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Effects of increasing inclusion of sodium hydroxide treatment on growth performance, carcass characteristics, and feeding behavior of steers fed 50% DDGS[1]

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ABSTRACT: Objectives were to determine the dietary inclusion level of NaOH in a dried distillers grains with solubles (DDGS)-based diet needed to improve growth performance and carcass characteristics of feedlot steers, and to determine the effects of NaOH treatment of DDGS on pattern of feed intake. Based on previous research regarding the acidity of DDGS, we hypothesized that using NaOH in cattle fed 50% DDGS-based diets to neutralize the acidity inherent in DDGS would improve growth performance of cattle but shift intake patterns. Angus-cross steers (120 total) were blocked into 2 BW blocks (light, initial BW = 211 ± 27 kg; and heavy, initial BW = 261 ± 27 kg) and allotted randomly within block to 20 pens (6 steers per pen; $n = 30$). Pens within block were assigned randomly to 1 of 4 dietary treatments: 1) 50% DDGS, untreated; 2) 50% DDGS, treated with 0.5% NaOH (DM basis); 3) 50% DDGS, treated with 1.0% NaOH (DM basis); or 4) 50% DDGS, treated with 1.5% NaOH (DM basis). The remainder of the diets contained 20% dry-rolled corn, 20% corn silage, and 10% mineral and vitamin supplement, on a DM basis. Cattle were fed in a GrowSafe system. There were no effects ($P \geq 0.21$) of increasing NaOH inclusion on final BW, ADG, or G:F. Increasing NaOH in the diet increased meal duration (linear; $P = 0.02$) and tended to increase meal size (linear; $P = 0.06$), but did not affect overall number of meals per day (linear; $P = 0.21$) or overall DMI ($P \geq 0.40$) for the course of the trial. Relative to cattle fed DDGS treated with 0, 0.5 or 1% NaOH (DM basis), steers fed DDGS treated with 1.5% NaOH consumed a larger proportion of their meals in the afternoon. However, regardless of treatment, all steers consumed 78% or more of their feed in the first 12 h post-feeding. There were no effects ($P \geq 0.19$) of increasing NaOH inclusion on HCW, LM area, dressing percentage, KPH, back fat thickness, and marbling. There was a linear ($P = 0.02$) decrease in USDA Yield Grade (YG) 3 and a tendency ($P = 0.09$) for a quadratic response in carcasses grading USDA YG 4 as NaOH concentration increased in the diets; however, there were no other YG differences. The quality grade response followed marbling score and was not different ($P \geq 0.11$) among treatments. Thus, there were no effects of feeding DDGS treated with NaOH on growing cattle performance or carcass characteristics. However, NaOH inclusion shifted the pattern of intake slightly to the afternoon hours, and increased meal duration without increasing the total number of meals per day.

Key words: beef, dried distillers grains, feed treatment, sodium hydroxide, steers

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INTRODUCTION

As market prices fluctuate, there are instances when dried distillers grains with solubles (**DDGS**) may be a cheaper energy source for beef cattle than corn; therefore, DDGS inclusion in cattle diets tends to fluctuate with changes in corn prices (USDA, 2015). However, the inclusion of DDGS in beef rations, to optimize growth performance, is only 20% of the diet DM (Ham et al., 1994). While other factors may limit

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DDGS inclusion such as fat and N content (Gunn et al., 2009), DDGS contain sulfuric acid and, independently, S can reduce DMI, ruminal pH, and fiber digestibility in beef cattle when DDGS are fed as the majority of the dietary DM (Klopfenstein et al., 2008; Felix et al., 2012). In addition, elevation of rumen pH to 6.35 can increase DMI and improve ruminal digestibility (Leventini et al., 1990). Felix et al. (2012) observed that cattle fed DDGS that were treated with 2% NaOH prior to feeding, increased in situ NDF disappearance when compared to cattle fed DDGS with no treatment. These authors postulated this was due to NaOH neutralizing the acidity from H_2SO_4 in DDGS. However, excess Na can reduce intake (Croom et al., 1982; NRC, 2000). Although there is much research on the addition of alkaline agents to modulate ruminal fermentation parameters in cattle consuming concentrate-based diets (Boukila et al., 1995; Felix et al., 2012; Nuñez et al., 2014; Schroeder et al., 2014; Freitas et al., 2016), the optimal inclusion of alkaline treatment to mitigate the inherent acidity of DDGS-based diets and improve beef cattle growth performance and carcass characteristics is not known. We hypothesized that using NaOH in cattle fed 50% DDGS-based diets to neutralize the acidity inherent in DDGS would improve growth performance of cattle but shift intake patterns. The objectives of this trial were to determine the dietary inclusion level of NaOH in a DDGS-based diet needed to improve growth performance and carcass characteristics of feedlot steers, and to determine the effects of NaOH treatment of DDGS on pattern of feed intake.

MATERIALS AND METHODS

All animal procedures were approved by the University of Illinois Institute of Animal Care and Use Committee and followed the guidelines recommended in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 2010).

Animals and Diets

One hundred and twenty Angus-cross steers were used in a randomized complete block design and housed in a confinement barn at the University of Illinois Beef Cattle and Sheep Field Laboratory in Urbana, IL. Calves had been given at birth 1 mL Bo-Se (Merck Animal Health, Madison, NJ), 1 mL Vitamin AD (Sparhawk Laboratories, Inc., Lenexa, KS), and 30 mL Quatracon-2X (Boehringer Ingelheim Vetmedica, Inc., St. Joeseph, MO); at weaning, calves received 2 mL Bovi-Shield GOLD FP5HB (Zoetis, Parsippany, NJ), 5 mL Covexin 8 (Merck Animal Health), 2 mL Inforce 3 (Zoetis), and 2 mL autogenous mycoplasma bovis (Newport Laboratories); 28 d later, steers were given 2 mL Bovi-Shield GOLD FP5HB (Zoetis), 5 mL Covexin 8 (Merck Animal Health), and 2 mL mycoplasma bovis (American Animal Health, Inc., Grand Prairie, TX). Upon arrival to the feedlot, steers were placed in pens (4.88 × 4.88 m) constructed of 5.08 cm galvanized steel tubing with concrete slatted floors covered in 1.91 cm thick rubber matting. After 24 h, steers were boostered with 2 mL Bovi-Shield GOLD FP5HB (Zoetis), 5 mL Covexin 8 (Merck Animal Health), and 2 mL autogenous mycoplasma bovis (Newport Laboratories). Steers received the final vaccine, 5 mL Bovi-Shield GOLD FP5 VL5 HB (Zoetis), 120 d after feedlot entry. Each pen was equipped with 1 GrowSafe Feed Intake bunk (GrowSafe Systems Ltd., Airdrie, AB Canada). A 21-d transition period took place, prior to beginning the experiment, to adjust the steers to the 50% DDGS diet. Intake was controlled during this initial acclimation period to aid in transitions and avoid gastrointestinal issues. From d -21 to d -15, the transition diet was 20% hay, 30% corn silage, 20% dry rolled corn, 20% DDGS, and 10% supplement (DM basis); DM offered per head per d was between 3.6 and 4.5 kg. From d -14 to d -8, the transition diet was 10% hay, 25% corn silage, 20% dry rolled corn, 35% DDGS, and 10% supplement (DM basis); DM offered was between 4.5 and 5.4 kg. From d -7 to Day 0, the transition diet was 0% hay, 20% corn silage, 20% dry rolled corn, 50% DDGS, and 10% supplement (DM basis); DM offered was between 5.4 and 6.7 kg.

After the 21-d acclimation, steers were weighed on 2 consecutive d to determine initial BW and were blocked into 2 BW blocks (light, initial BW = 211 ± 27 kg; and heavy, initial BW = 261 ± 27 kg). Steers were stratified within block and steers within the light block were allotted to 3 pens/treatment, and steers within the heavy block were allotted to 2 pens/treatment (6 steers/pen, 20 pens total) such that pens within a block had the same average initial BW. Pens within block were randomly allotted to 1 of 4 dietary treatments: 1) 50% DDGS, untreated; 2) 50% DDGS, treated with 0.5% NaOH (DM basis); 3) 50% DDGS, treated with 1.0% NaOH (DM basis); or 4) 50% DDGS, treated with 1.5% NaOH (DM basis). The remainder of the diets, on a DM basis, were composed of 20% corn silage, 10% supplement, and 20% dry rolled corn (Table 1). A 1:2 (NaOH:H_2O) solution was mixed as 50 kg of NaOH in 100 L of tap water. For each 100 kg of DDGS, we had: no added solution for the 0% treatment; 1 L for the 0.5% treatment; 2 L for the 1.0% treatment; and 3 L for the 1.5% treatment. For each DDGS treatment, 700 kg of DDGS was treated weekly by adding the NaOH solution to DDGS and mixing in a Knight Reel Auggie 2375 mixer wagon (KUHN North America, Brodhead, WI) for 15 min. Prior to feeding, DDGS was exposed to treatment for 1 to 7 d. The DDGS was delivered from One Earth Energy, LLC (Gibson City, IL)

Table 1. Composition of diets fed to steers in feedlots, on a DM basis

	% NaOH inclusion in the DDGS			
Item	0	0.5	1.0	1.5
Ingredient, %				
Corn Silage	20.0	20.0	20.0	20.0
Dry Rolled Corn	20.0	20.0	20.0	20.0
DDGS[1]	50.0	49.75	49.50	49.25
NaOH[2]	0.0	0.25	0.50	0.75
Supplement				
Ground Corn	7.197	7.197	7.197	7.197
Limestone	2.600	2.600	2.600	2.600
Dairy TM Salt[3]	0.100	0.100	0.100	0.100
Rumensin[4]	0.017	0.017	0.017	0.017
Tylosin[5]	0.011	0.011	0.011	0.011
Vegetable Oil	0.075	0.075	0.075	0.075
Analyzed composition, %				
NDF	32.22	32.38	32.12	32.06
ADF	14.91	15.06	14.88	14.87
CP	19.26	19.20	19.23	19.14
Fat	5.95	5.79	5.80	5.75
Ca	0.836	0.838	0.837	0.837
P	0.500	0.500	0.502	0.498
S	0.213	0.214	0.215	0.214
Na	0.148	0.271	0.388	0.493

[1]DDGS (One Earth Energy, LLC; Gibson City, IL) analyzed values: DM, 85.0%; NDF, 37.7%; CP, 30.8%; EE, 8.8%; S, 0.29%; pH, 5.5. Seven loads were received during the study.

[2]NaOH was added to DDGS approximately 7 d prior to feeding.

[3]Dairy trace mineral salt (included 8.5% Ca as $CaCO_3$, 5% Mg as MgO and $MgSO_4$, 7.6% K as KCl_2, 6.7% Cl as KCl_2, 10% S as S_8, prilled, 0.5% Cu as $CuSO_4$ and Availa-4 [Zinpro Performance Minerals; Zinpro Corp, Eden Prairie, MN], 2% Fe as $FeSO_4$, 3% Mn as $MnSO_4$ and Availa-4, 3% Zn as $ZnSO_4$ and Availa-4, 278 mg/kg Co as Availa-4, 250 ppm I as $Ca(IO_3)_2$, 150 mg/kg Se as Na_2SeO_3, 2205 KIU/kg vitamin A as retinyl acetate, 662.5 KIU/kg vitamin D as cholecalciferol, 22,047.5 IU/kg vitamin E as dl-a-tocopheryl acetate, and less than 1% CP, fat, crude fiber, salt).

[4]Rumensin 90 (200 g/kg; Elanco Animal Health, Greenfield, IN).

[5]Tylosin 40 (88 g/kg; Elanco Animal Health).

in 7 loads throughout the course of the study. Average analyzed values for the DDGS were: DM, 85.0%; NDF, 37.7%; CP, 30.8%; EE, 8.8%; S, 0.29%; and pH, 5.5. While the pH was not as acidic as previous reports attempting to buffer, the treatments with NaOH, discussed below, still altered the pH from acidic to neutral. Average pH was 5.5 ± 0.12, 6.1 ± 0.15, 6.6 ± 0.10, and 7.0 ± 0.11 for 0, 0.5, 1.0, and 1.5% NaOH treatments, respectively.

The total mixed rations were offered once daily at 0900 h and steers were fed for ad libitum intakes and allowed free-access to water during the entire trial. Dietary ingredient samples were collected every 14 d to adjust for DM (24 h at 105°C; method 934.01; AOAC, 1988). In addition, subsamples of each dietary ingredient were saved every 14 d and were composited for nutrient analysis at the end of the trial (described below).

On d 0, steers were implanted with Component TE-IS (80 mg trenbolone acetate and 16 mg estradiol; Elanco Animal Health; Greenfield, IN) and on d 62 they were re-implanted with Component TE-S (120 mg trenbolone acetate and 24 mg estradiol; Elanco Animal Health). Steers were weighed every 28 d during the trial and were then weighed on 2 consecutive d at the end of the trial to determine final BW before slaughter.

Growth Performance and Carcass Characteristics

Average daily gain, DMI, and G:F were measured from d 0 to slaughter (137 d total). Feed intake was measured on individual animals using the GrowSafe system (GrowSafe Systems Ltd., Airdrie, AB Canada). Meals were counted as such when individual steer left the feed bunk for more than 2 min prior to returning. All steers were weighed off test when the average back fat thickness of the group was 1.2 cm, estimated by ultrasound scan. Steers were hauled approximately 300 km to a commercial harvest facility (Tyson Foods, Joslin, IL) and were humanely slaughtered under USDA inspection. Hot carcass weight (HCW) and dressing percentage (**DP**) were recorded on the day of slaughter. Carcasses were chilled for approximately 24 h at -4°C. After, they were ribbed between the 12th and 13th ribs to determine subcutaneous back fat thickness (**BF**), LM area, marbling scores, KPH, and USDA Yield and Quality Grades via USDA grading cameras. Two steers from different treatments were removed from the study for health issues not related to dietary treatment.

Sampling and Analysis

Composited feed ingredient samples were lyophilized (12 L FreeZone, Labconco, Kansas City, MO) and ground through a 1 mm Wiley mill (Thomas Scientific, Swedesboro, NJ). Feed ingredients were analyzed for ADF and NDF (using Ankom Technology method 5 and 6, respectively; Ankom^{200} Fiber Analyzer, Ankom Technology, Fairport, NY; Ankom Technology, 2014), CP (Leco TruMac, LECO Corporation, St. Joseph, MI), fat (Method 2; Ankom Technology, 2014), and total ash (method 942.05: AOAC; 500°C for 12 h, HotPack Muffle Oven Model: 770750, HotPack Corp., Philadelphia, PA). Feed ingredients were also subjected to perchloric acid digestion and inductively coupled plasma atomic emission spectroscopy (Prodigy Dual View ICP; Teledyne Leman Labs; Hudson, NH) analysis of complete minerals (method 975.03; AOAC, 1988). The 4 DDGS samples treated with increasing levels of NaOH were analyzed for pH every 14 d during the experiment, using an Accumet Basic AB15 pH meter with an Accumet accuCap glass body, gel-filled electrode (Fisher Scientific,

Table 2. Growth performance of beef steers fed 50% DDGS-based diets with increasing NaOH concentration[1]

	% NaOH inclusion in the DDGS[2]					*P*-value[3]	
Item	0	0.5	1.0	1.5	SE	Linear	Quadratic
n, steers	30	29	30	29	–	–	–
Initial BW, kg	318	319	321	319	3.7	0.73	0.60
Final BW, kg	601	606	616	609	6.8	0.27	0.35
ADG, kg	2.07	2.10	2.15	2.12	0.036	0.21	0.36
DMI, kg·d^{-1}	12.60	12.77	12.89	12.82	0.22	0.40	0.57
G:F[4]	0.165	0.165	0.167	0.166	0.003	0.61	0.78

[1]Days on feed was 137 for all animals.

[2]DDGS = dried distillers grains with solubles.

[3]Orthogonal polynomial contrasts for increasing NaOH inclusion in the diets.

[4]G:F is calculated as ADG/DMI.

Pittsburgh, PA), and titratable acidity. Fifty g of DDGS sample was mixed with 200 mL of distilled water for 30 s before the pH electrode was submersed in the mixture and pH was recorded.

Statistical Analysis

The experimental design was a randomized complete block design. Any animal removed from the experiment was excluded from statistical analysis. Animal performance and carcass characteristics were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Carcass yield and quality grade distributions were compared using the GLIMMIX procedure of SAS. The model used for all the aforementioned parameters was:

$$Y_{ijk} = \mu + B_i + T_j + e_{ijk}$$

where Y_{ijk} = response variable; μ = mean; B_i = the fixed effect of block; T_j = the fixed effect of NaOH inclusion; e_{ijk} = the experimental error. Steer was the experimental unit, and single-degree-of-freedom polynomial contrasts were used to detect linear and quadratic effects of increasing NaOH inclusion in the diets on dependent variables. Differences were declared significant at $P \leq 0.05$. Trends, where discussed, were declared at $0.05 < P < 0.10$.

RESULTS AND DISCUSSION

We hypothesized that adding NaOH to DDGS prior to feeding would reduce acid load in the rumen, by neutralizing the H_2SO_4 in DDGS, and improve growth performance of steers. However, no differences ($P \geq 0.21$) were observed in final BW, ADG, DMI, or G:F as the concentration of NaOH in the diets was increased (Table 2). Morrow et al. (2013) observed that when lambs were fed 2% NaOH treated DDGS on 60% DDGS-based diets, there was a significant increase (greater than 4%) in final BW and tendency for greater ADG and DMI for lambs fed diets containing DDGS treated with NaOH compared to lambs fed DDGS that had not been treated. However, no difference for G:F in lambs was reported (Morrow et al., 2013).

Similar to the results from the current trial, Schroeder et al. (2014) observed no differences in ADG or final BW when steers were fed 0% and 1.2% CaO-treated dry or modified wet DGS; however, CaO treatment reduced DMI and increased G:F regardless of DGS type. This is similar to previous research by Nuñez et al. (2014) where steers fed diets containing 60% DDGS had a linear reduction in DMI with increasing dietary CaO, up to 2.4% of the diet DM. In all of the previous reports, the authors attempt was to alleviate ruminal acid load by treating the acidic DGS with an alkaline agent.

Boukila et al. (1995) attempted to alleviate ruminal acid load by feeding sheep barley-based diets treated with alkalizing agents [1% $Ca(OH)_2$, 0.79% $Mg(OH)_2$, and 0.5% $Ca(OH)_2$ 0.39% $Mg(OH)_2$] and reported an increase ($\geq$ 35%) in DMI, with all agents, when compared to sheep fed the control diet that had not been treated.

When DMI can be increased, ADG often increases as well because cattle are consuming more energy. In our trial, there was no effect on DMI and subsequently no effect on ADG or G:F. Nuñez et al. (2014) reported a quadratic response for ADG when cattle were fed 0, 0.8, 1.6, or 2.4% CaO, with the greatest gain in those fed the DDGS treated with 0.8% CaO. However, Nuñez et al. (2014) also pointed out that in 60% DDGS-based diets, the linear G:F increased up to 2.4% CaO inclusion on a DM basis. These authors attributed the increased G:F to the linear reduction in DMI with increasing CaO concentrations discussed above. Felix and Loerch (2011) did not treat DDGS, but fed 60% DDGS-based diets added with alfalfa haylage and observed that cattle fed the added forage had increased ruminal pH and greater DMI and ADG when compared to those fed diets without additional alfalfa haylage.

Feeding DDGS as an energy source can significantly reduce ruminal pH and performance in cattle (Klopfenstein et al., 2008; Felix and Loerch, 2011; Felix

Table 3. Pattern of intake and meal distribution of steers fed 50% DDGS-based diets with increasing NaOH inclusion[1]

	% NaOH inclusion in the DDGS[2]					*P*-value[3]	
Item	0	0.5	1.0	1.5	SE	Linear	Quadratic
Meals per day	14.97	15.06	14.49	14.45	0.39	0.21	0.85
Meal size, kg	0.85	0.85	0.90	0.90	0.03	0.06	0.92
Meal Duration, min[4]	6.98	7.06	7.66	7.72	0.27	0.02	0.97
Percentage of meals consumed							
0–3h[5]	29.9	29.8	30.8	27.9	0.52	< 0.01	< 0.01
3–6h	16.6	16.7	18.1	17.0	0.32	0.06	0.05
6–9h	19.2	19.6	20.2	19.6	0.32	0.20	0.07
9–12h	15.5	14.3	12.8	13.9	0.38	< 0.01	< 0.01
12–15h	6.2	6.2	6.0	7.4	0.25	< 0.01	< 0.01
15–18h	3.5	3.8	3.1	3.8	0.18	0.69	0.21
18–21h	3.1	3.6	3.8	5.1	0.25	< 0.01	0.10
21–24h	6.1	6.1	5.2	5.3	0.30	0.02	0.90

[1]Each pen was equipped with 1 GrowSafe Feed Intake bunk (GrowSafe Systems Ltd., Airdrie, AB Canada).

[2]DDGS = dried distillers grains with solubles.

[3]Orthogonal polynomial contrasts for increasing NaOH inclusion in the diets.

[4]Average meal event duration.

[5]Values reported as a percentage of total meals.

et al., 2012). Initially these authors theorized these effects were caused by excessive S intake, which reduces DMI and causes polioencephalomalacia (Gould, 1998). When ruminal pH is acidic, increasing dietary S intake can increase ruminal concentrations of H2S (Gould et al., 1997), which is also negatively correlated to DMI and feed efficiency (Uwituze et al., 2011). According to NRC (2000), the recommended dietary concentration of S for growing and finishing cattle is 0.15%, and the maximum tolerated concentration is 0.40%. The S concentrations in the current study were less than 0.215% for all diets (Table 1). These values are almost half of the maximum tolerated concentrations, and, therefore, not likely to cause any health issue, or even decrease DMI.

The lack of differences noted in the present trial may be attributed to the palatability issues associated with alkaline agents. Schroeder et al. (2014) analyzed the pattern of intake in cattle fed of dry or modified wet DGS with 0 or 1.2% CaO treatment and observed that cattle fed CaO-treated DGS stood at the bunk longer but ate smaller meals more distributed throughout the day. They suggested this pattern of longer, smaller meals was indicative of reduced palatability due to the CaO treatment. In the present trial, increasing NaOH in the diet increased (linear; $P = 0.02$) meal duration and tended (linear; $P = 0.06$) to increase meal size, but ultimately did not affect overall number of meals per day ($P = 0.21$; Table 3). Relative to cattle fed DDGS treated with 0, 0.5 or 1% NaOH (DM basis), steers fed DDGS treated with 1.5% NaOH consumed a larger proportion of their meals in the evening, 12 to 24 h post-feeding. However, regardless of treatment, all steers consumed 78% or more of their feed in the first 12 h post-feeding. Previous research has explained that acidosis is often associated with a large meal, and could be mitigated by altering animal intake in a way that smaller, more frequent meals are consumed (Britton and Stock, 1987; Pritchard and Knutsen, 1995). Felix et al. (2012) noted increased ruminal pH in cattle fed 60% DDGS-based diets treated with 2% NaOH prior to feeding and suggested that NaOH could be used as a means to mitigate acidosis in cattle fed DDGS-based diets. While differences in meal duration and distribution were strong enough to elicit statistical significance in this trial, a 1 to 2% unit change in meal distribution is not likely to be biologically relevant in the mitigation of acidosis. In addition, Freitas et al. (2016), feeding the same diets as the current experiment, did not observe differences in ruminal pH or fiber disappearance/apparent digestibility among cattle fed 50% DDGS-based diets with increasing concentrations of NaOH.

We had hypothesized that treating DDGS with increasing levels of NaOH would neutralize DDGS acidity, which subsequently could enhance fiber fermentation (Felix et al., 2012) and increase energy supply to these steers (Klopfenstein et al., 2008), thereby increasing HCW. However, similar to the responses observed for growth performance, feeding steers increasing dietary inclusions of NaOH did not affect ($P \geq 0.19$) HCW, LM area, dressing percentage, KPH %, fat thickness, and marbling (Table 4). Similarly, Nuñez et al. (2014) observed that HCW, LM area, fat thickness, or marbling of steers fed 60% DDGS-based diets with increasing levels of CaO did not differ among treatments. In that trial, there was a linear decrease for

Table 4. Carcass characteristics of steers fed 50% DDGS-based diets with increasing NaOH inclusion

	% NaOH inclusion in the DDGS[1]					*P*-value[2]	
Item	0	0.5	1.0	1.5	SE	Linear	Quadratic
n, steers	30	29	30	29	–	–	–
HCW, kg	371	376	381	378	4.75	0.19	0.38
LM area, cm^2	85.0	82.9	85.6	85.9	1.53	0.41	0.42
Dressing %[3]	61.58	61.89	61.79	62.00	0.295	0.38	0.87
KPH %	2.07	2.06	2.08	2.00	0.037	0.25	0.32
Back fat, cm	1.62	1.70	1.64	1.61	0.075	0.79	0.43
Marbling score[4]	455	455	436	431	15.919	0.19	0.89

[1]DDGS = dried distillers grains with solubles.

[2]Orthogonal polynomial contrasts for increasing NaOH inclusion in the diets.

[3]Dressing percentage was calculated by dividing hot carcass weight by final body weight.

[4]For marbling score: 300 to 399 = slight; 400 to 499 = small; 500 to 599 = modest.

KPH and a quadratic response for dressing percentage; however, authors did not explain those responses.

Freitas et al. (2016), feeding the same diets as this current experiment, observed no difference in acetate or propionate concentrations nor difference in ruminal fiber disappearance or fiber apparent digestibility as NaOH inclusion increased in the diets. Propionate can be converted to glucose, which is a precursor for marbling (Smith and Crouse, 1984), and cattle fed increasing concentration of DDGS in the diet can have increasing molar concentrations of propionate in the rumen (Felix et al., 2012). However, increased dietary inclusion of DGS have also been associated with decreasing marbling scores in cattle (Klopfenstein et al., 2008; Gunn et al., 2009; Schoonmaker et al., 2010; Luebbe et al., 2012). In this current study, with 50% DDGS-based diets, marbling scores among treatments were similar to studies that fed feedlot steers corn-based diets with no or low DGS (Schoonmaker et al., 2002; Koger et al., 2010; May et al., 2011). As expected, Quality Grade response followed marbling score (Table 4) and was not different (linear; $P \geq 0.11$; Table 5) among treatments. Similar to this current study, no difference in USDA Quality Grade was observed when researchers treated DDGS with CaO prior to feeding (Nuñez et al., 2014; Schroeder et al., 2014). However, there was a tendency for decreased proportion of carcasses grading USDA Select when feedlot steers were fed 60% DDGS-based diets added with alfalfa haylage (Felix and Loerch, 2011).

Yield Grade, an important estimate of carcass cutability or percentage of retail product, is calculated, or subjectively determined, based on back fat, KPH, HCW, and LM area. Because there was no difference in any of the aforementioned characteristics according to the dietary treatments, it would be reasonable not to have differences in USDA Yield Grade. However, there was an unexpected linear ($P = 0.03$) decrease in carcasses

Table 5. USDA Grades for carcasses from steers fed DDGS-based diets with increasing NaOH inclusion

	% NaOH inclusion in the DDGS[1]					*P*-value[2]	
Item	0	0.5	1.0	1.5	SE	Linear	Quadratic
n, steers	30	29	30	29	–	–	–
USDA yield grade[3]							
1, %	6.7	0.0	0.0	6.9	1.70	1.00	0.98
2, %	20.0	20.7	33.3	34.5	3.40	0.11	0.79
3, %	70.0	58.6	50.0	41.4	5.30	0.03	0.84
4, %	3.3	20.7	16.7	17.2	3.31	0.15	0.09
5, %	0.0	0.0	0.0	0.0	0.00	1.00	1.00
USDA Quality grade[4]							
Prime, %	6.7	0.0	3.3	3.4	1.18	0.98	0.98
Choice, %	66.7	79.3	63.3	62.1	3.41	0.42	0.38
Select, %	16.7	13.8	26.7	31.0	3.52	0.11	0.64
Dark cutters, %	6.7	6.9	6.7	3.4	0.73	0.59	0.65

[1]DDGS = dried distillers grains with solubles.

[2]Orthogonal polynomial contrasts for increasing NaOH inclusion in the diets.

[3]Carcass Yield Grade was calculated (USDA, 1997).

[4]Treatment 0 had 1 animal that was qualified as Bloodshot, which corresponds to 3.3%.

grading USDA Yield Grade 3 and a tendency ($P = 0.09$) for a quadratic response in carcasses grading USDA Yield Grade 4 as NaOH concentration increased in the diets (Table 5). The reasons for these responses are not clear. Similar to the carcass characteristics observed in this current study, no differences in yield grade of steers have been observed when trying to diminish ruminal acid load in other studies (Felix and Loerch, 2011; Nuñez et al., 2014; Schroeder et al., 2014).

Our hypothesis was that increasing NaOH concentration in the DDGS prior to feeding would alleviate its inherent acidity, which subsequently could improve fiber utilization and growth performance of steers. However, treating DDGS acidity with increasing levels of NaOH up to 1.5% did not improve growth performance or carcass characteristics in this study. The lack of NaOH effect was likely due to the less of acidic (pH = 5.5) DDGS fed, relative to previous trials (some citing pH as acidic as 3.2; Felix and Loerch, 2011). Changes in acidity of DDGS from plant to plant production could have significant impacts on the feeding value of DDGS. Routine pH analysis, prior to use DGS, is necessary to determine the impact alkaline agents may have in preventing ruminal acidosis and improving feedlot growth performance.

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