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Comparison of wet and dry distillers grains plus solubles to corn as an energy source in forage-based diets[1]

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ABSTRACT

Four experiments compared wet or dry distillers grains plus solubles (WDGS or DDGS) to corn as energy sources in forage-based diets. In Exp. 1, 66 individually fed steers (268 kg of initial BW) were fed a 60:40 blend of sorghum silage and alfalfa hay and supplemented at 0, 0.33, 0.67, or 1.0% of BW with either WDGS or DDGS. In Exp. 2, 160 steers (286 kg of initial BW) were fed 25% WDGS or 33.6% dry rolled corn (DRC) in 35% sorghum silage and grass hay diets (DM basis). In Exp. 3, 60 individually fed steers (231 kg of initial BW) were fed DRC at 22.0, 41.0, or 60.0%, or WDGS at 15.0, 25.0, or 35.0% of diet DM in 30% sorghum silage and grass hay diets. In Exp. 4, 120 individually fed steers (282 kg of initial BW) were fed DDGS, WDGS (15 or 30% of diet DM), or DRC (22 or 50% of diet DM) in sorghum silage and grass hay diets. In Exp. 1, 3, and 4, increasing DGS inclusion increased ADG (P < 0.01) in forage-based diets. In Exp. 3, cattle consuming WDGS gained more BW than cattle fed DRC (P < 0.01). Using regression analysis, data from Exp. 2, 3, and 4 were pooled to calculate the energy value of WDGS relative to DRC in forage diets. The energy value of WDGS was 137% and 136% of DRC when fed at 15 and 30% of diet DM, respectively.

Key words: beef, cattle, distillers grains, forage, growing

INTRODUCTION

Expansion of the corn milling industry to make ethanol has led to an increased usage of distillers grains plus solubles (**DGS**) by-products in beef diets. Research explored the benefit of using DGS in finishing diets in place of corn (Bremer et al., 2011). However, the energy value of DGS by-products in high-forage diets is not as well defined. Furthermore, research has shown that dry distillers grains plus solubles (**DDGS**) supplementation in forage-based diets decreases forage DMI (Loy et al., 2007, 2008). Thus, supplementation allows producers to increase carrying capacity of pastures without acquisition of additional land. An experiment compared dry-rolled corn (**DRC**) and DDGS at 2 supplementation levels in forage-based diets, and the energy value of DDGS was 118 to 130% that of DRC (Loy et al., 2008).

In contrast with forage-based diets, energy value of DGS in concentrate diets has been well researched. Prediction equations developed from a meta-analysis of 20 beef cattle finishing experiments suggest greater energy value for wet distillers grains plus solubles (**WDGS**; 130 to 143% the energy value of corn for inclusions of 20 to 40% of diet DM) than DDGS (112% for inclusions of 10 to 40% of diet DM; Bremer et al., 2011). Nuttelman et al. (2011) conducted an experiment directly comparing WDGS and DDGS in concentrate diets. Feeding values calculated from G:F resulted in WDGS and DDGS having 146 and 109% the energy value of corn, respectively, supporting values found by Bremer et al. (2011). Few direct comparisons between wet and dry DGS have been made in forage diets.

The objective of Exp. 1 was to determine differences in cattle performance between WDGS and DDGS. Results from Exp. 1 led to the objectives for Exp. 2, 3, and 4: to compare DRC, DDGS, and WDGS as energy

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sources in forage-based diets and determine the energy value of DGS relative to DRC.

MATERIALS AND METHODS

Four experiments were conducted at the University of Nebraska–Lincoln Agricultural Research and Development Center near Mead, Nebraska, for which animal use procedures were reviewed and approved by the University of Nebraska Institutional Animal Care and Use Committee.

Steers were treated similarly before initiation of each experiment. Crossbred steer calves were purchased from a sale barn in western Nebraska and delivered to the feedlot (approximately 7 mo of age). Upon arrival at the feedlot in October, steers were individually identified and vaccinated for prevention of *Haemophilus somnus* (Somubac; Zoetis Inc., New York, NY) for prevention of bovine viral diarrhea, infectious bovine rhinotracheitis, parainfluenza-3, and bovine respiratory syncytial virus (BoviShield Gold 5; Zoetis Inc.), and given an injectable parasiticide (Dectomax; Zoetis Inc.). Approximately 21 d after arrival, steers were revaccinated with a second dose of viral, bacterial, and clostridial vaccines (BoviShield Gold 5, Ultrabac 7/Somubac; Zoetis Inc.) and for prevention of pinkeye (Piliguard Pinkeye-1; Merck Animal Health, Summit, NJ). At receiving, steers grazed smooth bromegrass pastures (21 d) until revaccination, and then steers grazed cornstalks until experiment initiation. While grazing cornstalks, steers were supplemented with 2.3 kg/steer per d of wet corn gluten feed (Sweet Bran; Cargill Corn Milling, Blair, NE). Before the start of each experiment, steers were penned and limit fed a diet consisting of 47.5% alfalfa hay, 47.5% Sweet Bran, and 5.0% supplement (DM basis) at 2.0% of BW for 5 d (Watson et al., 2013) and then weighed on 2 or 3 consecutive days (Stock et al., 1983). The 2- or 3-d BW were averaged and used as initial BW for performance calculations. Similar weighing conditions (fed a common diet at 2% of BW for 5 d and weighed 2–3 d) were used at the conclusion of each experiment. Steers in Exp. 1, 3, and 4 were individually fed using Calan gates (American Calan Inc., Northwood, NH). Cattle in Exp. 2 were pen fed. Pen fed steers were weighed 2 consecutive days at initiation and end of the experiment, whereas those fed individually were weighed 3 consecutive days.

Orts were collected weekly. A sample of refused feed was taken, and DM was determined using a 60°C forced-air oven for 48 h (AOAC International, 1999; method 4.2.03). To obtain accurate DMI, all feed samples were sampled weekly and analyzed for DM using a 60°C forced-air oven for 48 h (AOAC International, 1999; method 4.2.03). Representative subsamples of dietary ingredients were collected and analyzed for NDF (Van Soest et al., 1991; Mertens et al., 2002), CP, and S (LECO FP-528, LECO Corp., St. Joseph, MI; AOAC International, 1999; method 990.03). Ash was determined using a muffle furnace for 6 h at 600°C (AOAC International, 1999; method 4.1.10), and OM was determined based on ash content. By-products used were analyzed for fat content using the fat procedure described by Bremer et al. (2010), and NDF content was determined using the subsequent sample following fat extraction (Van Soest et al., 1991; Mertens et al., 2002; Buckner et al., 2013).

Exp. 1

A total of 120 crossbred steers (initial BW = 268 kg; SD = 14 kg) were used to evaluate growth performance between different types of DGS. Steers were individually fed for 84 d using Calan gates (American Calan Inc.). The experimental design was a generalized randomized block design with treatments arranged in a 3 × 4 factorial plus a control. This is similar to the experimental design and treatment structure used by Peterson et al. (2015). The experimental design of data reported here was a 2 × 3 factorial plus a control, using 66 steers; these data were collected as part of the full experiment. All steers were fed a control diet consisting of 59.25% sorghum silage, 39.25% alfalfa hay, and 1.5% supplement. The supplement consisted of 72.8% limestone, 19.6% salt, 3.3% tallow, 3.3% trace minerals, and 1.0% vitamin A-D-E. Limestone was provided to ensure a minimum of 1.2:1 ratio of Ca:P. Treatments included DGS supplement at 1 of 3 levels: 0.33, 0.67, or 1.0% of BW/steer per d (DM basis). Control cattle received no DGS supplement (12 steers). The second factor was type of DGS supplemented and included DDGS or WDGS. Supplementation was adjusted to changes in BW using single-day interim BW every 28 d. Nutrient profiles of all ingredients fed are shown in Table 1.

The DGS (Abengoa Bioenergy, York, NE) were fed on top of the base

Table 1. Nutrient composition of dietary ingredients fed to growing steers, Exp. 1 (DM basis)

Nutrient, %	WDGS[1]	DDGS[1]	Alfalfa hay	Sorghum silage
DM	32.7	92.3	87.1	33.9
OM	96.0	95.7	91.4	91.6
CP	30.3	29.7	17.9	7.9
NDF	34.7	28.9	52.4	57.4
Fat	11.5	11.1	—	—
S	0.73	1.06	0.23	0.13

[1]WDGS = wet distillers grains plus solubles; DDGS = dry distillers grains plus solubles.

Table 2. Composition of diets fed to growing steers evaluating energy value of distillers grains relative to corn, Exp. 2 (DM basis)

Ingredient, %	WDGS[1]	DRC[1]
DRC	—	33.6
WDGS	25.0	—
Grass hay	39.0	26.5
Sorghum silage	35.0	35.0
Supplement		
Urea	0.30	0.90
SoyPass[2]	—	3.35
Limestone	0.29	0.15
Salt	0.30	0.30
Selenium	0.01	0.01
Trace mineral premix[3]	0.05	0.05
Vitamin ADE premix[4]	0.02	0.02
Tallow	0.03	0.12

[1]WDGS = wet distillers grains plus solubles; DRC = dry rolled corn.

[2]SoyPass (Cargill, Iowa Falls, IA).

[3]Trace mineral premix (10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, 0.05% Co).

[4]Vitamin A-D-E premix (1,500 IU of vitamin A, 3,000 IU of vitamin D, 3.7 IU of vitamin E per gram).

diet to encourage total consumption. The control diet was used to simulate a response in performance that is expected from steers grazing actively growing forages. The control diet was mixed every 2 to 3 d. Both DDGS and WDGS used in this experiment were delivered to the feedlot as needed.

Exp. 2

A total of 160 crossbred steers (initial BW = 286 kg; SD = 19 kg) were used in a 67-d growing experiment with a generalized randomized block design, comparing the energy value of WDGS to DRC in a forage-based diet. Calves were blocked into 2 BW groups (6 heavy and 4 light replications), stratified by BW within block, and assigned randomly to pens based on d-0 BW. Pens were assigned randomly within block to 1 of 2 dietary treatments (5 pens per treatment) with 16 steers per pen.

Dietary treatments included sorghum silage fixed at 35% for both treatments and grass hay inclusion adjusted according to inclusion of WDGS at 25% (Abengoa Bioenergy) or DRC at 33.6% of diet DM (Table 2). The nutrient profiles for dietary ingredients included in this experiment are shown in Table 3. Diets were mixed daily and formulated using the NRC (1996) model to meet energy and metabolizable protein (**MP**) requirements for a prescribed BW gain of 1.0 kg/d. Supplements for both diets included urea to meet RDP requirements. To prevent a performance response due to protein, SoyPass (Cargill, Iowa Falls, IA) was included in the diet containing DRC to provide RUP to meet MP requirements. For diet formulation, WDGS was assumed to contain 130% the energy value of DRC (Loy et al., 2008). Limestone was provided in the dry supplement to ensure a minimum 1.2:1 ratio of Ca:P. Bunks were evaluated daily and managed so that intakes were equal across both treatments for paired pens. The WDGS used in this experiment was delivered to the feedlot as needed throughout the experiment.

Table 3. Nutrient composition of dietary ingredients fed to growing steers, Exp. 2 (DM basis)

Nutrient, %	WDGS[1]	DRC[1]	Grass hay	Sorghum silage
DM	33.7	87.7	86.1	32.5
OM	95.6	98.9	92.7	89.7
CP	31.7	9.5	7.7	8.0
NDF	35.6	14.2	74.5	63.4
Fat	11.0	3.0	—	—
S	0.95	0.13	0.15	0.13

[1]WDGS = wet distillers grains plus solubles; DRC = dry rolled corn.

Exp. 3

Sixty crossbred steers (initial BW = 231 kg; SD = 14 kg) were used to compare the energy value of WDGS to DRC in forage-based diets for growing cattle. Steers were individually fed for 84 d using Calan gates (American Calan Inc.). The experimental design was a completely randomized design with treatments arranged in a 2 × 3 factorial. The 2 factors were energy source (WDGS or DRC) and level of inclusion. Inclusion of WDGS was 15.0, 25.0, or 35.0% of diet DM, and DRC was included at 22.0, 41.0, or 60.0% of diet DM (low, medium, and high). Different concentrations were used for DRC and WDGS to provide equal energy from DRC or WDGS. The balance of the diet was 30% sorghum silage and varying levels of grass hay depending on inclusion level of WDGS (Abengoa Bioenergy) or DRC (Table 4). The nutrient profiles for dietary ingredients included in this experiment are shown in Table 5. Dry supplement was included at 2.2 to 5.5% of diet DM to provide sufficient urea in all diets to meet RDP requirements as determined by the NRC (1996) and to supply limestone to meet a 1.2:1 minimum Ca:P ratio. SoyPass was included in the low and medium DRC treatments to meet MP requirements (NRC, 1996). Urea and SoyPass were used to ensure that any measured response was due to energy differences between WDGS and DRC instead of a protein response. Based on data from Loy et al. (2008), feeding value for WDGS was estimated to be 130% the energy value of DRC in forage-based diets. The WDGS energy value of 130% was used to calculate inclusion level of DRC in order for diets to be isocaloric. To keep intakes similar between the DRC and WDGS treatments, calves were pair fed within level (low, medium, or high) based on initial BW. The WDGS used in this experiment was delivered as needed.

Table 4. Composition of diets fed to growing steers evaluating the energy value of distillers grains relative to corn, Exp. 3 (DM basis)

	WDGS[1]			DRC[1]		
Ingredient, %	Low	Medium	High	Low	Medium	High
WDGS	15.0	25.0	35.0	—	—	—
DRC	—	—	—	22.0	41.0	60.0
Sorghum silage	30.0	30.0	30.0	30.0	30.0	30.0
Grass hay	52.8	42.8	32.8	42.5	24.6	6.8
Supplement						
Urea	0.8	0.8	0.8	1.0	1.3	1.6
SoyPass[2]	—	—	—	3.0	1.5	—
Limestone	0.98	0.98	0.98	0.98	1.11	1.14
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Selenium	—	—	—	0.01	0.01	0.01
Trace mineral premix[3]	0.05	0.05	0.05	0.05	0.05	0.05
Vitamin ADE premix[4]	0.02	0.02	0.02	0.02	0.02	0.02
Tallow	0.05	0.05	0.05	0.14	0.11	0.08

[1]WDGS = wet distillers grains plus solubles; DRC = dry rolled corn.

[2]SoyPass (Cargill, Iowa Falls, IA).

[3]Trace mineral premix (10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, 0.05% Co).

[4]Vitamin A-D-E premix (1,500 IU of vitamin A, 3,000 IU of vitamin D, 3.7 IU of vitamin E per gram).

Exp. 4

A total of 120 crossbred steers, in 2 BW blocks (initial BW = 247 kg; SD = 10 kg and initial BW = 317 kg; SD = 28 kg), were used in an 84-d growing experiment to compare the energy value of DDGS and WDGS to DRC in a forage-based diet. Steers were individually fed using Calan gates (American Calan Inc.). Calves were blocked into 2 weight groups based on start date, stratified by BW within block, and assigned randomly to 1 of 6 diets (17 steers per treatment) or the control (18 steers). The experimental design was a randomized complete block design with treatments arranged in a 2 × 3 factorial plus a control with factors being energy source (DDGS, WDGS, or DRC) and level of inclusion (low and high). Animals were randomly paired within block into groups of 3 (one animal from each energy source) based on BW, and groups were fed either the low or high level of each energy source. Dietary treatments consisted of DDGS, WDGS, or DRC replacing a 60:40 blend of grass hay and sorghum silage (Table 6). The DDGS and WDGS were fed at 15 or 30% of diet DM (Green Plains, Ord, NE), and DRC was fed at 22 or 50% of diet DM. All diets contained a supplement that included urea to meet RDP requirements. SoyPass was used in the control and DRC treatments to provide RUP to meet the MP requirement (NRC, 1996). The nutrient profiles for dietary ingredients included in this experiment are shown in Table 7.

Diets were formulated using the NRC (1996) model to meet energy and MP requirements. Diets were calculated to contain the same amount of energy using 83% TDN for DRC and 108% TDN for DGS based on Exp. 2 and Loy et al. (2008). Dry rolled corn diets were formulated to equal predicted ADG of the DGS treatments. Body weight gain for the DGS diets was predicted at 0.79 kg/d for the low inclusion level and 1.08 kg/d for the high inclusion level. Intakes were held equal, as a percentage of BW, within each group of 3 animals. Bunks were evaluated daily and managed based on the animal within each group of 3 eating the least.

Table 5. Nutrient composition of dietary ingredients fed to growing steers, Exp. 3 (DM basis)

Nutrient, %	WDGS[1]	DRC[1]	Grass hay	Sorghum silage
DM	33.7	87.2	85.2	35.7
OM	95.3	99.0	92.8	90.5
CP	31.3	9.1	8.4	6.8
NDF	36.1	13.3	77.3	58.8
Fat	12.1	3.9	—	—
S	0.80	0.12	0.14	0.11

[1]WDGS = wet distillers grains plus solubles; DRC = dry rolled corn.

Table 6. Composition of diets fed to growing steers evaluating the energy value of distillers grains relative to corn, Exp. 4 (DM basis)

Ingredient, %	Control, 60:40	WDGS[1] 15	WDGS[1] 30	DDGS[1] 15	DDGS[1] 30	DRC[1] 22	DRC[1] 50
Grass hay	56.5	49.5	40.5	49.5	40.5	43.1	26.3
Sorghum silage	37.7	33.0	27.0	33.0	27.0	28.7	17.4
DRC	—	—	—	—	—	22.0	50.0
DDGS	—	—	—	15.0	30.0	—	—
WDGS	—	15.0	30.0	—	—	—	—
Supplement							
Urea	0.65	1.13	1.13	1.13	1.13	1.05	1.51
SoyPass[2]	3.80	—	—	—	—	3.70	3.45
Limestone	0.83	0.94	0.94	0.94	0.94	0.94	0.83
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Trace mineral premix[3]	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Vitamin ADE premix[4]	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Tallow	0.15	0.06	0.06	0.06	0.06	0.14	0.14

[1]WDGS = wet distillers grains plus solubles; DDGS = dry distillers grains plus solubles; DRC = dry rolled corn.

[2]SoyPass (Cargill, Iowa Falls, IA).

[3]Trace mineral premix (10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, 0.05% Co).

[4]Vitamin A-D-E premix (1,500 IU of vitamin A, 3,000 IU of vitamin D, 3.7 IU of vitamin E per gram).

Statistical Analysis

Growth performance data from Exp. 1 were analyzed as a generalized randomized block design. The model for Exp. 1 included block, control, energy source within control (DDGS and WDGS), and level of dietary treatment within control supplemented (0.33, 0.67, or 1.0% of BW).

Data from Exp. 2 were analyzed as a generalized randomized block design with 2 energy sources (DRC and WDGS). The model included block and dietary treatment and the block × dietary treatment interaction.

Data from Exp. 3 were analyzed as a completely randomized design, with 2 different energy sources (WDGS and DRC) and 3 inclusions (low, medium, and high). Model effects included energy source, energy source inclusion, and interactions of these factors.

Data from Exp. 4 were evaluated as a randomized complete block design, with 2 feeding levels and 3 energy sources. Model effects included block, energy source (DDGS, WDGS, and DRC), energy source inclusion (low and high), and interactions of these factors.

Data from all 4 experiments were analyzed using the mixed procedures of SAS (SAS Institute Inc., Cary, NC). In Exp. 1, 3, and 4, individual animal was the experimental unit. Pen was the experimental unit in Exp. 2. In Exp. 1, 2, and 4, block was used as a fixed effect assigned by weight. In all 4 experiments, effects were considered significant when $P \leq 0.05$. In Exp. 1, 3, and 4, the interaction between energy source and level of supplementation was analyzed for linear and quadratic effects using orthogonal contrasts including the forage control diet with 0% inclusion. When no significant interactions ($P > 0.05$) were observed, main effects of energy source and level of energy source fed are presented.

Pooled Analysis

Data from the 3 experiments containing both DRC and WDGS (Exp. 2, 3, and 4) were pooled to predict the energy value of WDGS relative to DRC. Block et al. (2006) reported that NE adjuster values change with rate of ADG, with values declining

Table 7. Nutrient composition of dietary ingredients fed to growing steers, Exp. 4 (DM basis)

Nutrient, %	WDGS[1]	DDGS[1]	DRC[1]	Grass hay	Sorghum silage
DM	36.3	88.8	86.5	87.6	35.3
OM	95.4	95.4	98.8	93.2	90.6
CP	31.0	30.2	8.9	8.5	6.8
NDF	35.7	40.7	11.4	69.2	67.1
Fat	11.4	10.8	3.5	—	—
S	0.66	0.69	0.12	0.14	0.11

[1]WDGS = wet distillers grains plus solubles; DDGS = dry distillers grains plus solubles; DRC = dry rolled corn.

Table 8. Main effect of energy source in forage-based diets on growth performance of steers

Item	Treatment[1] WDGS[2]	DDGS[2]	DRC[2]	SEM	P-value[3]
Exp. 1[4]					
DMI, kg/d	7.0	7.7	—	0.28	0.15
ADG, kg	1.09	1.13	—	0.06	0.20
G:F	0.158	0.149	—	0.01	0.55
Exp. 2[5]					
DMI, kg/d	8.1	—	8.1	0.32	0.72
ADG, kg	1.31	—	1.24	0.04	0.11
G:F	0.163	—	0.151	0.01	0.25
Exp. 3[6]					
DMI, kg/d	7.2	—	7.2	0.11	0.82
ADG, kg	1.10	—	1.00	0.02	<0.01
G:F	0.153	—	0.140	0.003	<0.01
Exp. 4[7]					
DMI, kg/d	7.2	7.4	7.2	0.10	0.42
ADG, kg	0.96	0.97	0.99	0.03	0.78
G:F	0.135	0.132	0.137	0.01	0.61

[1]All energy sources were not fed in each experiment.

[2]WDGS = wet distillers grains plus solubles; DDGS = dry distillers grains plus solubles; DRC = dry rolled corn.

[3]No interaction between energy source (WDGS, DDGS, or DRC) and inclusion level ($P > 0.10$); main effect of energy source is shown.

[4]Exp. 1 = 84-d growing experiment using 66 individually fed steers.

[5]Exp. 2 = 67-d growing experiment using 160 steers in 10 pens.

[6]Exp. 3 = 84-d growing experiment using 60 individually fed steers.

[7]Exp. 4 = 84-d growing experiment using 120 individually fed steers.

as ADG increases. To prevent an overprediction of ADG, NE adjuster values had to be equal for both DRC and DGS diets. To facilitate the comparison of energy values of DRC and DGS, it was necessary to do the evaluation at equal ADG. Therefore, using regression analysis, estimates were made for the amount of DRC in the diet to provide equal ADG to 15 and 30% WDGS. The regression analysis was used to estimate ADG at differing amounts of energy supplementation (DRC or WDGS). This analysis was needed to use the same NE adjuster values when evaluating the DRC and WDGS diets using the NRC (1996) model.

Dry rolled corn and WDGS replaced both grass hay and sorghum silage as inclusion increased. The change in level of DRC or WDGS determined the calculated change in both hay and sorghum silage. Because DDGS was not included in Exp. 2 or 3, there were not sufficient observations for DDGS, and therefore, no DDGS data were included in the pooled data.

Pooled data were analyzed using the glimmix procedure of SAS (SAS Institute Inc.). Model effects included experiment (Exp. 2, 3, and 4), type of energy source (DRC or WDGS), block within experiment, and inclusion within energy source (15 or 30% WDGS and 27.7 or 54.7% DRC). Inclusion of energy source was treated as a covariate.

RESULTS AND DISCUSSION

Steer performance data for all 4 experiments are summarized by main effects in Tables 8 and 9. There were no source × level interactions ($P > 0.10$).

Exp. 1

Supplementing increasing amounts of wet or dry DGS quadratically ($P < 0.01$) increased DMI. Cattle supplemented with DDGS and WDGS had similar DMI ($P = 0.15$; Table 9). As expected, cattle fed the control (0% DGS) consumed the least at 6.2 kg/d. Because the DGS was supplemented as a set percentage of BW and forage was then fed ad libitum, cattle consuming the higher levels of DGS consumed less forage. No differences between energy source were observed for ADG ($P = 0.20$) or G:F ($P = 0.55$). When comparing inclusion of supplement, ADG increased linearly ($P < 0.01$), with the 0 level gaining 0.70 kg/d and the 1.0% BW level gaining 1.20 kg/d. Feed efficiency also improved linearly ($P < 0.01$) with increasing levels of DGS supplementation.

Exp. 2

By design, DMI did not differ ($P = 0.72$) between treatments (Table 8). Average daily gain tended ($P = 0.11$) to improve 5.6% for WDGS compared with the DRC diet. Similarly, G:F was not significantly different ($P = 0.25$) between treatments but was 7.9% greater for the WDGS treatment.

Exp. 3

By design, DMI was the same for WDGS and DRC treatments ($P = 0.82$; Table 8). Cattle consuming diets containing WDGS gained 0.10 kg/d more than cattle consuming diets with DRC ($P < 0.01$). Feed efficiency was also improved for cattle consuming WDGS ($P < 0.01$) due to greater ADG and constant DMI.

Level of WDGS or DRC inclusion did not affect DMI ($P = 0.18$; Table 9). There was a quadratic response for ADG, with the medium and high levels of DRC and WDGS gaining 0.22 and 0.31 kg/d more than the low level, respectively. Consequently, feed efficiency was also quadratically improved with increasing level of either DRC or WDGS ($P < 0.01$).

Exp. 4

By design, type of energy supplement (DRC, DDGS, or WDGS) did not affect DMI, ADG, or G:F ($P \geq 0.42$; Table 8). As inclusion of DRC or DGS increased, DMI, ADG, and G:F increased linearly ($P < 0.01$; Table 9). This linear improvement was expected, because energy content of the diet increased with increasing levels of DRC or DGS supplement.

Pooled Analysis

Regression analysis produced the following equations, used to predict ADG at differing levels: DRC [$y = 0.009\ (\pm 0.009)x + 0.72\ (\pm 0.05)$]; WDGS [$y = 0.018\ (\pm 0.009)x + 0.73\ (\pm 0.05)$]. The predicted inclusions of DRC to match the ADG of the 15 and 30% WDGS diets were 27.7 and 54.7% (DM basis; Figure 1). The 27.7% DRC diet (equivalent to 15% WDGS) was evaluated with the NRC model. An NE adjuster of 103.2 was needed to predict the observed BW gain. Based on Loy et al. (2008), the DRC was given an energy value of 83% TDN. The same NE adjuster was used with the 15% WDGS diet. The energy value of WDGS was adjusted until ADG for that diet (1.0 kg) was achieved. The energy value used was 113.5% TDN, which is 137% the value of DRC.

The same process was used to estimate TDN content of WDGS when fed at 30% of diet DM. In this case, a 54.7% DRC diet equaled the ADG of the 30% WDGS diets, and an NE adjuster of 96.8 was needed to predict the ADG of 1.3 kg on the 30% WDGS diet. The energy value of WDGS was 112.7% TDN, which is 136% the value of DRC.

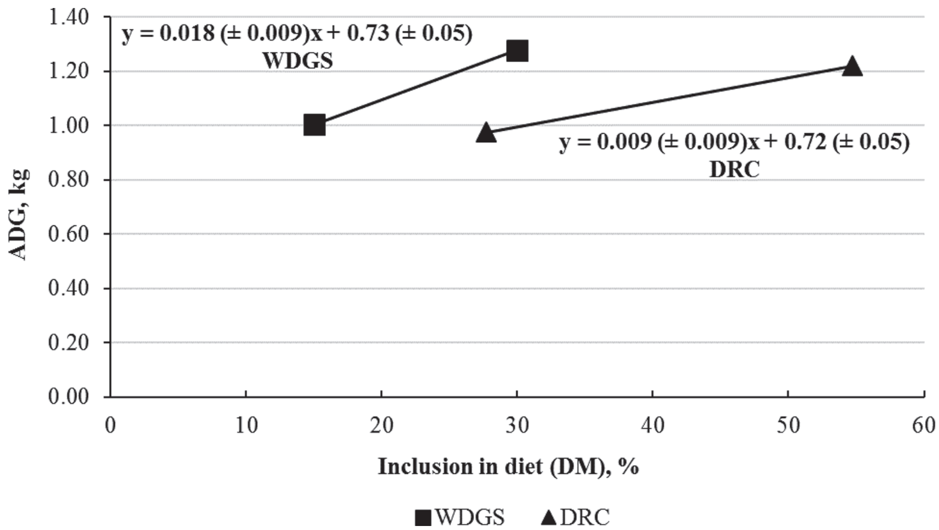

Figure 1. Regression analysis of pooled data (Exp. 2, 3, and 4) evaluating the energy value of wet distillers grains plus solubles (WDGS) relative to dry-rolled corn (DRC). Inclusion of WDGS was 15 to 30% of diet DM; equal ADG was observed with DRC inclusion of 27 to 55% of dietary DM.

Table 9. Main effect of inclusion level of corn or distillers grains in forage-based diets on growth performance of steers

	Treatment[1]					*P*-value[2]	
Item	Control	Low	Medium	High	SEM	Linear	Quadratic
Exp. 1[3]							
DMI, kg/d	6.2	7.2	7.6	7.2	0.28	0.02	<0.01
ADG, kg	0.70	0.98	1.08	1.20	0.06	<0.01	0.78
G:F	0.113	0.140	0.148	0.174	0.01	<0.01	0.23
Exp. 3[4]							
DMI, kg/d	—	7.1	7.3	7.1	0.13	0.35	0.18
ADG, kg	—	0.87	1.09	1.18	0.03	0.10	<0.01
G:F	—	0.123	0.151	0.165	0.004	0.02	<0.01
Exp. 4[5]							
DMI, kg/d	7.0	7.0	—	7.5	0.11	<0.01	0.17
ADG, kg	0.65	0.85	—	1.08	0.03	<0.01	0.63
G:F	0.093	0.122	—	0.146	0.006	<0.01	0.52

[1]All inclusion levels were not fed in each experiment.

[2]No interaction between energy source (wet distillers grains plus solubles, dry distillers grains plus solubles, or dry rolled corn) and inclusion level ($P > 0.10$); main effect of inclusion level is shown.

[3]Exp. 1 = 84-d growing experiment using 66 individually fed steers.

[4]Exp. 3 = 84-d growing experiment using 60 individually fed steers.

[5]Exp. 4 = 84-d growing experiment using 120 individually fed steers.

In Exp. 3, calves had improved ADG and G:F with WDGS usage compared with feeding DRC and SoyPass. The improvement in ADG and feed efficiency occurred even though the same ADG was targeted for WDGS and DRC diets. This is likely due to the low amount of starch and energy density of fat, undegradable protein, and corn fiber in DGS. In Exp. 4, no differences were observed between WDGS, DDGS, or DRC diets for ADG or G:F; this was done by targeting equal ADG between treatments before the initiation of the experiment in a similar manner to Exp. 2 and 3 but with greater assumed TDN value of WDGS. Increasing the inclusion of DGS or DRC supplemented in Exp. 1, 3, and 4 did increase ADG and G:F. According to Loy et al. (2008), similar results were observed when heifers were fed greater amounts of DDGS and DRC plus corn gluten meal compared with DRC.

Nutrient Profile of DGS

Griffin et al. (2012) observed linearly increasing ADG and quadratically increasing DMI with increasing levels of DDGS supplementation, similar to Exp. 1. The nutrient composition of DGS has shown variation among batches and plants with CP content between 28.7 and 34.0% of DM and fat content between 8.8 and 13.3% of DM (Spiehs et al., 2002; Buckner et al., 2011). Crude protein is composed of RDP, RUP, and NPN. Rumen undegradable protein is an important factor in cattle diets, and especially important in growing calf diets. Castillo-Lopez et al. (2013) determined the RUP content of DDGS to be 63% of CP. In a review conducted by Klopfenstein (1996) evaluating RUP supplementation in growing cattle, he discussed that with greater inclusions of supplemental RUP, BW gain increases. The increased BW gain is due to RUP meeting an MP deficiency, plus added energy. Differentiating between energy and protein responses is a challenge due to the potential to increase microbial production with energy supplementation and not being able to determine whether additional MP is from microbial residue or protein supplementation (Griffin et al., 2012).

Rapid fermentation of starch in DRC-based diets decreases rumen pH, which when coupled with other mechanisms of starch and fiber digestion, can affect fibrolytic activity in the rumen (Fieser and Vanzant, 2004). The increased feeding value of DGS in relation to DRC is attributed to decreased negative associative effects on fiber digestion that are observed with increasing amounts of starch.

Loy et al. (2008) used the NRC (1996) model to predict actual cattle performance. Due to underpredicted cattle performance at lower rates of BW gain, NE adjusters, within the model, were increased above 100%. Adjustments made to the NE adjusters were used for energy (TDN) calculations. Loy et al. (2008) suggested the TDN concentration, predicted using the NRC (1996) model, of DDGS declined as the level of DDGS inclusion increased. They also stated that the decline in energy could be due to an increase in fat content of the diet as inclusion of DDGS increased. Loy et al. (2007) suggested this increase in fat concentration, with greater inclusion of DDGS, had negative effects on ruminal fibrolytic activity. MacDonald et al. (2007) conducted an experiment using grazing heifers supplemented with DDGS, corn gluten meal, or corn oil. Cattle supplemented with DDGS showed a linear increase in ADG, whereas corn oil supplementation did not affect ADG. MacDonald et al. (2007) stated that an associative effect relative to protein and fat available from DDGS may cause the additional BW gain observed in cattle supplemented with DDGS.

Several experiments conducted by Corrigan et al. (2009) examined the effects of feeding different levels of dried distillers grains (**DDG**) and differing proportions of condensed distillers solubles (**CDS**) added back to DDG in forage-based diets. As expected, as inclusion of DDG increased, ADG increased. Steers responded quadratically to the 2 greatest CDS levels when supplemented with DDG at 0.5 and 0.75% of BW. However, ADG decreased at the greatest CDS level and when supplemented with DDG at 1.0% of BW, suggesting that the fat inclusion in the diet had a limiting effect on digestibility. Wilken et al. (2009a) conducted an experiment comparing ensiled CDS and WDGS fed to growing calves at differing levels. Similar to our experiments, as level of by-product increased, final BW, ADG, and G:F increased. Laboratory analysis performed on the feed ingredients showed fat to be greater for CDS than WDGS. Cattle fed WDGS had improved G:F compared with cattle fed CDS at the same inclusion (DM basis; Wilken et al., 2009a). Conclusions from these experiments indicate that fat available from by-products may affect growth performance at increased inclusions, although fat combined with RUP is an excellent energy source. Hess et al. (2008) suggested that total fat should not exceed 2 to 3% of dietary DM to prevent any negative associative effects on fiber digestion. The quadratic response, observed in Exp. 3, may be attributed to fat exceeding 3% of the diet DM when feeding WDGS at 35%. With the exception of the 35% inclusion of WDGS in Exp. 3, fat did not exceed 3% of the diet DM in the other experiments.

Improvements in ADG and G:F observed in Exp. 3 may be due to the increased fat content of WDGS diets relative to DRC diets. Another explanation is how grass hay was used compared with Exp. 4. In Exp. 3, sorghum silage was held constant in all diets, whereas grass hay was replaced with WDGS or DRC. In Exp. 4, a blend of sorghum silage and grass hay was replaced with the energy supplements. This would affect NDF content of all diets. Grass hay in Exp. 2 was replaced, and sorghum silage was held constant, similar to Exp. 3; however, only numerical differences in ADG and G:F were observed. The pooled data are evaluated as such to account for variation among studies. The energy values for DDGS determined previously (Loy et al., 2008) were 130% the energy content of corn when DDGS was fed at 10% of diet DM and 118% when fed at 33% of diet DM. The energy values from our experiments are slightly greater than determined by Loy et al. (2008): 137% the energy value of corn when fed at 15% of diet DM and 136% when fed at 30% of diet DM. The difference in energy value may be attributed to supplementing cattle as a percentage of BW versus feeding a fixed amount in the diet. In the study by Loy et al. (2008), cattle were supplemented either 0.21 or 0.81% of BW, which is relatively small compared with DGS inclusion in our experiments (pooled data). The number of observations included in the pooled data suggest greater accuracy in the predicted energy values relative to Loy et al. (2008).

Wet Versus Dry DGS

Data from Exp. 1 suggest there are no differences between types of DGS supplementation (wet or dry) in forage-based growing diets. Bremer et al. (2011) evaluated 20 experiments where WDGS was fed and 4 experiments where DDGS was fed to finishing cattle in a meta-analysis. Studies used in the meta-analysis included WDGS and DDGS at 10, 20, 30, or 40% of diet DM. Results showed a quadratic increase in G:F with increasing WDGS and a linear increase in G:F with increasing DDGS. Optimum feeding level for WDGS was between 30 and 40% of diet DM. The energy value of WDGS was 130 to 150% the energy value of corn, decreasing as inclusion increased. The energy value of DDGS was 112% the energy value of corn. In finishing diets, WDGS have a greater energy value than DDGS. This is in contrast to findings in the current studies, using forage-based diets for growing calves, in which DDGS and WDGS had similar energy values.

Data from Exp. 1 and 4 suggest there are no differences in energy value between WDGS and DDGS; there were no statistical differences in growth performance between DDGS and WDGS. However, without a direct comparison in all 4 experiments, we are unable to definitively conclude that WDGS and DDGS have the same energy content in forage-based diets. Wilken et al. (2009b) conducted an experiment comparing DDGS and modified DGS with wet (corn silage) or dry (oat hay: oat straw mix and DRC) forage. They found no interaction between forage type and by-product type. Similar to Exp. 1, there were no statistical differences in DMI, ADG, or G:F between DDGS and modified DGS. This further supports evidence from Exp. 1 and 4 that the energy value of DDGS and WDGS is not different in forage-based diets.

IMPLICATIONS

These experiments reiterate that DGS (dry and wet) have a high energy value relative to corn in forage-based diets. The moisture content of DGS does not affect the energy value relative to DRC in a forage-based diet. Cattle performance increased quadratically as inclusion of DGS increased up to 35% of dietary DM. The energy density of the fat, undegradable protein, and corn fiber in DGS are possible reasons DGS have greater energy value than corn when supplemented in forage-based diets.

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