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Effects of twenty percent corn wet distillers grains plus solubles in steam-flaked and dry-rolled corn-based finishing diets on heifer performance, carcass characteristics, and manure characteristics[1]

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ABSTRACT: Two hundred sixty-four crossbred heifers (initial BW = 354 kg ± 0.5) were used to determine effects of corn processing method and wet distillers grains plus solubles (WDGS) inclusion in finishing diets on animal performance, carcass characteristics, and manure characteristics. The study was conducted as a randomized complete block with a 2 × 2 factorial arrangement of treatments. Dietary treatments included steam-flaked corn (SFC)- and dry-rolled corn (DRC)-based finishing diets containing 0 or 20% WDGS (0SFC, 20SFC, 0DRC, and 20DRC, respectively). Heifers averaged 154 d on feed and were marketed in 3 groups. There were no interactions between corn processing method and WDGS detected ($P \geq 0.29$) for any performance or carcass response variables. Heifers fed diets containing WDGS tended to have greater final BW ($P = 0.10$) and increased G:F ($P = 0.08$) compared with heifers fed diets without WDGS. Heifers fed SFC-based diets consumed 7% less feed ($P < 0.01$) and were 9% more efficient ($P < 0.01$) than heifers fed DRC-based diets. Carcass characteristics were not affected by corn processing method or WDGS inclusion ($P \geq 0.16$). Intakes of OM, N, P, and K were greater ($P \leq 0.05$) for heifers fed DRC-based diets than those fed SFC-based diets, which resulted in greater net accumulation of the nutrients in the manure ($P \leq 0.04$). Heifers fed diets containing WDGS had greater ($P < 0.01$) intakes of N, P, and K than heifers fed diets without WDGS. As a result, a greater net accumulation of P and K ($P \leq 0.03$) and N ($P = 0.10$) were present in the manure from cattle fed diets containing WDGS compared with those fed diets without WDGS. There was no interaction ($P \geq 0.16$) between corn processing and WDGS on N volatilization losses. Nitrogen volatilization losses from manure (expressed as a percentage of intake and $g \cdot heifer^{-1} \cdot d^{-1}$) were greater ($P < 0.01$) for heifers fed SFC-based diets than heifers fed DRC-based diets. Feeding DRC-based finishing diets to heifers resulted in increased manure production and nutrient excretion and decreased N volatilization. Both corn processing method and WDGS inclusion affected animal performance and manure characteristics.

Key words: corn processing, distillers grains, finishing cattle, manure characteristics

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INTRODUCTION

The effect of feeding of distillers grains (**DG**) on feedlot animal performance has been variable. Cole et al. (2009a) suggested differences in feeding region and corn processing method may account for some of the variability in performance responses to feeding DG. Research from northern feeding regions where primarily dry-rolled corn (**DRC**) is fed has often resulted in positive performance responses (Larson et al., 1993; Ham et al., 1994; Al-Suwaiegh et al., 2002). Conversely, research from the southern feeding regions where

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primarily steam-flaked corn (**SFC**) is fed has resulted in largely negative responses to dietary DG inclusion (Vasconcelos et al., 2007; Depenbusch et al., 2008; Luebbe et al., 2012b). Research specifically investigating a DG inclusion by corn processing interaction is limited and inconsistent (Vander Pol et al., 2008; Corrigan et al., 2009; Leibovich et al., 2009).

There is also limited information on the interaction of corn processing method and dietary DG inclusion effects on beef feedlot manure quality and quantity. Crude protein and P concentrations in DG are approximately 3-fold greater than corn grain (NRC, 1996; Stock et al., 2000). Including DG in finishing diets may increase certain nutrient levels beyond what is required by the animal (Spiehs and Varel, 2009; Luebbe et al., 2012a,b). Fertilizer value of the manure may be affected, with implications for nutrient management planning and land area requirements for manure application (Bremer et al., 2008).

Todd et al. (2005) and Cole et al. (2006) used the ratio of N and P in the diet and manure to estimate N volatilization, but this technique has not been compared with the mass-balance technique in a controlled experiment. Additionally, there is increased interest in the higher heating value (**HHV**) of livestock manure as a biofuel (Sweeten et al., 2003; Preece et al., 2009). However, dietary effects on HHV of feedlot manure have been largely unquantified.

We hypothesized that feeding wet distillers grains plus solubles (**WDGS**) produced in the northern Great Plains would interact with corn processing method to result in animal performance similar to a SFC diet without WDGS. We also hypothesized that WDGS inclusion would increase manure N and P content, manure quantity, and manure HHV. Finally, we hypothesized that the dietary and manure N:P ratios would provide a reliable estimate of N volatilization. Therefore, the objectives of this research were to 1) evaluate WDGS produced in the northern Great Plains in a southern Great Plains feeding environment, 2) investigate the interaction of corn processing method and WDGS inclusion on animal performance, carcass characteristics, and manure quality, quantity, and HHV, and 3) investigate the reliability of the N:P ratio method to determine N volatilization losses.

MATERIALS AND METHODS

All animal care and management procedures were approved by the Amarillo Area Cooperative Research, Education, and Extension Team Institutional Animal Care and Use Committee.

Cattle Management

Two hundred sixty-four crossbred yearling heifers (initial BW = 354 ± 0.5 kg) were used to determine effects of corn processing method and WDGS inclusion on animal performance, carcass characteristics, and manure characteristics. The study was designed as a randomized complete block with a 2 × 2 factorial arrangement of treatments. Factors included corn processing method (SFC and DRC) and inclusion or absence of WDGS in the finishing diet of heifers.

Upon trial initiation, heifers were limit-fed (1.8% of BW) a common receiving diet containing 46% SFC, 45% alfalfa hay, 7% crude glycerin, and 2% supplement (DM basis) for 7 d to minimize differences in gut fill (Klopfenstein, 2011; Watson et al., 2012) and weighed on 3 consecutive days (Stock et al., 1983) to obtain an initial BW for the finishing period. Heifers were vaccinated against viral pathogens using modified live cultures of bovine rhinotracheitis virus, bovine viral diarrhea virus (Types 1 and 2), parainfluenza-3 virus, and bovine respiratory syncytial virus (Vista 5 SQ; Merck Animal Health, De Soto, KS) and clostridial bacteria including *Clostridium chauvoei*, *Clostridium septicum*, *Clostridium novyi*, *Clostridium sordellii*, and *Clostridium perfringens* Types C and D (Vision 7 with SPUR; Merck Animal Health) and were treated against internal and external parasites with an injectable anthelmintic (Ivomec Plus; Merial Ltd., Duluth, GA). All heifers received a single implant containing 14 mg estradiol and 140 mg trenbolone acetate (Revalor-H, Merck Animal Health) approximately 120 d before harvest and were on feed an average of 154 d.

Heifers were blocked by initial BW, stratified by BW within blocks, and randomly assigned to pens. Dietary treatments were randomly assigned among 24 pens, which housed 8, 10, or 18 heifers and were blocked by pen size, resulting in 6 pens per treatment. Four pens housed 8 heifers (1 block), 16 pens housed 10 heifers (4 blocks), and 4 pens housed 18 heifers (1 block). All pen facilities provided approximately 0.36 m of bunk space and approximately 16.7 m^2 of pen space per heifer. Weight blocks and pen size blocks were considered to be a single blocking factor in the statistical analysis.

Treatments included a SFC [348 g/L (27 pounds/bushel)]-based finishing diet containing 0 or 20% corn WDGS (**0SFC** and **20SFC**, respectively) and a DRC-based finishing diet containing 0 or 20% corn WDGS (**0DRC** and **20DRC**, respectively; Table 1). An inclusion level of 20% WDGS was selected to be representative of an industry average. Vasconcelos and Galyean (2007) identified 20% as the mode byproduct inclusion level in finishing diets. On 6 separate occasions, WDGS was purchased from a single ethanol plant located in the northern Great Plains

Table 1. Composition of DRC[1]- and SFC[1]-based diets with and without WDGS[2] fed to heifers (% of diet DM)

	0% WDGS		20% WDGS	
Item	SFC	DRC	SFC	DRC
Ingredient				
WDGS	–	–	20.0	20.0
DRC	–	76.0	–	60.8
SFC	76.0	–	60.8	–
Alfalfa hay	10.0	10.0	10.0	10.0
Yellow grease	2.00	2.00	2.00	2.00
Crude glycerin	4.00	4.00	4.00	4.00
Cottonseed meal	4.80	4.80	–	–
Urea	1.20	1.20	1.20	1.20
Limestone	1.40	1.40	1.40	1.40
Premix[3]	0.60	0.60	0.60	0.60
Analyzed nutrient composition				
DM	83.7	87.8	69.8	73.1
OM	95.2	95.1	93.4	93.3
CP	13.8	14.3	15.8	16.3
Ether extract	4.68	5.82	6.55	7.46
Ca	0.71	0.71	0.68	0.68
P	0.25	0.33	0.33	0.39
K	0.55	0.60	0.66	0.70
S	0.12	0.12	0.24	0.25
MP balance[4]	211	245	301	365
RDP balance[5]	13	115	80	152

[1]Corn processing method: DRC = dry-rolled corn; SFC = steam-flaked corn.

[2]WDGS = wet distillers grains plus solubles. Purchased from Chief Ethanol Fuels, Hastings, NE.

[3]Premix formulated to provide a dietary DM inclusion of 0.30% salt, 60 mg/kg Fe, 40 mg/kg Zn, 30 mg/kg Mg, 25 mg/kg Mn, 10 mg/kg Cu, 1 mg/kg I, 0.15 mg/kg Co, 0.10 mg/kg Se, 1.5 IU/g vitamin A, 0.15 IU/g vitamin D, 8.81 IU/kg vitamin E, 33 mg/kg monensin (Elanco Animal Health, Indianapolis, IN), and 8.7 mg/kg tylosin (Elanco Animal Health).

[4]MP = MP balance (g/d), predicted by NRC (1996) using observed animal performance.

[5]RDP = rumen degradable protein balance (g/d), predicted by NRC (1996) using observed animal performance.

(Chief Ethanol Fuels, Hastings, NE), mixed with chopped alfalfa hay, and stored in agricultural bags. Alfalfa hay was co-stored with WDGS to maintain the integrity of the agricultural bag. The mixture included two-thirds WDGS and one-third alfalfa hay (DM basis) and was included in the final 20SFC and 20DRC diets at 30% dietary DM. Deliveries of WDGS occurred as needed, approximately once per month. At the same time as the WDGS was delivered, alfalfa hay was also delivered to the facility. The alfalfa hay from each delivery that remained after mixing with WDGS was fed to the SFC and DRC control diets so that the alfalfa source was consistent across diets. At the time of each delivery, samples of the WDGS and alfalfa hay were collected, dried in a 60°C oven for 48 h, and retained for analysis. Each delivery of WDGS was mixed and bagged within 48 h of being produced at the ethanol plant. Although, an individual load of WDGS was fed over the course of approximately 1 mo, each load was initially fed within 7 d of being delivered to the feedlot. Dry-rolled corn was purchased in bulk and stored in a commodity bay for the duration of the trial. Steam-flaked corn was purchased 3 to 4 times per week from a local feedlot. Geometric mean diameter was 2,730 ± 1.8 μm for the DRC and 3380 ± 1.6 μm for the SFC. Alfalfa hay, crude glycerin, yellow grease, limestone, urea, and supplement amounts were fixed and all diets contained 33 mg/kg monensin (Rumensin; Elanco Animal Health, Indianapolis, IN) and 8.7 mg/kg tylosin (Tylan; Elanco Animal Health). Diets not containing WDGS were formulated to contain 13.5% CP and included cottonseed meal as a natural CP source. At the time of diet formulation, supplemental RDP requirements for diets containing WDGS were not established. Therefore, all diets contained 1.2% urea to ensure RDP was not limiting. Dietary CP was not equilibrated across diets to ensure adequate RDP so that animal performance was not limited. Dietary MP and RDP balances were estimated (NRC, 1996) using actual animal performance and analyzed dietary composition. Heifers were stepped up to the final finishing diets over a 21-d period using 3 steps containing 35, 25, and 15% alfalfa hay. Diets were offered once daily in the morning in an amount to allow ad libitum intake throughout the finishing period.

Heifers were marketed in 3 groups at 132 (n = 2), 160 (n = 3), and 181 (n = 1) d on feed. On the day of harvest, feed was withheld and heifers were pen weighed. A 4% shrink (NRC, 1996) was applied to determine final shrunk BW and to calculate dressing percentage. Cattle were transported 40 km to a federally inspected commercial facility (Tyson Fresh Meats, Inc., Amarillo, TX) for harvest and subsequent carcass data collection (West Texas A&M University Beef Carcass Research Center, Canyon, TX). Hot carcass weights were recorded on the day of harvest. Twelfth-rib fat thickness, LM area, and marbling score were recorded after a 48-h chill and yield grade was calculated using carcass measurements (USDA, 1997). Live performance calculations were made using shrunk final BW whereas carcass-adjusted final BW, ADG, and G:F were calculated using HCW and an average dressing percentage of 64.5. Dietary NE_m and NE_g values were calculated using the equivalent BW scaling approach of NRC (1996) with a standard reference BW of 478 kg as described by Vasconcelos and Galyean (2008).

Throughout the feeding period, feed refusals were collected, weighed, sampled, and dried to determine DM. Refusals were subtracted from feed offered (DM basis) to calculate DMI. Ingredient samples were collected daily for wet ingredients (WDGS and SFC) and once weekly for all other ingredients for DM determination. Ingredient DM was determined by drying in a 60°C oven for 48 h and was updated weekly for ration formulation. A composite sample was made for each ingredient using DM samples collected over the duration of the study and sent to a commercial laboratory (Servi-Tech Laboratories, Amarillo, TX) for nutrient analysis. Feed samples were analyzed according to AOAC International official methods (AOAC Int., 2000) for OM (method 923.03), CP (method 990.03), and crude fat (method 954.02). Calcium, P, K, and S were analyzed using U.S. Environmental Protection Agency methods 3050B (USEPA, 1986) for acid digestion and 6010C (USEPA, 1986) for Inductively coupled plasma atomic emission spectroscopy (**ICP-AES**) detection (Wang, et al., 1999; Kerr, et al., 2008). Nitric acid and peroxide were used alone in the digestions, rather than a combination of hydrochloric, nitric acid, and peroxide, to prevent instrument interference as explained by Poppiti (1994).

At the end of the experiment, composite samples from the WDGS and alfalfa hay (collected at the time of delivery) and the WDGS and alfalfa hay mixture (collected daily during the experiment) were ground in a Wiley mill (Thomas Scientific, Swedesboro, NJ) to pass a 1-mm screen. Samples of the ground WDGS, alfalfa hay, and mixture were sent to Dairy One Laboratory (Ithaca, NY) for analysis of NDF, ADF, in vitro true digestibility (**IVTD**), and NDF digestibility to determine if co-storage of the alfalfa hay and WDGS altered the composition or digestibility of the 2 feed ingredients. Analysis of NDF and ADF were conducted in an Ankom A200 fiber analyzer (Ankom Technology, Macedon, NY) using a 75 min reflux. Solutions of NDF and ADF were prepared according to AOAC International method 973.18 (AOAC Int., 2000) and Van Soest et al. (1991), respectively. Neutral detergent fiber analysis included the addition of alpha amylase and sodium sulfite. In vitro true digestibility was conducted in a Daisy II Incubator (Ankom Technology) using rumen fluid collected from a high producing dairy cow fed a total mixed diet. The IVTD procedure is similar to the in vitro DM digestibility procedure described by Holden (1999) modified by washing the filter bag in NDF solution in the Ankom A200 fiber analyzer after in vitro fermentation. Digestibility of NDF was calculated from the IVTD analysis by correcting the initial sample weight in the filter bag for NDF content.

Manure Characteristics

Total manure collections were performed on 12 pens (n = 3) paved with 15 to 20 cm of hydrated compacted mixture of fly ash and crushed bottom ash from a coal-fired power plant. Manure was removed from the surface of each individual pen using a skid-steer loader and placed in a dump-bed truck for weighing. Weights were measured using an 18,000-kg capacity truck scale (7560 Digitol Truckmate; Mettler Toledo, Columbus, OH) with a resolution of 2.3 kg. After weighing, the dump-bed was emptied and reweighed to calculate manure mass. Manure samples were taken from each pen during the removal and weighing process for nutrient, pH, and HHV analyses. Determination of DM, OM, N, P, and K content was conducted by a commercial laboratory (Servi-Tech Laboratories, Amarillo, TX). Manure samples were analyzed for OM (method 923.03; AOAC Int., 2000) and total Kjeldahl N (method 4500-N_{org}; APHA, AWWAA, and WEF, 1999; VanderZaag et al., 2008). Phosphorus and K were analyzed according to U.S. Environmental Protection Agency methods (USEPA, 1986) using acid digestion (method 3050) and ICP-AES detection (method 6010), omitting hydrochloric acid (Poppiti 1994). Manure pH was determined in our laboratory by mixing manure with deionized water (1 g of DM/5 mL of water), shaking for 10 min, centrifuging for 20 min at 3,900 × *g* at 20°C, and then reading the pH with a combination electrode (Model 125, Corning, Medfield, MA). Manure samples were sent to Hazen Research, Inc. (Golden, CO) for determination of the dry, ash-free HHV (**HHV_{daf}**) using Standard Test Method D5865-11a (ASTM Int., 2011).

Nitrogen Volatilization Losses

Apparent N volatilization losses were estimated using 2 methods. The first method used a N mass balance technique similar to procedures outlined by Erickson and Klopfenstein (2001) and Luebbe et al. (2012a). Briefly, N intake was accounted for using DMI and analyzed N concentration of dietary ingredients. Nitrogen retention was estimated using NRC (1996) NE and protein equations based on actual animal performance. Specifically, N retention was calculated from net protein requirement and converted to net N using the equation (SWG × {268 – [29.4 × (RE / SWG)]})/6.25 in which **SWG** is shrunk BW gain (carcass-adjusted ADG) and **RE** is retained energy. Retained energy was calculated from the equations which utilized the NRC (1996) definitions for equivalent empty body weight (**EQEBW**), empty body gain (**EBG**), equivalent shrunk body weight (**EQSBW**), standard reference weight (**SRW**), and final shunk body weight (**FSBW**). The equations used were: RE = 0.0635 × EQEBW0.75 × EBG1.097, EQEBW = 0.891× EQSBW, and EQSBW = SBW × (SRW /FSBW), in which SRW= 478 kg, FSBW is the carcass-adjusted final BW and EBG = 0.956 × SWG (NRC, 1996). Nitrogen excretion was calculated as the difference between N intake (from Kjeldahl analysis) and N retention. Nitrogen lost ($g \cdot heifer^{-1} \cdot d^{-1}$) to volatilization and runoff was calculated by subtracting manure N (from Kjeldahl analysis) from calculated excreted N. Nitrogen volatilization loss was calculated as a percentage of intake (N lost/N intake) and as a percentage of excretion (N lost/N excretion).

The second method was based on the change in the ratio of N and P of the diets and pen manure samples (Todd et al., 2005; Cole et al., 2006). Nitrogen volatilization loss as a percentage of intake was calculated by subtracting N:P of air-dried manure from N:P of diet and dividing by N:P of diet. The N:P ratio was used to estimate N volatilization on samples of total manure collections at the end of the finishing period (referred to as total manure collection samples) as well as on a sample collected during the finishing period (referred to as spot manure samples). Spot samples were obtained by collecting air dried manure (approximately 100 g, as-is) from the loose unconsolidated layer (Cole et al., 2009b) of the pen floor surface. Spot samples were collected from 5 random locations in the pen, avoiding fresh urine spots, fecal pats, or wet areas. Spot samples were collected midmorning on the day cattle were shipped to the abattoir.

Statistical Analysis

Data were analyzed using the mixed model procedures (PROC MIXED; SAS Inst. Inc., Cary, NC) with pen serving as the experimental unit. The model included corn processing method, WDGS inclusion, and their interaction as fixed effects and block as a random effect. Effects were considered significant when $P \leq 0.05$ and tendencies were declared when *P*-values were between 0.05 and 0.10.

RESULTS AND DISCUSSION

Nutrient Composition of Corn, Wet Distillers Grains Plus Solubles, and Diets

Actual CP, ether extract, and P content of the WDGS (collected at the time of delivery) were 28.8, 12.3, and 0.88%, respectively (Table 2). The WDGS was co-stored with alfalfa hay to maintain integrity of the agricultural bag. Samples of the mixture of WDGS and alfalfa hay collected during the experiment contained 40.3% NDF and 28.8% ADF and had a 24-h in vitro NDF digestibility of 50.0% and a 24-h IVTD of 80.0% (data not shown). Similar analyses were conducted on samples of the alfalfa hay and WDGS collected at the time of delivery. When combined in the same proportion as the mixture (two-thirds WDGS and one-third alfalfa hay; DM basis) the mathematical mixture of the 2 components contained 40.5% NDF and 24.1% ADF and had a 24-h in vitro NDF digestibility of 54.3% and a 24-h IVTD of 80.0% (data not shown). Therefore, we conclude that co-storage of WDGS and alfalfa hay for approximately 7 to 30 d had little impact on the composition or digestibility of the mixture of the 2 components. Harding et al. (2012) reported WDGS had an initial pH of 3.7 before storage. Although WDGS pH was not measured in the current study, we expect a low pH of WDGS may have limited fermentation in the agricultural bag.

Table 2. Analyzed composition (% of DM) of dry-rolled corn (DRC), steam-flaked corn (SFC), and wet distillers grains plus solubles (WDGS) used in heifer finishing diets

Item	DRC	SFC	WDGS[1]
DM	87.36	81.86	33.90
CP	9.20	8.50	28.8
Ether extract	4.80	3.30	12.3
Ca	0.04	0.04	0.05
P	0.32	0.22	0.88
K	0.37	0.30	1.18
S	0.10	0.09	0.83

[1]Nutrient composition of WDGS was analyzed from samples collected at the time of delivery.

Dry-rolled corn contained 9.20% CP, 4.80% ether extract, and 0.32% P compared with 8.50, 3.30, and 0.22% CP, ether extract, and P, respectively, in the SFC. Analysis of dietary MP and RDP balances from animal performance suggests that MP exceeded requirements of all diets and RDP was fed in excess of requirements for all diets except 0SFC (Table 1). Therefore, effects of corn processing method in the current study should be viewed within the context that DRC and SFC were from different sources and thus had slightly different nutrient profiles. Additionally, effects of both corn processing and WDGS inclusion should be viewed within the context of the different protein status of each diet.

Cattle Performance

A primary objective of the experiment was to investigate a possible interaction of corn processing method and WDGS inclusion. Interactions between corn processing method and WDGS inclusion level were not detected for any cattle performance variable of interest ($P \geq 0.34$; Table 3); therefore, main effects are discussed. Similarly, Leibovich et al. (2009) observed no interactions of corn processing (DRC and SFC) and 15% sorghum WDGS inclusion. However, inclusion of WDGS reduced animal performance (ADG and G:F) in the study of Leibovich et al. (2009). Corrigan et al. (2009) reported a significant interaction ($P < 0.01$ for ADG and G:F) of DRC and SFC in diets where WDGS increased from 0 to 40% of diet DM and suggested the energy value of WDGS was similar to SFC. The current data set used a WDGS product that more closely resembled the experiment of Corrigan et al. (2009) at a single inclusion level similar to Leibovich et al. (2009). A greater inclusion of WDGS or multiple levels of WDGS may be required for an interaction of corn processing and WDGS inclusion to be evident.

Table 3. Effects of corn processing method and dietary wet distillers grains plus solubles (WDGS) inclusion on heifer performance and carcass characteristics

	0% WDGS		20% WDGS			*P*-value[1]		
Item	SFC[2]	DRC[2]	SFC	DRC	SED	Corn	By-product	Interaction
Pens	6	6	6	6	–	–	–	–
Live performance[3]								
Initial BW, kg	355	354	354	355	0.5	0.91	0.75	0.34
Final BW, kg	538	533	543	543	6	0.62	0.10	0.55
DMI, kg/d	9.04	9.80	9.15	9.81	0.26	<0.01	0.73	0.79
ADG, kg	1.20	1.18	1.23	1.23	0.04	0.77	0.14	0.69
G:F, kg/kg	0.133	0.120	0.135	0.126	0.003	<0.01	0.08	0.40
Carcass-adjusted performance[4]								
Final BW, kg	534	536	542	543	7	0.82	0.16	0.88
ADG, kg	1.17	1.20	1.23	1.23	0.05	0.71	0.14	0.68
G:F, kg/kg	0.130	0.122	0.135	0.126	0.005	0.04	0.21	0.79
Carcass characteristics								
HCW, kg	344	346	350	350	5	0.83	0.16	0.87
Dressing percent[3]	64.1	64.9	64.5	64.5	0.5	0.27	0.95	0.29
Fat thickness, cm	1.31	1.22	1.32	1.32	0.12	0.57	0.54	0.63
Marbling score[5]	545	544	528	529	16	0.97	0.19	0.90
LM area, cm^2	92.8	93.6	95.4	93.3	2.3	0.69	0.48	0.40
USDA yield grade	2.46	2.33	2.39	2.49	0.20	0.92	0.77	0.43
Dietary NE_m[6]	1.84	1.73	1.87	1.77	0.04	<0.01	0.26	0.93
Dietary NE_g[6]	1.20	1.11	1.23	1.14	0.04	<0.01	0.29	0.90

[1]Overall treatment *F*-test where Corn = main effect of corn processing method; Byproduct = main effect of dietary WDGS inclusion; Interaction = interaction of corn processing method and dietary WDGS inclusion.

[2]Corn processing method: SFC = steam-flaked corn; DRC = dry-rolled corn.

[3]Final BW measured live and shrunk 4% (NRC, 1996).

[4]Final BW calculated as HCW/64.5% (common dressing percent).

[5]400 = Slight^0; 500 = Small^0; 600 = Modest^0.

[6]Dietary NE_m and NE_g concentrations calculated as described by Vasconcelos and Galyean (2008), which used the equivalent BW scaling approach of NRC (1996) with a standard reference weight of 478 kg.

Effects of Corn Processing Method. Final BW and ADG were not affected ($P \geq 0.62$; Table 3) by corn processing method. However, heifers fed SFC-based diets consumed 7% less ($P < 0.01$) feed than heifers consuming DRC-based diets. This resulted in a 9% increase ($P \leq 0.03$) in feed efficiency in heifers fed SFC-based diets compared with those fed DRC-based diets. Performance responses comparing SFC and DRC have been well established; we have observed similar responses to corn processing method in previous studies conducted at our facility (Luebbe et al., 2012b; E. K. Buttrey, K. H. Jenkins, J. B. Lewis, West Texas A&M University, Canyon, S. B. Smith, Texas A&M University, College Station, R. K. Miller, Texas A&M University, T. E. Lawrence, West Texas A&M University, F. T. McCollum III, P. J. Pinedo, Texas A&M AgriLife Research, Amarillo, N. A. Cole, and J. C. MacDonald, unpublished data). Similarly, Owens et al. (1997) reviewed the literature and reported that although rate of gain was similar between cattle fed DRC- and steam-rolled corn (**SRC**)-based diets, DMI was reduced and efficiency of BW gain was greater for cattle fed SRC-based diets than those fed DRC-based diets. Supporting this were the observations reported by Leibovich et al. (2009) in which improved feed efficiency was the result of reduced DMI in cattle fed SFC-based diets compared with DRC-based diets. Conversely, Huck et al. (1998) and Scott et al. (2003) reported that an increase in rate of BW gain rather than a decrease in DMI resulted in an improvement in feed efficiency in cattle fed SFC-based diets compared with those fed DRC-based diets.

Dietary NE_m and NE_g values calculated using animal performance were greater ($P < 0.01$) for diets containing SFC than those containing DRC. Cooper et al. (2002), Scott et al. (2003), and Leibovich et al. (2009) also reported greater calculated NE values of diets containing SFC than those containing DRC. This is presumed to be the result of increased starch (Zinn et al., 1995; Huntington, 1997) and total OM digestion (Zinn et al., 1995).

Effects of Wet Distillers Grains Plus Solubles Inclusion. On a live, shrunk basis, heifers consuming diets containing WDGS tended ($P = 0.10$) to be heavier at the end of the finishing period than heifers fed diets without WDGS. Even though DMI and ADG were not affected ($P \geq 0.14$) by the addition of 20% WDGS, slight shifts in these variables resulted in a tendency ($P = 0.08$) for improved G:F on a live basis when WDGS were included in finishing diets. However, carcass-adjusted final BW, ADG, and G:F were not different ($P \geq 0.14$) between heifers fed diets with and without WDGS. Larson et al. (1993) and Ham et al. (1994) observed improvements in ADG and G:F in cattle fed DRC-based diets containing 40% wet distillers byproducts over cattle fed diets without byproducts. Al-Suwaiegh et al. (2002) also reported 10% greater ADG and 8% greater feed efficiency in steers fed a DRC-based finishing diet with 30% WDGS than steers fed the control diet without WDGS. Similarly, Corrigan et al. (2009) reported a linear increase in G:F when adding WDGS to DRC-based diets. However, the authors reported no change in G:F when adding WDGS to SFC-based diets, suggesting that WDGS has an energy value similar to SFC. The studies of Larson et al. (1993), Ham et al. (1994), Al-Suwaiegh et al. (2002), and Corrigan et al. (2009) were conducted in the northern Great Plains using WDGS produced in that region. Conversely, research conducted in the southern Great Plains has resulted in reduced animal performance due to WDGS inclusion (Vasconcelos et al., 2007; Leibovich et al., 2009; Luebbe et al., 2012b). Depenbusch et al. (2008) observed a decrease in feed efficiency when feeding 25% corn WDGS in SFC-based diets and suggested that the relative response to WDGS in SFC-based diets may be less than in DRC-based diets because of the energetic differences associated with these 2 corn processing methods. In the current experiment, including WDGS in either DRC- or SFC-based finishing diets had minimal impact on ADG and G:F. The current experiment was conducted in the southern Great Plains with WDGS produced in the northern Great Plains. Differences in the observed responses to WDGS in the northern and southern Great Plains may be explained by WDGS source in addition to differences in corn processing methods. We currently hypothesize that differences in WDGS sources may be related to the proportion of solubles added back to the DG.

Dietary NE_m and NE_g values were similar between ($P \geq 0.26$) diets containing 20% WDGS and diets without WDGS. Likewise, May et al. (2010) and Quinn et al. (2011) reported similar dietary NE values calculated from performance data when diets with and without WDGS were fed. However, greater (Ham et al., 1994; Al-Suwaiegh et al., 2002; Buckner et al., 2008) and lesser (Depenbusch et al., 2008; Leibovich et al.,2009) calculated NE values have been reported for finishing diets containing DG compared with diets without DG. Differences in calculated dietary NE values in response to DG may be the result of differences in processing method of the primary grain source, source of grain fermented to produce WDGS, inclusion of supplemental fat, amount of solubles added to the WDGS, or energy density of the basal diet (Cole et al., 2009a).

Carcass Characteristics

Dietary treatment had no effect on HCW, dressing percent, marbling score, LM area, calculated yield grade, or fat thickness ($P \geq 0.16$; Table 3). In agreement with the current study, Depenbusch et al. (2009) reported similar HCW, LM area, and fat thickness between steers fed diets with or without DG. Quinn et al. (2011) found that including 15 or 30% WDGS in finishing diets did not affect carcass characteristics of steers compared with steers fed a control diet. On the other hand, inclusion of DG in finishing diets has reduced HCW, dressing percentage, and LM area in some instances (Vasconcelos et al., 2007; Leibovich et al., 2009; May et al., 2010). Likewise, Scott et al. (2003) reported that HCW were lighter for steers fed DRC-based diets than those fed SFC- or high-moisture corn-based diets with no effect on marbling score, yield grade, fat thickness, or LM area. Leibovich et al. (2009) observed greater fat thickness and yield grade and slightly smaller LM area in carcasses of steers fed SFC-based diets compared with DRC-based diets; however, HCW, dressing percent, and marbling score were not affected. In the current experiment, dietary treatment primarily affected G:F through changes in DMI, which resulted in minimal effects on carcass characteristics.

Manure Characteristics

Nutrient intakes and manure characteristics are presented in Table 4. An interaction between corn processing and WDGS inclusion was detected for HHV_{daf} ($P = 0.02$), in which HHV_{daf} of manure was greatest for the 0DRC treatment and least for the 0SFC treatment. An estimate of HHV_{daf} provides the energy density (cal/g) for the combustible fraction of manure on a dry, ash-free basis. The reason for the interaction between corn processing method and WDGS inclusion is not clearly evident. However, manure consists of combustible and noncombustible fractions, with the combustible fractions comprising C, H, O, N, and S (Channiwala and Parikh, 2002) from complex carbohydrates, proteins, trace organic compounds, and fats. Although we did not analyze for C, H, or O in this experiment, we suspect that differences in HHV_{daf} may be attributed to those components. Interactions were not detected for other manure characteristics ($P \geq 0.40$). Therefore, main effects are discussed.

Effects of Corn Processing Method. Intake and excretion of DM, OM, N, P, and K were greater ($P \leq 0.05$; Table 4) for heifers fed DRC-based diets than heifers fed SFC-based diets. These differences can be largely attributed to differences in the nutrient composition of the DRC and SFC used in the experiment (Table 2). Additionally, the dietary CP formulation likely affected N excretion of heifers fed DRC-based diets. It is known that DRC-based diets have a reduced RDP requirement than SFC-based diets (Cooper et al., 2002), yet dietary urea was held constant across all diets in the current experiment (Table 1) because the RDP requirement of diets containing WDGS was unknown at the time the experiment was conducted. Ponce et al. (2010) demonstrated that the addition of more than 0.52% urea did not improve steer performance when fed 15% WDGS in SFC-based diets. Therefore, RDP was likely fed in excess of requirements for all diets except 0SFC. Accordingly, feeding DRC-based diets to heifers resulted in greater quantities ($g \cdot heifer^{-1} \cdot d^{-1}$) of DM, OM, N, P, and K present in the manure than heifers fed SFC-based diets ($P < 0.05$). Additionally, the concentration of OM, P, and K were greater in manure from heifers fed DRC-based diets than in heifers fed SFC-based diets ($P \leq 0.01$). However, corn processing method did not significantly affect the concentration of N in manure ($P = 0.13$), likely because both N and OM excretion concomitantly increased in DRC-based diets.

Table 4. Effects of corn processing method and dietary wet distillers grains plus solubles (WDGS) inclusion on characteristics (DM basis) of manure collected from fly ash surfaced feedlot pens

	0% WDGS		20% WDGS			*P*-value[1]		
Item	SFC[2]	DRC[2]	SFC	DRC	SED	Corn	Byproduct	Interaction
Pens	3	3	3	3	–	–	–	–
Nutrient intake, $g \cdot heifer^{-1} \cdot d^{-1}$								
DM	8,829	9,129	8,962	9,495	249	0.05	0.20	0.53
OM	8,425	8,702	8,350	8,863	240	0.05	0.81	0.51
N	195.5	209.4	226.1	247.8	6.2	<0.01	<0.01	0.40
P	22.1	30.2	29.5	37.1	0.8	<0.01	<0.01	0.71
K	48.7	60.4	53.7	66.5	1.6	<0.01	<0.01	0.64
Nutrient present in manure, $g \cdot heifer^{-1} \cdot d^{-1}$								
DM	1,735	2,471	2,085	2,795	229	<0.01	0.08	0.94
OM	1,283	1,895	1,482	2,044	157.7	<0.01	0.16	0.83
N	57.1	84.8	66.5	98.6	8.5	<0.01	0.10	0.72
P	17.7	22.1	21.8	25.5	1.9	0.02	0.03	0.81
K	41.4	52.1	53.8	63.3	5.6	0.04	0.02	0.89
Nutrient concentration in manure, %								
OM	74.3	77.3	71.3	73.8	1.1	0.01	<0.01	0.78
N	3.31	3.44	3.21	3.53	0.19	0.13	0.96	0.47
P	1.02	0.90	1.05	0.92	0.04	<0.01	0.48	0.91
K	2.41	2.14	2.60	2.29	0.11	<0.01	0.08	0.79
HHV_{daf}[3], cal/g	4,903.0[c]	5,250.7[a]	5,077.7[b]	5,113.0[ab]	76.7	<0.01	0.74	0.02
Manure energy[4], Mcal $heifer^{-1} \cdot d^{-1}$	8.5	13.0	10.6	14.2	1.1	<0.01	0.08	0.64

[a–c]Means within row with unlike superscripts tend to differ ($P \leq 0.06$) when interaction is significant ($P \leq 0.05$).

[1]Overall treatment *F*-test where Corn = main effect of corn processing method; byproduct = main effect of dietary WDGS inclusion; Interaction = interaction of corn processing method and dietary WDGS inclusion.

[2]Corn processing method: SFC = steam-flaked corn; DRC = dry-rolled corn.

[3]HHV_{daf} = dry, ash-free higher heating value (of manure).

[4]Calculated as ($HHV_{daf} \times$ DM captured in the manure)/1,000,000.

The manure OM concentrations reported in the current experiment are slightly greater than those reported by Cole et al. (2009b) for the “loose unconsolidated layer” of the pen floor of soil-surfaced pens of commercial feedlots. The pens in the current experiment were paved with fly ash (a concrete-like surface) specifically to minimize ash contamination, which results when underlying soil is mixed with the manure layer by livestock hoof action or manure harvesting equipment. Sakirkin et al. (2011) and Sweeten et al. (2006) reported 20 and 30% (DM-basis) increases, respectively, in ash concentration in manure harvested from soil-surfaced pens when compared with manure harvested from pens paved with fly ash.

Manure gross energy ($Mcal \cdot heifer^{-1} \cdot d^{-1}$) was greater ($P \leq 0.01$) in manure from heifers fed DRC-based diets than SFC-based diets (Table 4). Manure GE is a function of its HHV (cal/g) and DM mass ($g \cdot heifer^{-1} \cdot d^{-1}$) and provides an estimate of the value of manure for use as a biofuel. For example, the main effect of corn processing resulted in heifers fed DRC-based diets generating 4.05 $Mcal \cdot heifer^{-1} \cdot d^{-1}$ more manure energy than heifers fed SFC-based diets. Texas lignite coal has an energy value of approximately 3.4 Mcal/kg (Sweeten et al., 2006). Therefore, a dietary change from SFC to DRC-based diets would generate additional energy equivalent to 1.2 kg lignite $coal \cdot heifer^{-1} \cdot d^{-1}$. Multiplied across a 30,000 head feedlot at 100% capacity year-round, this difference would result in the energy equivalent of an additional 13,000 t of lignite coal production per year. If lignite coal were valued at US$23/t and the feedlot were paid on an energy basis equivalent to coal, the dietary change would be valued at approximately $300,000/yr of potential income for the feedlot. Clearly diet can affect the value of manure marketed as a biofuel. We currently hypothesize that diet digestibility and manure energy may be inversely related; therefore, feedlots marketing manure as a biofuel must consider dietary effects on both animal performance and manure GE.

The effects of corn processing method on the nutrient and energy profiles of manure are likely the result of differences in DMI and diet digestibility. Cattle fed DRC-based diets often consume more feed, thus consuming more nutrients, compared with cattle fed SFC-based diets (Leibovich et al., 2009; Luebbe et al., 2012b). Nutrients consumed in excess of the amount required by the animal will increase the quantity excreted in the feces and urine (Cole et al., 2005; Archibeque et al., 2007; Luebbe et al., 2012a). Additionally, the digestibility of DRC-based diets is known to be lower than SFC-based diets (Huntington, 1997; Owens and Zinn, 2005; Luebbe et al., 2012b), thereby increasing the fecal output of nutrients.

Effects of Wet Distillers Grains Plus Solubles Inclusion. Inclusion of WDGS did not affect DMI or OM intake ($P \geq 0.20$; Table 4). However, differences in the nutrient composition of finishing diets resulted in greater ($P < 0.01$) intakes of N, P, and K for heifers consuming diets containing WDGS than those fed diets without WDGS. Manure DM and N present at the time of manure collection tended ($P \leq 0.10$) to be greater for heifers fed diets with 20% WDGS than heifers fed diets without WDGS. The amount of P and K in the manure was also greater ($P \leq 0.03$) for cattle fed diets with WDGS. Cole et al. (2011) reported that including 30% WDGS in finishing diets increased the quantities of N and C excreted in the urine but not in the feces. Although urinary N was not measured in the current study, the tendency for increased manure N as a result of WDGS inclusion may be related to an increase in urinary N excretion rather than fecal N excretion. Similar to our discussion for the main effect of corn processing, the fact that 1.2% urea was included in all diets likely affected our estimate of N intake and N present in manure. Manure DM ($P = 0.08$) and OM ($P = 0.16$) output appeared to be greater for heifers fed diets containing WDGS than heifers fed diets without WDGS even though intake of DM and OM was similar ($P \geq 0.20$) between the 2 dietary treatments. This response is likely the result of reduced digestibility of diets containing WDGS. Luebbe et al. (2012b) fed increasing levels of WDGS (0 to 60% diet DM) in SFC-based diets. Although OM intake was similar across treatments, fecal OM output increased linearly and total tract OM digestibility decreased linearly with increasing levels of WDGS. Corrigan et al. (2009) and Uwituze et al. (2010) also reported a reduction in total tract DM and OM digestibility when DG were included in finishing diets.

Manure energy ($Mcal \cdot heifer^{-1} \cdot d^{-1}$) tended ($P = 0.08$; Table 4) to be greater when diets contained WDGS and was largely the result of greater ($P = 0.08$) manure output. We hypothesized that including WDGS would increase manure energy because of decreased diet digestibility and increased manure OM. These results tend to confirm our hypothesis. However, the main effect of corn processing method appears to have affected manure energy to a larger degree than inclusion of WDGS. The main effect of corn processing resulted in a difference of 4.05 $Mcal \cdot heifer^{-1} \cdot d^{-1}$ vs. a difference of 1.68 $Mcal \cdot heifer^{-1} \cdot d^{-1}$ for the main effect of WDGS inclusion. We had not anticipated that corn processing would have greater effects on manure GE compared with WDGS inclusion. The need to quantify dietary effects on manure energy will become increasingly important as more feedlots market manure as biofuel.

Nitrogen Volatilization Losses

Estimates of N volatilization losses are presented in Table 5. A tendency ($P = 0.07$) for a corn processing method by WDGS interaction was detected for N retention ($g \cdot heifer^{-1} \cdot d^{-1}$), in which N retention was reduced in heifers fed 0DRC diets compared with all other treatments. Retained N was calculated from net protein using the NRC (1996) equations. Net protein is a function of retained energy and shrunk BW gain (carcass-adjusted ADG in the current data set). Although we did not observe an interaction of corn processing method and WDGS inclusion for our estimates of carcass-adjusted ADG ($P = 0.68$; Table 3), the tendency for an interaction of retained N where heifers fed 0DRC tended to retain less N would appear to support the interaction described by Corrigan et al. (2009). Interactions were not detected for N volatilization loss estimates, manure pH, or N:P of manure ($P \geq 0.16$).

Effects of Corn Processing Method. Nitrogen intake, excretion, and concentration in manure were greater ($P < 0.01$; Table 4) when DRC-based diets were fed compared with SFC-based diets. Two methods were used to estimate N volatilization losses (N mass balance technique and N:P technique). Although the 2 techniques resulted in different estimates of treatment means, the relative differences were similar between the 2 techniques: N volatilization losses (expressed both as a percentage of N intake and $g \cdot heifer^{-1} \cdot d^{-1}$) were greater ($P < 0.01$; Table 5) when SFC-based diets were fed compared with DRC-based diets. Paz and Weiss (2011) used the ratio of N and ash or specific mineral markers to estimate N volatilization losses in incubated manure samples from dairy cows. The ratio method underestimated N losses in cows in a negative N balance and overestimated N losses in cows in a positive N balance. Furthermore, the authors reported that using the N:P ratio underestimated N losses (Paz and Weiss, 2011). In the current data set, using the N:P ratio in total manure samples estimated N volatilization losses from –16 to +0.5% as estimated using the mass balance technique. When using spot manure samples to estimate N losses, values were underestimated by 9 to 46% as compared with the mass balance technique, especially in DRC-based diets. Using the N:P ratio appears to be an adequate method for estimating N volatilization losses provided that representative manure samples are used. Increasing the amount of OM in manure (by feeding less digestible diets) or on the pen surface (by applying sources of OM, such as sawdust) has been shown to decrease N volatilization losses from beef feedlot pens (Erickson and Klopfenstein, 2001; Adams et al., 2004). Reduced fecal pH may also reduce N volatilization by increasing the proportion of N in the ionized ammonium form; DRC-based diets resulted in reduced fecal pH compared with SFC-based diets (*P*

Table 5. Effects of corn processing method and dietary wet distillers grains plus solubles (WDGS) inclusion on N volatilization losses from manure (DM basis)

	0% WDGS		20% WDGS			*P*-value[1]		
Item	SFC[2]	DRC[2]	SFC	DRC	SED	Corn	Byproduct	Interaction
Pens	3	3	3	3	–	–	–	–
N mass balance technique								
Intake, g·heifer^{-1}·d^{-1}	195.4	209.4	226.1	247.8	6.2	<0.01	<0.01	0.40
Retention[3], g·heifer^{-1}·d^{-1}	24.1	22.1	24.6	24.1	0.5	<0.01	<0.01	0.07
Excretion[4], g·heifer^{-1}·d^{-1}	171.1	187.1	201.2	223.5	6.0	<0.01	<0.01	0.48
Manure, g·heifer^{-1}·d^{-1}	57.4	84.8	66.5	98.6	8.5	<0.01	0.10	0.72
Lost[5], g·heifer^{-1}·d^{-1}	114.4	102.7	135.1	125.3	6.6	0.06	<0.01	0.85
Volatilization[6], % of intake	58.5	49.1	59.8	50.6	3.0	<0.01	0.53	0.95
Volatilization[7], % of excretion	66.7	54.8	67.0	56.1	3.5	<0.01	0.75	0.85
Total manure collection samples[8]								
N:P of manure	3.24	3.83	3.06	3.85	0.15	<0.01	0.51	0.41
N volatilization[9], % of intake	63.2	44.9	60.1	42.3	2.2	<0.01	0.11	0.87
N volatilization[10], g·heifer^{-1}·d^{-1}	123.6	94.0	136.0	104.8	5.5	<0.01	0.02	0.85
Spot manure samples[11]								
N:P of manure	4.15	5.10	4.27	4.85	0.32	0.01	0.78	0.44
N volatilization[9], % of intake	53.0	26.4	44.3	27.5	4.4	<0.01	0.25	0.16
N volatilization[10], g·heifer^{-1}·d^{-1}	103.6	55.3	100.1	68.1	10.5	<0.01	0.57	0.32
N:P of diet	8.80	6.94	7.67	6.67	–	–	–	–
Manure pH	7.65	7.10	7.82	7.24	0.25	0.01	0.41	0.96

[1]Overall treatment *F*-test where Corn = main effect of corn processing method; byproduct = main effect of dietary WDGS inclusion; Interaction = interaction of corn processing method and dietary WDGS inclusion.

[2]Corn processing method: SFC = steam-flaked corn; DRC = dry-rolled corn.

[3]Calculated as net protein requirement and converted to net N using the NRC (1996) definitions for shrunk weight gain (SWG), retained energy (RE), equivalent empty body weight (EQEBW), empty body gain (EBG), equivalent shrunk body weight (EQSBW), standard reference weight (SRW), and final shunk body weight (FSBW). The equations used were: RE = 0.0635 × EQEBW0.75 × EBG1.097, EQEBW = 0.891× EQSBW, and EQSBW = SBW × (SRW /FSBW), in which SRW= 478 kg, FSBW is the carcass-adjusted final BW, SWG is the carcass-adjusted ADG, and EBG = 0.956 × SWG (NRC, 1996).

[4]Calculated as intake – retention.

[5]Calculated as excretion – manure.

[6]Calculated as lost/intake.

[7]Calculated as lost/excretion.

[8]Samples collected at the end of the finishing period during complete removal of manure from pen surface.

[9]Calculated as (N:P of diet – N:P of manure)/(N:P of diet).

[10]Calculated as (N volatilization as % of intake) × intake.

[11]Samples collected on a single day during the finishing period.

= 0.01; Table 5). In the current study, N volatilization losses were lower when DRC-based diets were fed even though CP was overfed in those diets, presumably as a result of increased manure OM concentration and reduced fecal pH when compared with SFC-based diets.

Effect of Wet Distillers Grains Plus Solubles Inclusion. Nitrogen intake and excretion were greater ($P < 0.01$) and amount of N in manure tended ($P = 0.10$) to be greater when WDGS were included in finishing diets. However, N volatilization expressed as a percentage of intake was not affected ($P \geq 0.11$) by WDGS inclusion using either technique. Similarly, Luebbe et al. (2012a) reported an increase in N intake and excretion when feeding diets containing WDGS with no effect on N volatilization. Nitrogen volatilization losses from total manure samples, expressed as g·heifer^{-1}·d^{-1}, were greater ($P = 0.02$) when finishing diets contained WDGS than when WDGS were absent. During monitoring of N emissions from commercial feedlots using open path laser spectroscopy and an inverse dispersion model, Todd et al. (2011) anecdotally observed that when a commercial feedlot switched from finishing diets without WDGS to diets with WDGS, ammonia-N flux increased as well, presumably through increased urinary N excretion. Similar to differences observed in N volatilization as a result of corn processing method, our observations related to effects of WDGS inclusion on N volatilization may be explained by differences in OM concentration of the manure. Additionally, Felix et al. (2011) noted that increasing dried distillers grains concentration in the diets of sheep reduced urine pH. Similar to reducing fecal pH, a reduction in urinary pH could increase the proportion of N in the ammonium form, thereby potentially inhibiting additional volatilization of N. Given that all diets except for 0SFC were overfed RDP, increasing manure OM or reducing urine pH or both appear to be effective in reducing N volatilization.

A secondary objective of this experiment was to compare N volatilization estimates from the mass balance technique to the N:P technique. When N volatilization was estimated using the N:P technique on the same samples collected for mass balance analysis (total manure collection samples), results were similar (Table 5). When spot manure samples were collected during the feeding period, N volatilization estimates were less for all treatments and were substantially less for DRC-based diets (Table 5). It is important to note that spot samples were collected from a wet pen surface and therefore may have been contaminated with fresh feces or urine. We conclude that the N:P ratio technique is an appropriate method for determining relative differences in N volatilization when the mass balance technique cannot be used provided that the samples collected are representative of the total manure produced. Additional research is needed to determine collection methodology and number of spot manure samples needed to accurately estimate N volatilization using this technique.

The current data set provides little evidence of an interaction between corn processing and WDGS inclusion at a level commonly used by industry. However, both grain processing and WDGS inclusion can affect feedlot cattle performance and manure characteristics. Feeding DRC reduced N volatilization compared with feeding SFC-based diets, which was unexpected given that both RDP and MP were fed in greater excess in DRC-based diets in the current experiment. Increased excretion of OM or reduced fecal pH or both may have been effective at capturing excreted N. Both corn processing method and WDGS inclusion can affect manure energy, although corn processing appears to have a greater effect. The N:P technique appears to provide reasonable estimates of N volatilization provided that representative manure samples are used.

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