Evaluation of Corn and Sorghum Distillers Byproducts[1]

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ABSTRACT: Two trials were conducted to determine the feeding value of sorghum distillers byproducts. Trial 1, a finishing trial, used 160 yearling steers (327 kg). Treatments consisted of dry-rolled corn (DRC) control, sorghum wet distillers grains (SWDG), sorghum wet distillers grains plus solubles (SWDGS), and sorghum dried distillers grain plus solubles (SDDGS). Distillers byproducts were fed at 40% of the diet DM. Cattle fed diets containing SWDG, SWDGS, or DRC were similar in efficiency of gain ($P > .10$); cattle fed SDDGS were less efficient ($P < .10$) than all other treatments. Sorghum wet distillers grains, SWDGS, and SDDGS contained 96, 102, and 80% relative NE_g of corn, respectively. In Trial 2, 16 crossbred lambs (55 kg) were used to determine the digestibility of sorghum and corn distillers byproducts. Byproducts were fed at 80% of the diet DM and treatments consisted of corn wet distillers grains (CWDG), corn dried distillers grains plus solubles (CDDGS), SWDG, and SDDGS. Neutral detergent fiber digestibility was not different among treatments ($P > .10$). Corn wet distillers grains were higher in true nitrogen ($P < .001$), apparent nitrogen ($P < .01$), and organic matter digestibility ($P < .05$) than SWDG. Wet distillers byproducts were higher ($P < .01$) in apparent organic matter and nitrogen digestibility than dried distillers byproducts. Digestibility of distillers byproducts and subsequent energy values are influenced by type of grain used in the fermentation process and drying of the finished byproduct.

Key Words: Distillers Grains, Distillers Solubles, Digestibility, Sorghum, Corn, Cattle

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Introduction

Distillers byproducts are a good source of protein and energy in cattle diets (Rouse and Trenkle, 1980; Farlin, 1981; Larson et al., 1993; Ham et al., 1994). The majority of research has been conducted with distillers byproducts produced primarily from the fermentation of corn. Dry milling plants and commercial distilleries have the flexibility to use a variety of cereal grains to produce ethanol, corn flour, distillers byproducts, and condensed distillers solubles. However, this flexibility may affect the feeding value of distillers byproducts. Ward and Matsushima (1981) observed no difference in gain or efficiency when steers were fed a steam-flaked corn finishing diet or steam-flaked corn diets containing a blend of sorghum and corn dried distillers byproducts. Larson et al. (1993) replaced dry-rolled corn with corn distillers byproducts produced by a small on-farm distillery plant. As the level of byproducts increased (5.2, 12.6, and 40% of the diet DM) in the diet, rate and efficiency of gain were improved. Thus, the objectives of the trials reported herein were to determine the digestibility and NE_g value of distillers grains produced from a fermentation blend of approximately 80% grain sorghum and 20% corn at a commercial dry milling fuel ethanol plant.

Materials and Methods

Trial 1

A finishing trial was conducted beginning December 8, 1994, for 130 d. One hundred sixty crossbred yearling steers (BW = 352 ± 27 kg) were used to evaluate distillers byproducts produced at a commercial ethanol plant (Chief Industries Inc., Hastings, NE) using a grain blend of approximately 80% sorghum and 20% corn. Cattle were blocked by weight into four blocks and allotted randomly within block to one of four treatments (four pens per treatment, 10 steers per pen). Blocks were 304 ± 6, 320 ± 5, 333 ± 5, and 354 ± 11 kg initial body weight. Treatments consisted of dry-rolled corn (**DRC**) control, sorghum wet distillers grains (**SWDG**), sorghum wet distillers

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grains plus solubles (**SWDGS**), and sorghum dried distillers grains plus solubles (**SDDGS**). Distillers byproducts were fed at 40% of the dietary DM. All diets contained 78.9% DRC or DRC plus distillers byproduct, 5% alfalfa hay, 5% corn silage, 6.1% molasses, and 5% dry supplement (DM basis; Table 1). Diets were formulated (DM basis) to contain a minimum of 13.0% CP, .7% Ca, .3% P, .65% K, and contained 28 mg monensin (Elanco Animal Health, Indianapolis, IN) per kilogram of dietary DM and 11 mg of tylosin (Elanco Animal Health) per kilogram of dietary DM. Supplemental protein (as a percentage of total supplemental nitrogen) for the control diet was composed of 50% escape protein (80:20 blend [CP basis] of feather meal and blood meal) and 50% urea. Distillers byproducts replaced feather meal, blood meal, urea, and a portion of the corn. The proportion of wet distillers grains to condensed distillers solubles in the SWDGS treatment was a ratio (2:1; DM basis) determined by Larson et al. (1993) and Ham et al. (1994). Steers were adapted to final diets in 21 d using four grain adaptation diets containing 45 (3 d), 35 (4 d), 25 (7 d), and 15% forage (7 d; DM basis). Forage was a mixture of corn silage and alfalfa hay with corn silage assigned a value of 50% forage. Wet distillers grains were delivered monthly to the Beef Feedlot, Agricultural Research and Development Center, Mead, NE and stored on a covered concrete pad. Trial composites for SWDG and SDDGS were analyzed for DM content (AOAC, 1975), Kjeldahl N (AOAC, 1975), NDF (Robertson and Van Soest, 1977), ADF (Robertson and Van Soest, 1977), and lipid (chloroform-methanol extraction; Moore et al., 1986). Cattle were implanted at the beginning of the trial with Revalor (Hoechst Roussel, Somerset, NJ), housed in outside pens, and allowed ad libitum access to feed with fresh feed provided daily. Initial weights were based on the average of two consecutive day weights taken before feeding. To minimize variation in gut fill, hot carcass weight adjusted for 62% dressing percentage was used to calculate final weight. Cattle were slaughtered at the IBP plant at West Point, NE and grades were determined by the USDA grader. Hot carcass weight and liver abscess score were recorded at slaughter. Livers were scored by a modification of the Elanco Products Company (1974) procedure using the following system: 0 = healthy; 1 = one to four small abscesses; 2 = one to four medium abscesses; 3 = one or more large abscesses; and 4 = adherence of abscess to diaphragm and digestive tract. Fat thickness, quality grade, and yield grade were recorded after the carcasses were chilled for 48 h.

Table 1. Composition of yearling finishing diets (% of DM)

Item	Control	SWDG[a]	SWDGS[a]	SDDGS[a]
Dry-rolled corn	78.9	38.9	38.9	38.9
SWDG	—	40.0	26.7	—
SDDGS	—	—	—	40.0
Condensed distillers solubles	—	—	13.3	—
Molasses	6.1	6.1	6.1	6.1
Corn silage	5.0	5.0	5.0	5.0
Alfalfa hay	5.0	5.0	5.0	5.0
Dry supplement				
Finely ground corn	.96	2.89	2.89	3.10
Tallow	.10	.10	.10	.10
Feather meal	1.47	—	—	—
Blood meal	.36	—	—	—
Limestone	1.46	1.39	1.39	1.39
Potassium chloride	.24	.34	.34	.13
Salt	.21	.21	.21	.21
Urea	.13	—	—	—
Trace mineral premix[b]	.02	.02	.02	.02
Vitamin premix[c]	.02	.02	.02	.02
Monensin premix[d]	.02	.02	.02	.02
Tylosin premix[e]	.01	.01	.01	.01
Nutrient composition[f]				
Crude protein	13.0	17.5	17.9	17.5
NDF	11.9	25.8	26.2	25.8
Dry matter	79.4	46.9	81.5	45.1

[a]SWDG = sorghum wet distillers grains; SWDGS = sorghum wet distillers grains plus solubles; SDDGS = sorghum dried distillers grains plus solubles.
[b]10% Mg, 6% Zn, 4.5% Fe, 2% Mn, .5% Cu, .3% I, and .05% Co.
[c]15,000 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of vitamin E/g premix.
[d]132 g monensin/kg premix.
[e]88 g tylosin/kg premix.
[f]Based on ingredient values measured in our laboratory.

Net energy for gain of each diet was calculated using the procedures outlined by Larson et al. (1993). These calculations include the NE_g of each grain adaptation diet as well as the final finishing diet. The net energy required for gain (**NE_gR**) was calculated using the equation $NE_gR = .0557\ BW^{.75}(ADG^{1.097})$, where NE_gR (Mcal/kg gain) is the net energy required for daily weight gain (ADG; NRC 1984). Maintenance net energy required (**NE_mR**, Mcal/d) was calculated by the equation $NE_mR = .077\ BW^{.75}$ (NRC, 1984). The NE content of the diet was assumed to fit the relationship: $NE_g = .877\ NE_m - .41$ (derived from NRC, 1984; Zinn, 1989). By the process of iteration, the NE_g and NE_m contents (Mcal/kg) of the diets were calculated to fit the equation DMI (kg/d) = $(NE_gR/NE_g) + (NE_mR/NE_m)$. The NE_g content of the distillers byproducts was calculated by substitution, assuming basal ingredients possess the same energy value (NRC, 1984) across all diets. The NE_g content of condensed distillers solubles was calculated by substitution assuming all basal ingredients in the SWDG diet contained the same energy value as when fed in the SWDGS diet.

Finishing performance and carcass traits were analyzed as a randomized complete block design according to the GLM procedure of SAS (1989). Pen was used as an experimental unit and model effects included treatment and block. Least squares means were separated using the Least Significant Difference method when a significant ($P < .10$) F-test was detected.

Trial 2

Sixteen crossbred wether lambs (BW = 55 ± 5 kg) were blocked by weight and allotted randomly within block (blocks were 51, 54, 57, and 58 kg) to one of four treatments consisting of the following: 1) corn wet distillers grains (**CWDG**), 2) SWDG, 3) SDDGS, and 4) corn dried distillers grains plus solubles (**CDDGS**). Sorghum wet distillers grains and SDDGS were from the same sources as the byproducts used in Trial 1; however, the SDDGS were from a different fermentation batch. Corn wet distillers grains were produced at a commercial dry milling plant (High Plains Corp., York, NE). Corn dried distillers grains plus solubles were the same product (designated as medium acid detergent insoluble nitrogen) described by Ham et al. (1994). Wet distillers byproducts were frozen in drums, thawed as needed, and stored at 3°C until fed. Diets (Table 2) contained 80% distillers byproducts, 10% molasses, 8% alfalfa hay, and 2% vitamins, minerals, and urea (DM basis). Urea was used to equalize CP content of all diets. Diets were fed at 3.0% (DM basis) of body weight once daily. The trial consisted of a 7-d adaptation period and a 7-d fecal collection period and was replicated twice (eight total lambs per treatment), with no lamb receiving the same treatment twice.

Composite samples of distillers byproducts and alfalfa hay were collected each time a batch of feed was mixed (every 3 d). Orts were collected daily from each animal, weighed to determine DM, sampled, and discarded. Feed, feces, and orts were oven-dried at 60°C for 72 h to determine DM content of each sample. Samples were analyzed for Kjeldahl N, NDF, lipid (feed only) as previously described in Trial 1, ash (AOAC, 1975), and starch (Herrera-Saldana and Huber, 1989). Crude protein, NDF, and organic matter content of each diet was determined using the values from our laboratory. Neutral detergent fiber, apparent organic matter, and apparent nitrogen digestibility were calculated using the following equation: Nutrient digestibility = ([amount of nutrient in diet − amount of nutrient in feces]/amount of nutrient

Table 2. Composition of digestibility diets (% of DM)

Item	CWDG[a]	SWDG[a]	SDDGS[a]	CDDGS[a]
CWDG	80.0	—	—	—
SWDG	—	80.0	—	—
SDDGS	—	—	80.0	—
CDDGS	—	—	—	80.0
Molasses	10.0	10.0	10.0	10.0
Alfalfa hay	8.0	8.0	8.0	8.0
Limestone	1.60	1.98	1.80	1.80
Urea	.38	—	.18	.18
Trace mineral premix[b]	.01	.01	.01	.01
Vitamin premix[c]	.01	.01	.01	.01
Nutrient composition[d]				
Crude protein	20.0	21.1	22.2	27.8
NDF	50.0	50.0	55.6	56.9

[a]CWDG = corn wet distillers grains; SWDG = sorghum wet distillers grains; SDDGS = sorghum dried distillers grains plus solubles; CDDGS = corn dried distillers grains plus solubles.
[b]10% Mg, 6% Zn, 4.5% Fe, 2% Mn, .5% cu, .3% I, and .05% Co.
[c]15,000 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of vitamin E/g premix.
[d]Based on ingredient values measured in our laboratory.

Table 3. Nutrient composition of distillers byproducts[a]

Item[b]	CWDG[c]	SWDG[c]	SDDGS[c]	CDDGS[c]
Dry matter, %	31.3	23.5	91.4	92.2
Crude protein	29.6	31.6	31.4	29.2
Starch	4.6	10.2	7.4	5.1
Lipid	13.7	11.3	11.8	11.4
NDF	51.9	45.4	51.1	51.3
Ash	1.2	2.5	1.8	2.0

[a]Based on values from finishing and digestibility trials.
[b]All values, except DM, expressed as a percentage, DM basis.
[c]CWDG = corn wet distillers grains; SWDG = sorghum wet distillers grains; SDDGS = sorghum dried distillers grains plus solubles; CDDGS = corn dried distillers grains plus solubles.

in diet) × 100. True nitrogen digestibility was calculated using neutral detergent fiber insoluble nitrogen as the measure of indigestible N in feces.

True and apparent nitrogen, NDF, and apparent organic matter digestibilities were analyzed as a randomized complete block design according to the GLM procedures of SAS (1989). Lamb was used as the experimental unit. Model effects included treatment and lamb in replication. Treatment contrasts included CWDG and SWDG vs SDDGS and CDDGS; SWDG vs CWDG; and SDDGS vs CDDGS. A significant difference was detected when an *F*-test of ($P < .10$) was detected.

Results

The nutrient composition of the byproducts used in these trials is given in Table 3. Sorghum distillers byproducts numerically contained more crude protein and starch than corn distillers byproducts. Additionally, corn wet distillers grains contained more lipid than all other byproducts.

In Trial 1, no differences were seen in daily gain or dry matter intake among treatments ($P > .10$; Table 4). Feed efficiencies of cattle fed SWDG, SWDGS, or DRC were similar ($P > .10$); however, steers fed SDDGS were less efficient ($P < .05$) than all other treatments. Fat thickness, quality grade, yield grade (data not shown), and liver abscess scores (data not shown) were not different among treatments ($P > .10$). The NE_g content of SWDG, SWDGS, and DRC diets was similar ($P > .10$). The NE_g content of the SDDGS diet was lower ($P < .05$) than all other treatments. Compared with corn, the relative NE_g value of SWDG, SWDGS, and SDDGS was 96, 102, and 80%, respectively. The relative energy value of condensed distillers solubles in the SWDGS treatment was 113% that of corn.

In Trial 2, apparent organic matter ($P < .001$), apparent nitrogen ($P < .01$), and true nitrogen ($P < .01$) digestibility was the highest for wet distillers grains and lowest for dried distillers grains plus solubles ($P < .001$; Table 5). When comparing CWDG with SWDG, CWDG was higher ($P < .05$) in apparent organic matter, true nitrogen ($P < .001$), and apparent nitrogen ($P < .01$) digestibility. No differences in NDF digestibility ($P > .10$) were observed among treatments.

Discussion

The energy values obtained in Trial 1 were lower than values reported in the literature for corn distillers byproducts. Larson et al. (1993) fed corn

Table 4. Effect of sorghum wet and dry distillers byproducts on finishing yearling performance and net energy for gain

Item	Control	SWDG[a]	SWDGS[a]	SDDGS[a]	SEM
DM intake, kg/d	12.11	11.97	12.23	12.49	.38
Daily gain, kg	1.86	1.83	1.91	1.78	.10
Gain/feed	.153[b]	.153[b]	.155[b]	.142[c]	.003
NE_g, Mcal/kg[d]	1.29[b]	1.29[b]	1.32[b]	1.20[c]	.02
Fat thickness, cm	1.1	1.1	1.1	1.1	.03
Quality grade[f]	18.8	19.0	19.0	19.3	.3

[a]SWDG = wet distillers grains; SWDGS = wet distillers grains plus solubles; SDDGS = dried distillers grains plus solubles.
[b,c]Means within a row with unlike superscripts differ ($P < .05$).
[d]Based on cattle performance (Larson et al., 1993).
[f]High Select = 18; Low Choice = 19.

Table 5. Digestibility of corn and sorghum distillers byproducts (%)

Item	CWDG[a]	SWDG[a]	SDDGS[a]	CDDGS[a]	SEM
Apparent organic matter[b]	85.6	80.8	73.7	71.6	1.5
NDF	77.8	75.9	76.4	71.7	2.2
Apparent nitrogen[c]	82.8	77.3	74.3	65.5	2.1
True nitrogen[d]	93.8	89.4	88.1	78.4	1.0

[a]CWDG = corn wet distillers grains; SWDGS = sorghum wet distillers grains plus solubles; SDDGS = sorghum dried distillers grains plus solubles; CDDGS = corn dried distillers grains plus solubles.
[b]CWDG vs SWDG ($P < .05$); CWDG and SWDG vs SDDGS and CDDGS ($P < .001$).
[c]CWDG vs SWDG ($P < .01$); SDDGS vs CDDGS ($P < .001$); CWDG and SWDG vs SDDGS and CDDGS ($P < .01$).
[d]CWDG vs SWDG ($P < .001$); SDDGS vs CDDGS ($P < .001$); CWDG and SWDG vs SDDGS and CDDGS ($P < .01$).

wet distillers grains and thin stillage, produced from a farm-scale alcohol plant, at 5.2, 12.6, and 40% of dietary DM and reported that wet distillers byproducts contained 80, 62, and 47% more NE_g, respectively, than corn when fed to yearling steers. More recently, Ham et al. (1994) reported that cattle fed corn wet distillers grains plus thin stillage gained faster ($P < .05$) and more efficiently ($P < .05$) than cattle fed a DRC control diet. Corn wet distillers grains plus thin stillage contained 39% more NE_g than DRC and dried distillers grains plus solubles contained 21% more NE_g than DRC in the study by Ham et al. (1994). In our trial, SWDG and SWDGS contained 96 and 102%, respectively, the energy value of corn. The SDDGS were lower in NE_g, with only 80% the energy value of corn.

A combination of factors may contribute to the differences in energy value between sorghum and corn distillers byproducts. Starch is removed during fermentation and the remaining nutrients are concentrated. The remaining nutrients include lipid (corn oil), protein, and fiber. The lipid content of the corn wet distillers grains, used in Trial 2, was 13.7% (DM basis). This is similar to the value reported by Larson et al. (1993). Sorghum wet distillers grains contained 10.2% lipid (DM basis). Fat contains three times more NE_g than does corn (Zinn, 1989); however, Larson et al. (1993) noted the lipid content of the corn wet distillers grains could only account for wet corn distillers byproducts containing 9% more energy than corn in their trials. Farlin (1981) and Firkins et al. (1985) speculated that the increased feed efficiency when wet corn distillers byproducts are fed may be due in part to a reduction in subacute acidosis. High starch intake leads to increased production of ruminal organic acids that may result in subacute acidosis (Burrin and Britton, 1986), resulting in reduced gain and efficiency (Stock et al., 1990). Subacute acidosis is characterized by fluctuations in feed intake (Burrin and Britton, 1986). The starch content of the SWDG was higher (10.2%; DM basis) than that of SDDGS, CDDGS, and CWDG (mean = 5.7%; DM basis). But, in Trial 1, DMI was not different among treatments. Therefore, the higher starch content of SWDG did not increase the risk of acidosis compared with SDDGS. Cattle also attempt to eat to a constant energy level (Baile and Della-Fera, 1981; Miner, 1992). Because SWDG and SWDGS were similar in energy content to corn, similar intakes would be expected. However, SDDGS contained only 80% the energy value of corn and DMI increased slightly.

The effect of drying on distillers byproducts has been debated by numerous authors (Van Soest and Sniffen, 1984; Britton et al., 1986; Chase, 1987; Klopfenstein, 1987; Van Soest, 1989; Weiss et al., 1989). Ham et al. (1994) used the same CDDGS as was used in Trial 2. These authors observed that distillers byproducts fed wet or dry to growing cattle had no effect on protein efficiency. When CDDGS and CWDG plus thin stillage were fed in finishing diets, efficiency was improved 9.5 and 18.7%, respectively, compared with cattle fed the DRC. Aines et al. (1987) summarized numerous studies conducted with wet or dried distillers grains and reported that dried distillers byproducts are equal or slightly superior in energy value to DRC. In Trial 2, wet distillers grains were more digestible than dried distillers grains plus solubles ($P < .10$) regardless of grain type. This could be a result of dried grains being smaller in particle size (Firkins et al., 1985) and having a faster rate of passage, reducing the amount of time spent in the digestive tract. Differences in particle size among the byproducts was not measured in these trials. Wet distillers grains were higher ($P < .001$) in apparent organic matter digestibility than dried distillers grains plus solubles, perhaps indicating more complete ruminal digestion.

It is well documented that corn grain is more digestible than sorghum grain (Riley, 1984; Rooney and Pflugfelder, 1986; Wester et al., 1992). Zinn (1991) reported a decrease in gains (6.1%; $P < .05$) when steam-flaked sorghum replaced steam-flaked corn in finishing steer diets. Additionally, this author estimated that steam-flaked sorghum had 92% the NE_m of steam-flaked corn. Therefore, the type of grain used during the fermentation process to produce wet and dried distillers byproducts could affect the feeding value of the byproducts.

Firkins et al. (1985) suggested that increases in gain and efficiency observed when corn wet distillers byproducts replaced corn could be due to a higher digestible energy content of wet distillers grains than of corn. These authors also theorized that removal of the starch, during the distilling process, may result in a feed product that would reduce ruminal pH less than corn. The higher ruminal pH may allow for greater fiber digestibility. In addition, replacing corn with a highly digestible fiber source, such as distillers grains (DeHaan, 1983), may cause a shift in organic matter digestion to the small intestine (Ham et al., 1994). A number of authors have reported that shifting the site of organic matter digestion from the rumen to the lower gut may result in more efficient energy utilization by reducing losses associated with fermentation (Blaxter, 1962; Øsrkov et al., 1969; Black and Tribe, 1973). Ruminal fiber digestibility is usually low in finishing diets (Axe et al., 1987; Stock et al., 1987). In Trial 2, NDF digestibility was not different ($P > .10$) among treatments and was relatively high (> 70%) for all treatments. Ward and Matsushima (1981) evaluated dried distillers grains and found performance to be similar to the steam-flaked corn control diet. Distillers grains used by these authors were from corn, sorghum, and a mixture of grains and contained less fat and CP than the distillers byproducts used in our trials. The combination of less digestible organic matter and nitrogen may decrease the feeding value of SWDG compared with CWDG.

Implications

Distillers byproducts produced from the fermentation of sorghum seem to have a lower energy value than corn distillers byproducts. This reduction in feeding value could be a result of the organic matter of sorghum wet distillers grain being less digestible than corn wet distillers grains. Even though the feeding value of the sorghum wet distillers grains is lower than what has been observed with corn distillers grains, it is still equal or slightly higher in net energy for gain compared with corn grain.

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