg	0.20	0.23	0.27	0.25	0.02	0.17	0.06	0.33
S, mg	761.4	947.6	1112.1	1130.5	90.6	0.05	0.009	0.37
Urine, L	0.59	0.85	1.1	2.4	0.3	0.008	0.002	0.12
S, mg	674.9	2,370.8	3,236.0	3,945.1	268.8	<0.001	<0.001	0.09
Total S, mg	1,436.3	3,318.4	4,348.0	5,075.6	344.5	<0.001	<0.001	0.12
Sulfur Balance, mg	1,146.1	2,867.2	3,197.1	4,102.8	568.0	0.02	0.004	0.49

[1] 1 kg = 2.205 lbs
[2] DDGS = Distillers dried grains with solubles.
[3] n = 4.
[4] *P*-value for linear and quadratic effects of increasing concentration of DDGS in diet.

DDGS ($P < 0.01$). Increased water intake resulted in an increase of 300% in urine volume and a 480% increase in urine S excretion ($P < 0.01$) compared to lambs fed no DDGS. Given the water intake and urine output data, ad libitum access to low sulfate water may be key to preventing S toxicity when high amounts of DDGS are fed. Sulfur balance increased linearly ($P = 0.004$) with increasing inclusion of DDGS in finishing diets. However, true S balance is not reported as the total volume of eructated H_2S, as well as S accumulation in wool and muscle were not measured. It is likely that substantial amounts of S were excreted via rumen gases through eructation. Therefore, further research is needed to quantify S excretion via H_2S gas and eructation.

IMPLICATIONS

Increasing concentration of DDGS in the diet increased S intake and excretion but did not result in the occurrence of PEM. Understanding that S excretion increased with increasing dietary S concentrations explains, in part, why S toxicity did not occur. The present study along with previous research at our institution has demonstrated that feeding up to 60% dietary DDGS concentrations is possible without affecting lamb health or performance if free access to low sulfate water is provided.

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