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Summary

A study was conducted to determine the effects of feeding varying concentrations of dried distillers grains with solubles (DDGS) to finishing steers on feedlot performance, nutrient management, and odorant emissions. Prior to initiation of the trial, 192 steers (initial BW = 826 ± 18 lb) were blocked by receiving date, weighed, and randomly allotted to 16 dirt floor pens (48.2 ft x 113.8 ft; 5% slope). Pens were then randomly assigned to one of four dietary treatments. The control diet (CON) contained 82% cracked corn, 10% alfalfa hay, 4% molasses, 3.2% supplement, and 0.8% urea. In the remaining three treatment diets, all of the urea and portions of the cracked corn were removed and replaced with DDGS at 15% (15% DDGS), 25% (25% DDGS), and 35% (35% DDGS) of the diet DM. The diets were formulated to be isocaloric and to provide similar levels of crude protein (CP) for CON and 15% DDGS (13.2 and 13.3% CP, respectively) and a stepwise increase in CP for 25% and 35% DDGS (15.4 and 17.6%, respectively). Analysis of weekly feed samples collected throughout the trial determined that the CP concentrations were 11.4, 12.2, 14.3, and 16.5% for CON, 15% DDGS, 25% DDGS, and 35% DDGS, respectively.

Cumulative dry matter intake (DMI) was greater ($P < 0.05$) and ADG tended ($P < 0.10$) to be greater for cattle consuming the 25% DDGS treatment compared to CON with 15% DDGS and 35% DDGS being intermediate (DMI = 23.7, 24.1, 24.8 and 24.1 lb/d and ADG = 4.25, 4.39, 4.55, and 4.45 lb for CON, 15%, 25%, and 35% DDGS, respectively). Dry matter intake responded quadratically ($P < 0.05$) as the level of DDGS in the diet increased. Steers fed DDGS also tended to consume more dry matter than steers fed the control diet ($P < 0.07$). There were no differences in final weight between treatments.

Dressing percent and backfat increased ($P < 0.05$) and hot carcass weight and yield grade tended ($P < 0.10$) to increase in a linear fashion as level of DDGS in the diets increased. No differences were detected between treatments for marbling, kidney, pelvic, and heart fat, or ribeye area.

Air samples were collected via wind tunnel at 3 locations per pen over a 3-d period prior to animal introduction and on d 78 to 80. Hydrogen sulfide levels were greatest ($P < 0.05$) in pens containing cattle fed the 35% DDGS treatment compared to pens with cattle consuming the remaining treatments. No differences in odor characteristics were detected between treatments.

Pen floor core samples (7 per pen) were taken prior to animal introduction and upon completion of the trial. No differences were found for nitrogen (N), phosphorus (P), potassium, organic matter, pH or salt concentrations. Manure samples collected from pens scrapings were weighed and analyzed for dry matter, ammonia-N, Kjedahl-N, and Olsen-P. Ammonia-N and Olsen-P increased in a linear fashion ($P < 0.05$) as the levels of DDGS in the diets increased.

Dried distiller's grains with solubles can be included in feedlot finishing diets at up to 35% of DMI without negatively affecting performance. However, animal performance is maximal when DDGS is included at 25% of DMI. Changes in carcass characteristics with increasing DDGS levels may affect days on feed needed to reach

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optimum terminal endpoint. Hydrogen sulfide emissions from pen floors may increase as the level of DDGS in the diet increases. However, when the feedlot is the sole source of H_2S, the impact of increased H_2S on odor or human health is negligible. General odor detection is not affected by feeding DDGS.

Introduction

Distillers grains are becoming increasingly more prevalent as a feed ingredient in the diets of growing and finishing cattle. Previous research suggests that DDGS can substitute for corn in finishing diets, up to approximately 20% of the diet DM, without sacrificing animal performance.

Gordon et al. (2002), in a heifer feeding experiment utilizing DDGS levels of 0, 15, 30, 45, 60, and 75%, found that average daily gain, feed efficiency, and dry matter intake all peaked in the 15% DDGS treatment and declined as the level of DDGS increased to 75%. Hot carcass weights of heifers fed by Gordon et al. (2002) peaked at 15% DDGS and decreases as the level of DDGS increased. Mateo et al. (2004) reported no differences in HCW or dressing percentage in cattle fed 20 and 40% DDGS rations, but marbling scores were greater from steers fed 20% DDGS compared to those fed 40% DDGS.

Odor has become, and will continue to be, an issue of concern for livestock operations. Unfortunately, odor is difficult to quantify in practice. Dose-response relationships have been recognized for ammonia, hydrogen sulfide (H_2S), and dust as potentially detrimental to human health (Nicolai and Pohl, 2005).

Additionally, H_2S can be detected by the human nose at levels as low as 0.5 ppb (Tamminga, 1992).

Manure has been and should continue to be utilized as a fertilizer and soil amendment. However, crops require approximately 5:1 nitrogen (N) to phosphorus (P) ratio and manure typically contains approximately 2:1 N to P ratio as a result of N volatilization (Erickson et al., 1998). Historically, manure has been applied based on N concentration of the manure and the N requirement of the crops. However, given the ratio of N to P in manure, this practice could become an environmental concern. Regulatory agencies have recognized this concern and have begun implementation of P-based land application regulations. Therefore, an understanding of how dietary manipulation can affect the P concentrations in manure is of great importance to feedlot managers.

This trial was designed to determine the effect of increasing levels of DDGS in feedlot diets on performance and carcass characteristics of yearling steers, odorant emissions from feedlot pens, and nutrient concentrations in manure and soil.

Materials and Methods

This experiment was conducted at the South Dakota State University (SDSU) Southeast Research Farm near Beresford, SD. One hundred ninety-two steers (initial BW = 826 ± 18 lb) received on two separate dates were weighed, blocked by receiving date, and randomly allotted to 16 dirt floor pens (48.2 ft x 113.8 ft; 5% slope). The pens were then randomly assigned to one of four dietary treatments. The control diet (CON) contained cracked corn, alfalfa hay, molasses, supplement, and urea. In the remaining three diets, all of the urea and portions of the cracked corn were removed and replaced with DDGS at 15% (15% DDGS), 25% (25% DDGS), and 35% (35% DDGS) of the diet DM (Table 1). The diets were formulated to provide similar levels of crude protein (CP) for CON and 15% DDGS (13.2 and 13.3% CP, respectively) and a stepwise increase in CP for 25% and 35% DDGS (15.4 and 17.6%, respectively). Analysis of weekly feed samples collected throughout the trial determined that the CP concentrations were 11.4, 12.2, 14.3, and 16.5% for CON, 15% DDGS, 25% DDGS, and 35% DDGS, respectively. All steers were vaccinated at the beginning of the trial and received a Revalor© IS (80mg trenbolone acetate and 16mg estradiol) implant on day 28. Diets were mixed daily and delivered in the morning. Steers were fed the finishing diet on day one at 14.6 lb dry matter (DM) and intakes were increased in a step-wise manner over a four-week period until animals were allowed to consume feed *ad libitum.* Feed ingredients and treatment diets were sampled weekly, frozen immediately, and stored at -20^{O} C for later analysis of chemical composition. Steers were fed until they had approximately 0.4 in. backfat, by visual appraisal, at which time they were sent to a commercial packing plant and carcass data was collected.

Wind tunnel samples (9 L) were taken from three locations on each pen floor over three days prior to animal introduction and on d 76-78. Sample locations were predetermined with location A and B being approximately 20 ft back from the bunks and 16 ft from each sides fence line, respectively. Location C was located in the center of each pen both by length and width. Samples were taken in the pens by day and location, i.e. on the first day of sampling, location A was sampled in all 16 pens; on day two location B; and on day three location C. Samples were collected in Tedlar® bags and shipped overnight to the University of Minnesota, Department of Biosystems and Agricultural Engineering, St. Paul, MN for analysis via dynamic triangular forced-choice olfactometry. Samples were analyzed using the Ac'scent International Olfactometer (St. Croix Sensory, Stillwater, MN,). Briefly, air samples were diluted and presented to a trained sensory panel along with two filtered air samples in three separate air streams. Intensity of odor was calculated by determining the concentration of the odor samples at which the panelists could distinguish it from the other filtered air samples. Hydrogen sulfide gas was analyzed at the time of odor sampling from air collected in each individual bag. It was quantified using a Jerome® meter calibrated to detect H_2S at levels as low as 1 part per billion (ppb).

Soil samples were taken from pen floors prior to animal introduction as well as after manure removal. Soil cores (0-6 in) were taken from seven locations in each pen, pooled within pen, and chemically analyzed for organic matter (OM), nitrate nitrogen (NO_3-N), ammonia nitrogen (NH_4-N), Kjeldahl nitrogen (Kjedahl-N), Olsen phosphorus (Olsen-P), pH, salts and potassium (K) (Table 7). Manure removed from pens after animal removal was weighed wet, sub-sampled, and analyzed for DM, Olsen-P, NH_4-N, and Kjedahl-N (Table 5).

Performance, carcass, soil, and odor data were analyzed as a randomized complete block using the GLM procedure of SAS (2002) with pen as the experimental unit When the model was significant ($P < 0.05$), treatment means were separated using least significant differences. Orthogonal contrasts were performed to compare control vs distillers treatments and to test for linear and quadratic effects.

Results and Discussion

Over the 105-d experiment, cattle fed 25% DDGS consumed more ($P < 0.05$) dry matter than cattle fed the CON diet (Table 2). Dry matter intake of steers fed 15% and 35% DDGS was intermediate but not different than that of steers fed CON or 25% DDGS. Dry matter intake increased quadratically as the level of DDGS in the diet increased ($P < 0.05$). Steers fed DDGS consumed more feed than steers fed the CON diet ($P < 0.10$). Average daily gain tended ($P < 0.10$) to be greater for cattle fed 25% DDGS than CON cattle. Average daily gain of steers fed 15% and 35% DDGS was intermediate but not different than that of steers fed CON or 25% DDGS. Feed efficiency (gain:feed) was not affected by treatment.

Carcass data are reported in Table 3. Hot carcass weights and Yield Grades were greater ($P < 0.05$) for 35% DDGS vs CON with 15% and 25% DDGS being intermediate but not different than that of steers fed CON or 35% DDGS. Backfat tended ($P < 0.10$) to be greater for 35% DDGS vs CON with 15% and 25% DDGS being intermediate but not different than that of steers fed CON or 35% DDGS. Dressing percentage was lower ($P < 0.05$) for steers fed CON than those fed 15% or 35% DDGS, but was not different than those fed 25% DDGS. Steers fed 35% DDGS had greater dressing percent than steers fed CON or 25% DDGS but were not different than those fed 15% DDGS. Dressing percent and backfat increased ($P < 0.05$) and hot carcass weight and Yield Grade tended ($P < 0.10$) to increase in a linear fashion as level of DDGS in the diets increased. Increasing the level of DDGS did not affect ribeye area, kidney, pelvic, and heart fat, or marbling score.

Hydrogen sulfide was detected at higher ($P < 0.05$) levels in the 35% DDGS treatment (Table 4). The Occupational Safety and Health Administration (OSHA) limits workplace hydrogen sulfide at 2000 ppb over an eight-hour workday (Agency for Toxic Substances and Disease Registry, 1999). The highest reading from any one sample in this study was 13 ppb. In areas where odor may be a public concern, it should be noted that H_2S can be detected by the human nose at levels as low as 0.5 ppb (Tamminga, 1992). The levels in this study are below levels of concern from a human health perspective; however H_2S should be considered a contributor to malodors. A trained panel was unable to detect differences in odor produced between the test diets, and as a whole, odors were near or below the threshold for detection by the panel.

Since manure can be used as a fertilizer and crops require approximately 5:1 nitrogen to phosphorus ratio, understanding the concentration of N and P in the manure is critical. Because manure typically contains approximately 2:1 N to P ratio as a result of N volatilization (Erickson et al., 1998), excess P can become a potential environmental concern. In this study, increasing levels of DDGS significantly ($P < 0.05$) increased ammonia –N and Olsen-P in manure removed from pens (Table 5). These results agree with previous work (Geisert et al., 2005) that demonstrates an increase in fecal P as the P content of the ration increases. Increase in concentration of P in livestock manure is of notable importance as regulations pertaining to manure P distribution on cropland are becoming increasingly stringent. Some caution must be used as this is a small dataset for making such decisions, but an example of how manure application may be affected by increasing dietary DDGS can be found in Table 6. Based on this experiment more than a 75% increase in corn acreage would be needed for manure application to account for the increase in P between control and 35% distillers diets.

Pen floor soil analysis (Table 7) showed no differences for OM, NO_3-N, NH_4-N, Kjedahl-N, Olsen-P, pH, salts, and K between pens before or after animal introduction. There was, however, a trend ($P < 0.15$) for the 35% DDGS treatment to increase Olsen- P and NH_4-N between initial and final core sampling periods. Previous research from the University of Nebraska suggests that diets formulated to contain lower P concentrations can result in lower P levels in core samples from pens where manure has been removed (Erickson et al., 2000).

Pen soil contamination and leeching from feedlot pens are generally not environmental concerns in permitted feedlots, due to regulations guiding pen construction methods, compaction, and slope. There is a concern with down slope areas where runoff tends to pool and settle allowing N to move vertically through the soil profile. Interesting to note in this study is that even with the clay pen construction and 5% slope, the higher manure N and P concentrations were able to penetrate the soil, at least to the 6 in. test depth. Rainfall during the trial (11.7 in.) may have pooled as a result of manure buildup in the pens. This pooling may have contributed to the increased infiltration of N and P into the pen floors.

Implications

Dried distillers grains with solubles are a suitable feed ingredient for finishing steers based on performance and carcass traits. From this study, inclusion of up to 35% DDGS was not detrimental to animal performance; however, performance was maximized at 25% DDGS. Increasing levels of DDGS appears to increase subcutaneous fat deposition. As such careful attention should be paid to days on feed and terminal endpoints. Inclusion appears to have no noteworthy effects on odor emission from the feedlot. However, increasing levels of DDGS does affect the nutrient composition of manure, which may limit its use, particularly in states where manure application is currently regulated under a P-based management system.

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Tables

Table 1. Composition of finishing diets

	Treatment			
Item, % DM	CON	15% DDGS	25% DDGS	35% DDGS
Alfalfa hay	10.0	10.0	10.0	10.0
DDGS	-	15.0	25.0	35.0
Dry rolled corn	82.0	67.0	57.0	47.0
Molasses	4.0	4.0	4.0	4.0
Supplement				
Ground corn	1.93	2.35	2.35	2.35
Urea	0.83	-	-	-
Limestone	0.58	1.00	1.00	1.00
TM salt	0.57	0.57	0.57	0.57
Premix[a]	0.08	0.08	0.08	0.08
Nutrient composition				
Dry Matter, %	87.9	87.8	88.8	89.0
Ash, %	9.7	9.6	9.2	8.9
CP, %	11.4	12.2	14.3	16.5
NDF, %[b]	14.4	18.9	21.8	24.9
ADF, %[b]	6.8	8.1	8.9	9.7
Fat, %	4.7	5.8	6.5	7.3
P, %[c]	0.29	0.37	0.42	0.47

[a] Provides:18 g/ton monensin; 10 mg Cu, 9.2 IU Vitamin E, and 2,200 IU Vitamin A per kg total diet DM.
[b] Derived from assay values for alfalfa and DDGS and NRC (1996) tabular values for remaining dietary ingredients.
[c] Derived from tabular values for feeds used (NRC, 1996).

Table 2. Performance of finishing steers fed increasing levels of dried distillers grains with solubles[a]

	Treatment					Contrasts		
						---------- *P* –value ----------		
Item	CON	15% DDGS	25% DDGS	35% DDGS	SEM	CON vs. DDGS	Linear	Quadratic
Initial Weight, lb	829	828	826	823	3.35	0.426	0.232	0.757
d 0-28								
ADG, lb/d	3.35^{j}	3.82^{k}	3.74^{jk}	3.59^{jk}	0.17	0.094	0.475	0.096
DMI, lb/d	18.45^{f}	18.49^{g}	18.56^{h}	18.61^{i}	0.01	0.000	0.000	0.631
Gain:Feed	0.182^{j}	0.207^{k}	0.201^{jk}	0.193^{jk}	0.009	0.114	0.574	0.097
Feed:Gain	5.55^{j}	4.88^{k}	4.96^{jk}	5.23^{jk}	0.240	0.096	0.490	0.086
d 28-56								
ADG, lb/d	5.16^{j}	4.33^{k}	4.87^{jk}	5.08^{jk}	0.27	0.225	0.659	0.085
DMI, lb/d	24.81^{b}	24.75^{b}	24.96^{c}	25.26^{d}	0.10	0.161	0.009	0.122
Gain:Feed	0.208^{j}	0.175^{k}	0.195^{jk}	0.201^{jk}	0.010	0.180	0.843	0.097
Feed:Gain	4.84^{j}	5.77^{k}	5.12^{jk}	5.05^{jk}	0.296	0.202	0.818	0.127
d 56-84								
ADG, lb/d	3.47^{b}	4.87^{c}	5.19^{c}	4.59^{c}	0.23	0.001	0.007	0.002
DMI, lb/d	25.75^{f}	26.85^{fg}	28.68^{g}	26.40^{f}	0.56	0.043	0.116	0.017
Gain:Feed	0.135^{b}	0.182^{c}	0.181^{c}	0.174^{c}	0.006	0.000	0.004	0.002
Feed:Gain	7.46^{b}	5.53^{c}	5.54^{c}	5.87^{c}	0.220	0.000	0.002	0.001
d 84-105								
ADG, lb/d	5.03^{j}	4.41^{jk}	4.12^{k}	4.35^{jk}	0.32	0.082	0.142	0.219
DMI, lb/d	26.54	27.06	27.69	26.48	0.61	0.472	0.802	0.195
Gain:Feed	0.190^{j}	0.164^{jk}	0.149^{k}	0.165^{jk}	0.013	0.069	0.146	0.130
Feed:Gain	5.29^{j}	6.31^{jk}	6.79^{k}	6.13^{jk}	0.500	0.087	0.207	0.130
Final Weight, lb	1275	1289	1303	1290	11.97	0.204	0.278	0.284
Cumulative (d 0-105)								
ADG, lb/d	4.25^{j}	4.39^{jk}	4.55^{k}	4.45^{jk}	0.10	0.106	0.124	0.269
DMI, lb/d	23.74^{f}	24.13^{fg}	24.81^{g}	24.06^{fg}	0.25	0.070	0.130	0.048
Gain:Feed	0.179	0.182	0.184	0.185	0.003	0.262	0.223	0.822
Feed:Gain	5.59	5.50	5.46	5.42	0.096	0.272	0.238	0.830

[a] All calculations based on computed 3% BW shrink.
[b,c,d,e] Means with different superscripts differ ($P < 0.01$).
[f,g,h,i] Means with different superscripts differ ($P < 0.05$).
[j,k] Means with different superscripts differ ($P < 0.10$).

Table 3. Carcass characteristics of finishing steers fed increasing levels of dried distillers grains with solubles

	Treatment					Contrasts		
						----------*P* – value----------		
Item	CON	15% DDGS	25% DDGS	35% DDGS	SEM	CON vs. DDGS	Linear	Quadratic
HCW, lb	787.8[a]	804.9[ab]	809.4[ab]	811.5[b]	4.22	0.033	0.054	0.377
Shrunk dress, %	60.0[a]	60.6[bc]	60.2[ab]	61.0[c]	0.11	0.011	0.017	0.866
Marbling score[f]	537	518	530	510	6.25	0.213	0.284	0.969
KPH fat, %	2.12	2.16	2.03	2.11	0.04	0.951	0.620	0.837
Backfat, in.	0.45[d]	0.46[de]	0.47[de]	0.51[e]	0.01	0.345	0.010	0.411
REA, in^2.	13.1	13.1	13.1	13.1	0.10	0.919	0.979	0.904
Yield grade	2.84[a]	2.96[ab]	2.96[ab]	3.15[b]	0.05	0.120	0.059	0.747

[a,b,c] Means with different superscripts differ ($P < 0.05$).
[d,e] Means with different superscripts differ ($P < 0.10$).
[f] $Small^0$=500, $Modest^0$=600.

Table 4. Effects of feeding increasing levels of dried distillers grains with solubles on hydrogen sulfide (H_2S) and odor detection[a]

	Treatment				
Item	CON	15% DDGS	25% DDGS	35% DDGS	SEM
H_2S, ppb					
Initial[b]	0.00	0.00	0.08	0.01	0.028
On trial[c]	0.67[e]	0.56[e]	0.81[e]	2.22[f]	0.355
Difference	0.666[e]	0.556[e]	0.722[e]	2.223[f]	0.360
Odor Detection, OU[d]					
Initial[b]	30.5	30.5	36.1	36.5	3.092
On trial[c]	35.7	26.7	32.2	36.3	3.701
Difference	4.17	-3.67	-5.13	0.33	4.860

[a] Stocking density on monoslope pens 450 ft^2/hd.
[b] Samples taken prior to animal introduction (June 21,23-24).
[c] Samples taken at d78-80 (Oct. 4-6).
[d] Odor Units (OU).
[e,f] Means with different superscripts differ ($P < 0.05$).

Table 5. Manure scraping nutrient compositions

	Treatment			
Item	CON	15% DDGS	25% DDGS	35% DDGS
lb removed[a]	10,223	11,151	10,661	10,616
DM, %	65	67	65	67
NH_4, ppm	241[b]	411[b,c]	764[c]	1304[d]
Kjedahl-N, %	0.2	0.2	0.2	0.1
Olsen-P, ppm	710[b]	860[c]	1013[d]	1163[e]

[a] Calculated from study animals; four pens per treatment containing 12 head per pen, feed 105 d.
[b,c,d,e] Means with different superscripts differ (*P* < *0.05*).

Table 6. Calculated crop production for manure phosphorus utilization

	Treatment			
Item	CON	15% DDGS	25% DDGS	35% DDGS
P_2O_5, lb / hd[a]	178.29	246.60	265.30	315.26
Corn, bu[b]	509.4	704.6	758.0	900.7
Acres of corn[c]	3.92	5.42	5.83	6.93
Soybean, bu[b]	231.55	320.26	344.55	409.43
Acres of soybeans[d]	5.79	8.01	8.61	10.24
Alfalfa, ton[b]	14.86	20.55	22.11	26.27
Acres of alfalfa[e]	6.46	8.93	9.61	11.42

[a] Calculated from study animals; four pens per treatment, 12 head per pen, fed 105 d.
[b] Represent production needed to utilize manure P without soil loading or depletion.
[c] Based on average production of 130 bushels per acre.
[d] Based on average production of 40 bushels per acre.
[e] Based on average production of 2.3 tons per acre.

Table 7. Composition of soil core samples taken from pen floor.

	Initial[a]				Final[b]				Difference			
	CON	15% DDGS	25% DDGS	35% DDGS	CON	15% DDGS	25% DDGS	35% DDGS	CON	15% DDGS	25% DDGS	35% DDGS
OM, %	6.2	7.5	6.5	6.5	8.6	8.3	8.1	7.7	2.4	0.8	1.6	1.2
NO_3-N, ppm	45.5	45.0	39.5	44.8	113.0	136.7	120.8	127.6	67.5	91.7	81.3	82.9
Olsen-P, ppm	425.0	485.0	417.5	357.5	430.0	428.8	425.0	452.5	5.0[c]	-56.3[c]	7.5[c]	95.0[d]
K, ppm	3407.5	3367.5	3500.0	3387.5	4090.0	4225.0	4637.5	4240.0	682.5	857.5	1137.5	852.5
pH	8.0	8.1	8.1	8.1	8.1	8.0	8.1	8.0	0.08	-0.15	-0.08	-0.15
Salt, mmho/cm	2.9	2.7	2.7	2.6	3.6	3.8	3.9	3.8	0.7	1.1	1.2	1.2
NH_4, ppm	9.5	13.3	6.5	2.8	66.9	38.3	59.6	97.1	57.4[e]	25.1[e]	53.1[e]	94.3[f]
Kjedahl-N, %	0.56	0.68	0.57	0.54	0.62	0.68	0.66	0.64	0.05	0.00	0.08	0.08

[a] Prior to animal introduction.
[b] After animal removal and pen scraping.
[c,d] Values within column lacking common superscripts tend to be different ($P < 0.11$).
[e,f] Values within column lacking common superscripts tend to be different ($P < 0.14$).