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Effect of feeding combinations of wet distillers grains and wet corn gluten feed to feedlot cattle[1]

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ABSTRACT: Three experiments were conducted to evaluate the use of combinations of wet corn gluten feed (WCGF) and wet distillers grain plus solubles (WDGS) in dry-rolled and high-moisture corn-based finishing diets for beef cattle. In Exp. 1, 250 steers (BW = 343 ± 13.5 kg) were fed 5 treatments consisting of a corn-based, control diet with 0% coproducts, and diets including 30% WCGF, 30% WDGS, 15% WCGF plus 15% WDGS, or 30% WCGF plus 30% WDGS. No associative effects resulted from feeding 15% WCGF plus 15% WDGS; DMI, ADG, and G:F were intermediate between steers fed WCGF or WDGS at 30% of diet DM. Feeding coproducts in combinations at 30 and 60% of diet DM increased ADG, G:F, and final BW ($P < 0.05$) compared with the corn-based diet. In Exp. 2, 280 yearling steers (BW = 370 ± 0.45 kg) were used to evaluate feeding 0, 25, 50, or 75% coproducts as a combination of 50% WCGF:50% WDGS (DM basis). Additional diets were fed containing decreased alfalfa hay at 5, 2.5, and 0% (DM basis) as coproduct blend inclusions increased at 25, 50, and 75% (DM basis), respectively. No interactions were observed between alfalfa hay and coproduct blend levels, and no effects on ADG or G:F ($P > 0.21$) were observed due to alfalfa hay. Intake, ADG, and G:F responded quadratically ($P < 0.05$) across coproduct levels, with the greatest ADG and G:F at 25 and 50% blend, and similar ADG and G:F for the 0 and 75% blend levels. In Exp. 3, 504 steers (BW = 376 ± 16 kg) were fed to evaluate 0, 10, 15, 20, 25, and 30% (DM basis) WDGS in diets containing 30% WCGF (DM basis) as well as a control diet with no coproducts. The inclusion of 30% WCGF in the diets increased DMI, ADG, and G:F ($P < 0.05$) when compared with control. Response to inclusion level of WDGS tended to be quadratic for DMI ($P = 0.12$), quadratic for ADG ($P = 0.05$), and no effect for G:F ($P = 0.96$). Greatest ADG was achieved with 15 to 20% WDGS inclusion in diets containing 30% WCGF. The use of combinations of WCGF and WDGS in finishing diets resulted in similar or improved steer performance compared with corn, suggesting replacement of corn with coproduct combinations up to 75% diet DM is possible if a roughage source is fed.

Key words: corn, distillers grain, finishing cattle, gluten feed

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INTRODUCTION

The expansion of the corn milling industry to make ethanol and sweeteners in the United States will continue to increase coproduct feed production. Two of these coproducts most frequently fed in cattle finishing diets are wet corn gluten feed (**WCGF**) and wet distillers grains plus solubles (**WDGS**; Stock et al., 2000). Feeding WCGF at 30% DM inclusion in finishing diets is beneficial in controlling acidosis (Krehbiel et al., 1995) and may allow a reduction in roughage inclusions in feedlot diets (Farran et al., 2006). Traditionally considered a source of protein in the diet, WCGF and WDGS are currently included as an energy source due to their cost competitiveness (Block et al., 2005; Klopfenstein et al., 2008). Ham et al. (1994) and Larson et al. (1993) observed an increase in G:F of 18 and 20%, respectively, when diets included 40% WDGS (DM basis) compared with a dry-rolled corn (**DRC**) control diet. More recently, feeding WDGS resulted in maximum ADG and G:F when the inclusion level was at 40% of diet DM (Klopfenstein et al., 2008), but a 50% DM inclusion resulted in decreased ADG. The relatively greater fat and S content in WDGS could be the cause of the decreased response observed when increased quantities of this co-

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product were fed to finishing cattle. Feeding a combination of WCGF and WDGS provides an opportunity to replace more expensive grain in finishing diets.

The objectives for Exp. 1 were to determine if feeding a WDGS and WCGF combination would result in associative effects compared with feeding each coproduct alone and to compare feeding a 60% coproduct blend diet with a dry-rolled, high-moisture corn-based diet. The objectives of Exp. 2 were to evaluate the effects of inclusion level of a WCGF and WDGS mixture and to evaluate forage inclusion levels with those mixtures on animal performance and carcass characteristics. The objective of Exp. 3 was to determine the optimum WDGS inclusion level in finishing diets containing 30% WCGF.

MATERIALS AND METHODS

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

Exp. 1

Two hundred fifty crossbred, steer calves (BW = 343 ± 13.5 kg) were used in a randomized complete block design experiment to compare a DRC and high-moisture corn- (**HMC**) based control with no coproducts, a coproduct blend of WCGF and WDGS, or these coproducts alone in finishing diets to evaluate performance and carcass characteristics. Upon arrival at the feedlot in October 2004, steers were individually identified and vaccinated with Pyramid 4 (for prevention of infectious bovine rhinotracheitis, bovine viral diarrhea, bovine respiratory syncytial virus, and parainfluenza-3, Fort Dodge Animal Health, Overland Park, KS) and Somubac (for prevention of *Haemophilus somnus*, Pfizer Animal Health, New York, NY) and given an internal parasiticide (Dectomax, Pfizer Animal Health). Approximately 14 d after initial processing, steers were revaccinated with Pyramid 4 (Fort Dodge Animal Health), Vision 7 (for prevention of *Clostridium chauvoei*, *septicum*, *novyi*, *sordellii*, and *perfringens* type C and D infections; Intervet-Schering Plough, Millsboro, DE), and injected with Piliguard Pinkeye Triview (for prevention of pinkeye, Intervet-Schering Plough). Steers grazed corn stalks during the winter and were supplemented with 2.27 kg of WCGF daily. Before experiment initiation in February, steers were limit-fed a diet consisting of 50% alfalfa hay and 50% WCGF (DM basis) at 2.0% of BW (6.9 kg of DM) for 5 d, then weighed on 2 consecutive days (d 0 and d 1). These BW were averaged (343 kg) and used as initial BW for performance calculations. Steers were blocked into 3 BW blocks (1 heavy, 3 moderate, 1 light), stratified by BW within block, and assigned randomly to pens based on d 0 BW. Pens were assigned randomly within block to 1 of 5 dietary treatments (5 pens/treatment) with 10 steers/pen. The experiment was conducted from February 10, 2005, through June 14, 2005.

Dietary treatments included a DRC- and HMC-based control with 0% coproducts, 30% WCGF (Sweet Bran, Cargill, Blair, NE), 30% WDGS (Abengoa Bioenergy, York, NE), 30% coproduct blend (15% WCGF plus 15% WDGS), and 60% coproduct blend (30% WCGF plus 30% WDGS) on a DM basis (Table 1). The composition of WDGS was 33% DM, 32% CP, 35% NDF, 13% fat, and 0.79% S (DM basis). Composition of WCGF was 60% DM, 24% CP, 39% NDF, 2.4% fat, and 0.50% S. When included, coproducts in the diets replaced a 1:1 ratio (DM basis) of DRC and HMC and urea in supplements to meet protein needs. High-moisture corn was stored in a bunker from September until the trial began in February and was rolled before ensiling and covered with plastic. All finishing diets contained 7% ground alfalfa hay and 5% dry supplement (DM basis). No additional fat sources were included in any of the diets. Minimum dietary CP of 13% was met in all diets by supplying urea in the dry supplement to only the control treatment, and all diets met or exceeded MP requirements (NRC, 1996). Limestone was provided in the dry supplement to ensure a minimum 1.2:1 ratio of Ca:P. The dry supplement was formulated to provide monensin (320 mg/steer daily; Elanco Animal Health, Greenfield, IN), thiamine (150 mg/steer daily; International Nutrition, Omaha, NE), and tylosin (90 mg/steer daily, Elanco Animal Health).

Steers were adapted to finishing diets over a 21-d period in which corn replaced alfalfa hay in diets at decreasing alfalfa hay levels of 44, 34, 24, and 14% (DM basis) using 4 adaptation diets that were fed for 3, 4, 7, and 7 d, respectively. Coproduct inclusions remained the same throughout the adaptation period to the finishing diets except for 60% coproduct blend treatment that included 51% coproduct blend and 44% alfalfa hay (DM basis), with no corn in the first step-up diet, then continued with 60% coproduct blend inclusion (DM basis) throughout the remainder of the experiment. Steers were fed ad libitum for 124 d at approximately 0800 h and allowed ad libitum access to water. Feed refusals were collected when feed was spoiled by weather or an excessive amount remained in the feedbunks, weighed, sampled, and stored frozen until analysis for DM, to accurately calculate DMI. Steers were implanted on d 28 with Revalor-S (containing 120 mg of trenbolone acetate and 24 mg of estradiol, Intervet-Schering Plough, Boxmeer, the Netherlands).

Both coproducts used in this study were delivered to the feedlot as needed (approximately 2 semi-truck loads weekly). Wet samples were taken from each delivered WDGS load and individually frozen and later analyzed for DM and CP using combustion (AOAC, 1999; method 990.03). Additionally, all feed samples were sampled weekly and analyzed for DM at 60°C for 48 h to obtain accurate DMI. All feed samples, except

Table 1. Composition and nutrient analysis for dry-rolled and high-moisture corn finishing diets containing wet corn gluten feed (WCGF) or wet distillers grains plus solubles (WDGS) at 30% of diet DM or a combination of both at 30 and 60% of diet DM for Exp. 1[1]

	Treatment[2]				
Item	Control	30WCGF	30WDGS	30Blend	60Blend
Ingredient					
Dry-rolled corn	44.0	29.0	29.0	29.0	14.0
High-moisture corn	44.0	29.0	29.0	29.0	14.0
Wet corn gluten feed	—	30.0	—	15.0	30.0
Wet distillers grains plus solubles	—	—	30.0	15.0	30.0
Alfalfa hay	7.0	7.0	7.0	7.0	7.0
Dry supplement	5.0	5.0	5.0	5.0	5.0
Fine-ground corn	1.188	2.928	2.798	2.888	2.758
Limestone	1.55	1.53	1.54	1.53	1.70
Urea	1.13	—	—	—	—
Potassium chloride	0.59	—	0.12	0.04	—
Sodium chloride	0.30	0.30	0.30	0.30	0.30
Tallow	0.13	0.13	0.13	0.13	0.13
Trace mineral premix[3]	0.05	0.05	0.05	0.05	0.05
Vitamin A-D-E premix[4]	0.02	0.02	0.02	0.02	0.02
Rumensin-80 premix[5]	0.017	0.017	0.017	0.017	0.017
Thiamine premix[6]	0.016	0.016	0.016	0.016	0.016
Tylan-40 premix[7]	0.009	0.009	0.009	0.009	0.009
Nutrient composition					
CP[8]	13.1	14.2	16.4	15.3	20.6
Ether extract[8]	4.19	3.56	6.77	5.17	6.14
Ca[9]	0.70	0.70	0.78	0.74	0.85
P[8]	0.31	0.49	0.45	0.47	0.63
K[9]	0.71	0.72	0.68	0.69	0.94
S[8]	0.13	0.24	0.45	0.29	0.44

[1] Values presented on a percent of DM basis.

[2] Where control = 0% coproduct; 30WCGF = 30% wet corn gluten feed (WCGF), 30Blend = 15% WCGF + 15% wet distillers grains plus solubles (WDGS), 30WDGS = 30% WDGS, 60Blend = 30% WCGF + 30% WDGS (DM basis); inclusion of coproducts replaces a 1:1 ratio of dry-rolled and high-moisture corns.

[3] Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, 0.05% Co.

[4] Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, 3.7 IU of vitamin E·g^{-1}.

[5] Premix contained 176 g of monensin·kg^{-1} (Elanco Animal Health, Greenfield, IN).

[6] Premix contained 88 g of thiamine·kg^{-1}.

[7] Premix contained 88 g of tylosin·kg^{-1} (Elanco Animal Health).

[8] Based on analyzed nutrients for each ingredient.

[9] Based on composition from NRC (1996) for each ingredient.

WDGS, were composited by month and analyzed for CP. All samples were also analyzed at a commercial laboratory (Ward Laboratories Inc., Kearney, NE) for ether extract (AOAC, 1999; method 920.39), P by wet ashing and colorimetric analysis (AOAC, 1999; methods 968.08 and 965.17), and S by wet ashing and colorimetric analysis (Tinsdale et al., 1985; AOAC, 1999; method 968.08).

The day before slaughter, steers were weighed using a pen scale to collect final BW and shipped on d 124. Final BW was pencil shrunk 4% for calculation of dressing percent. Steers were slaughtered on d 125 at a commercial abattoir (Greater Omaha Pack, Omaha, NE) where HCW and liver scores were recorded on day of slaughter. Fat thickness, LM area, % KPH, and USDA marbling scores were recorded after a 48-h chill. Calculated USDA yield grade was calculated as [2.50 + (6.35 × fat thickness, cm) + (0.0017 × HCW, kg) – (2.06 × LM area, cm^2) + (0.2 × KPH, %); Boggs and Merkel, 1993]. Final BW, ADG, and G:F were calculated based on HCW adjusted to a common dressing percentage of 63% to obtain an accurate final BW by minimizing errors associated with gut fill. Sulfate concentrations in water samples were analyzed and averaged 80 mg/kg from 2003 to 2008.

Exp. 2

Two hundred eighty crossbred, yearling steers (BW = 370 ± 0.45 kg) were used in a randomized complete block design experiment to evaluate the effect of feeding a blend of WCGF and WDGS at increasing inclusion levels and the effect of decreasing alfalfa hay levels as level of coproduct blend increased. Upon arrival at the feedlot in October, 2002, steers were received, identified, and given similar vaccinations to Exp. 1. Approximately 14 d after initial processing, steers were revaccinated with the same products as in Exp. 1. Steers grazed corn stalks during the winter and were supplemented with 2.27 kg of WCGF daily, and then grazed

Table 2. Composition and nutrient analysis for dry-rolled and high-moisture corn finishing diets containing increasing levels of a wet corn gluten feed (WCGF) and wet distillers grains plus solubles (WDGS) blend and different alfalfa hay inclusions for Exp. 2[1]

	Treatment[2]						
	0 CB	25 CB		50 CB		75 CB	
Item	7.5 AH	5 AH	7.5 AH	2.5 AH	7.5 AH	0 AH	7.5 AH
Ingredient							
Dry-rolled corn	43.75	32.5	31.25	21.5	18.75	10.0	6.25
High-moisture corn	43.75	32.5	31.25	21.5	18.75	10.0	6.25
Wet distillers grains plus solubles	—	12.5	12.5	25.0	25.0	37.5	37.5
Wet corn gluten feed	—	12.5	12.5	25.0	25.0	37.5	37.5
Alfalfa hay	7.5	5	7.5	2.5	7.5	—	7.5
Supplement	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Fine-ground corn	0.857	2.230	2.230	2.711	2.711	2.153	2.451
Limestone	1.53	1.69	1.69	1.75	1.75	2.32	2.03
Urea	1.10	0.25	0.25	—	—	—	—
Potassium chloride	0.48	0.318	0.318	0.023	0.023	—	—
Ammonium sulfate	0.521	—	—	—	—	—	—
Copper oxide	—	—	—	0.004	0.004	0.007	0.007
Sodium chloride	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Tallow	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Trace mineral premix[3]	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Rumensin-80 premix[4]	0.014	0.014	0.014	0.014	0.014	0.014	0.014
Vitamin A-D-E premix[5]	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Thiamine premix[6]	—	—	—	—	—	0.008	—
Tylan-40 premix[7]	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Nutrient composition							
CP[8]	13.4	15.2	15.4	19.9	20.2	24.6	25.1
Ether extract[8]	3.97	4.90	4.83	5.84	5.69	6.78	6.55
Ca[9]	0.70	0.90	0.93	1.02	0.97	1.03	1.01
P[8]	0.31	0.45	0.44	0.58	0.58	0.72	0.72
K[9]	0.66	0.73	0.76	0.81	0.87	0.99	1.08
S[8]	0.24	0.24	0.24	0.35	0.35	0.45	0.46

[1] Values presented on a percent of DM basis.

[2] Coproduct blend (CB) = proportion of total diet consisting of a 1:1 mix of WCGF and WDGS. AH = alfalfa hay.

[3] Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, 0.05% Co.

[4] Premix contained 176 g of monensin·kg^{-1} (Elanco Animal Health, Greenfield, IN).

[5] Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, 3.7 IU of vitamin E·g^{-1}.

[6] Premix contained 88 g of thiamine·kg^{-1}.

[7] Premix contained 88 g of tylosin·kg^{-1} (Elanco Animal Health).

[8] Based on analyzed nutrients for each ingredient.

[9] Based on composition from NRC (1996) for each ingredient.

brome grass pastures during the spring and summer. Before experiment initiation, steers were limit-fed the same diet as in Exp. 1 at 2.0% of BW (7.4 kg of DM) for 5 d, then weighed on 2 consecutive days (d 0 and 1). The 2 d BW were averaged (370 kg) and used as initial BW for performance calculations. Steers were blocked by BW into 3 blocks (1 light, 3 moderate, 1 heavy), stratified by BW within block, and then assigned randomly within block to 1 of 35 pens (8 steers/pen) based on d 0 BW. Pens were assigned randomly to 1 of 7 treatments (5 pens/treatment) and pen was used as the experimental unit. The experiment was conducted from September 30, 2003, through January 28, 2004.

Dietary treatments included feeding a WDGS (Abengoa Bioenergy) and WCGF (Sweet Bran, Cargill) blend (formulated in a 1:1 ratio, DM basis) at 4 inclusion levels of 0, 25, 50, and 75% (DM basis) with 7.5% ground alfalfa hay (Table 2). Three additional treatments were fed with ground alfalfa hay inclusion level decreasing to 5, 2.5, and 0% (DM basis) as coproduct blend inclusion increased to 25, 50, and 75% (DM basis), respectively. Composition of WDGS was 32% DM, 34% CP, 34% NDF, 13% fat, and 0.61% S. The composition of WCGF was 60% DM, 25% CP, 39% NDF, 2.6% fat, and 0.51% S. Inclusion of coproducts replaced a 1:1 ratio (DM basis) of DRC and HMC, urea, and sodium sulfate in the diets. High-moisture corn was rolled and ensiled in a bunker for approximately 30 d before study initiation. No additional fat sources were included in any of the diets. Dry supplement was included in diets at 5% of DM to provide sufficient urea to the 0% coproduct treatment to meet a minimum 13% CP in all diets and to supply limestone to meet a 1.2:1 minimum Ca:P ratio. All diets met or exceeded MP requirements (NRC, 1996). The dry supplement was formulated to provide monensin (320 mg/steer daily, Elanco Animal Health) and tylosin (90 mg/steer daily, Elanco Animal Health).

Steers were adapted to treatment diets over 28 d, and the finishing diets were fed until the end of the trial. Cattle were adapted to finishing diets using diets in which alfalfa hay was replaced with a 1:1 combination of DRC:HMC (DM basis). Alfalfa hay inclusion decreased from 45, 35, 25, 15, and 7.5% DM, and was fed for 3, 4, 7, 7, and 7 d, respectively, for all treatments. To achieve a final alfalfa hay level of 5, 2.5, or 0% of diet DM, alfalfa hay was reduced to the desired level on d 29. Coproduct blend inclusions were kept constant throughout the adaptation diets for the 25 and 50% (DM basis) treatments, whereas the 75% DM inclusion level was achieved after increasing coproduct blends at 60, 65, 70, and 72.5% in each adaptation diet.

Steers were fed ad libitum at the same time as in Exp. 1 and allowed ad libitum access to water. Feed refusals were collected and handled similarly to Exp. 1. Steers were implanted on d 21 with Revalor-S (Intervet-Schering Plough). Twelve steers on the 75% coproduct blend with 0% alfalfa hay treatment were diagnosed and treated for polioencephalomalacia (**PEM**) during the adaptation period; 2 of them were removed from the study. No incidences of PEM were observed on any of the other treatments. After the occurrence of these 12 cases of PEM, the supplement for cattle consuming the 75% coproduct diet with 0% alfalfa hay was formulated to provide thiamine (140 mg/steer daily; International Nutrition).

On d 105, the heavy BW block of steers was slaughtered. On d 121, steers from the medium and light BW blocks were slaughtered. All steers were slaughtered at a commercial abattoir (Tyson, West Point, NE). Carcass data were collected, and HCW was used for final performance calculations similar to Exp. 1. Final BW were not obtained on all steers in this study and are not presented.

Weekly truckloads of WDGS were delivered to the feedlot, and samples were collected. Alfalfa hay, corn, and WCGF were also sampled on a weekly basis. Samples were dried at 60°C for 48 h, ground using a sample mill (Cyclotec 1093 Sample Mill), and sent to a commercial laboratory (SDK Lab, Hutchinson, KS) for analysis. Each sample of WDGS and monthly composites of the other ingredients were analyzed for ether extract (AOAC, 1999; method 920.39), whereas minerals including P (AOAC, 1999; method 965.17), Ca, K, Mg, Na (AOAC, 1999; method 968.08), S, Al, Co, Cu, Fe, Mn, Mo, and Zn (AOAC, 1999; method 985.01) were determined by wet ashing and analyzed colorimetrically.

Exp. 3

Five hundred four yearling steers (BW = 376 ± 16 kg) were used to determine the optimum inclusion level of WDGS in diets containing 30% WCGF (DM basis). Upon arrival at the feedlot in October, 2004, steers were individually identified and vaccinated similar to Exp. 1. Approximately 14 d after initial processing, steers were revaccinated similarly to Exp. 1. Steers grazed corn stalks during the winter and were supplemented with 2.27 kg of WCGF daily (DM basis) and then grazed pastures during the spring. Before trial initiation, steers were limit fed the same diet as in Exp. 1 at 2.0% of BW (7.5 kg of DM) for 5 d, then weighed on 2 consecutive days (d 0 and 1). These BW were averaged (376 kg) and used as initial BW for performance calculations. Steers were blocked by BW (3 light, 3 moderate, 3 heavy), stratified by BW within block, and assigned randomly to 1 of 63 pens (8 steers/ pen) based on d 0 BW. Pens were assigned randomly to 1 of 7 treatments within block (9 pens/ treatment). The experiment was conducted from May 13, 2005, through September 20, 2005.

Dietary treatments consisted of a corn-based control diet, along with 6 diets containing 30% WCGF (Sweet Bran, Cargill) plus 0, 10, 15, 20, 25, or 30% WDGS (Abengoa Bioenergy, DM basis, Table 3. Coproduct inclusion in the diets replaced a 1:1 ratio (DM basis) of DRC and HMC, urea, and potassium chloride. High-moisture corn was rolled and ensiled in a bunker for approximately 250 d before study initiation. The composition of WDGS was 33% DM, 32% CP, 35% NDF, 12% fat, and 0.76% S. Composition of WCGF was 60% DM, 24% CP, 41% NDF, 3.0% fat, and 0.47% S. No additional fat sources were included in any of the diets. All finishing diets contained 7% ground alfalfa hay and 5% dry supplement (DM basis). Urea was provided in the supplement to provide sufficient protein to meet a minimum 13% CP in all diets. All diets met or exceeded MP requirements (NRC, 1996). The dry supplement was formulated to provide steers the same additives as in Exp. 1.

Steers were adapted to treatment diets using 4 adaptation diets, where alfalfa hay was included at decreasing levels of 44, 34, 24, and 14% (DM basis) and was replaced by a 1:1 ratio blend of DRC:HMC (DM basis). Adaptation diets were fed for 3, 4, 7, and 7 d, respectively. Coproduct inclusion levels remained the same throughout the adaptation period to the finishing diets except for the diet that included 60% coproducts (30WCGF:30WDGS), which had 51% coproduct blend, 44% alfalfa hay, and no corn in step 1, then continued with 60% total coproduct inclusion throughout the remainder of the adaptation diets. Steers were fed ad libitum at the same time as in Exp. 1, and feed refusals were collected and handled similarly to Exp. 1 to accurately calculate DMI. Steers were implanted on d 21 with Revalor-S (Intervet-Schering Plough).

On d 116, steers were slaughtered at a commercial abattoir (Greater Omaha Pack). Steers were weighed individually the day before slaughter. Final BW data were shrunk 4% and used to calculate dressing percentage. Carcass data were collected and recorded, and HCW were used for final performance calculations similar to Exp. 1.

All feed samples were collected weekly and analyzed for DM to determine accurate DMI. Feed samples were

Table 3. Composition and nutrient analysis for dry-rolled and high-moisture corn finishing diets with 0 to 30% DM inclusions of wet distillers grains plus solubles (WDGS) containing 30% wet corn gluten feed (WCGF) for Exp. 3[1]

	Treatment						
	0% WCGF	30% WCGF					
Item	0% WDGS	0% WDGS	10% WDGS	15% WDGS	20% WDGS	25% WDGS	30% WDGS
Ingredient							
High-moisture corn	44.0	29.0	24.0	21.5	19.0	16.5	14.0
Dry-rolled corn	44.0	29.0	24.0	21.5	19.0	16.5	14.0
Wet corn gluten feed	—	30.0	30.0	30.0	30.0	30.0	30.0
Wet distillers grains plus solubles	—	—	10.0	15.0	20.0	25.0	30.0
Alfalfa hay	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Dry supplement	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Fine-ground corn	1.241	2.981	2.981	2.671	2.671	2.671	2.671
Limestone	1.45	1.48	1.48	1.79	1.79	1.79	1.79
Urea	1.17	—	—	—	—	—	—
Potassium chloride	0.60	—	—	—	—	—	—
Sodium chloride	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Tallow	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Trace mineral premix[2]	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Rumensin-80 premix[3]	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Thiamine premix[4]	0.014	0.014	0.014	0.014	0.014	0.014	0.014
Vitamin A-D-E premix[5]	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Tylan-40 premix[6]	0.009	0.009	0.009	0.009	0.009	0.009	0.009
Nutrient composition							
CP[7]	13.5	14.7	16.9	17.9	19.0	20.1	21.2
Ether extract[7]	4.78	4.12	4.83	5.18	5.53	5.89	6.24
Ca[8]	0.66	0.68	0.71	0.84	0.86	0.87	0.89
P[7]	0.30	0.47	0.52	0.55	0.58	0.60	0.63
K[8]	0.71	0.72	0.79	0.83	0.87	0.90	0.94
S[7]	0.14	0.24	0.30	0.33	0.36	0.40	0.43

[1] Values expressed on a percent of DM basis.

[2] Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, 0.05% Co.

[3] Premix contained 176 g of monensin·kg^{-1} (Elanco Animal Health, Greenfield, IN).

[4] Premix contained 88 g of thiamine·kg^{-1}.

[5] Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, 3.7 IU of vitamin E·g^{-1}.

[6] Premix contained 88 g of tylosin·kg^{-1} (Elanco Animal Health).

[7] Represented as percent of diet DM using analyzed nutrients for each ingredient.

[8] Based on NRC (1996) values of the diet ingredient.

then composited monthly and analyzed for CP, ether extract, P, and S similar to Exp. 1.

Statistical Analysis

Data from all experiments were evaluated as a randomized complete block design using PROC MIXED (SAS Inst. Inc., Cary, NC). Pen was considered the experimental unit, BW block was used as a fixed effect, and probabilities less than or equal to α (0.05) were considered significant. In Exp. 1, data were analyzed using a Bonferroni t-test if the F-test was significant.

Data for Exp. 2 were analyzed as a 2 × 3 plus 1 factorial design, with 2 forage levels (7.5% DM, and a reduced alfalfa hay level of 0, 2.5, and 5% diet DM) and 3 coproduct blend levels. Model effects included coproducts blend levels, alfalfa hay inclusion level (7.5% DM or reduced level), and interactions of these factors. When no significant interactions ($P > 0.05$) were observed, main effects of coproduct blend and alfalfa level were presented. When significant interactions were observed, simple effects were presented. Main effects of coproduct blend were analyzed for linear and quadratic effects using orthogonal contrasts including the corn control diet for 0% inclusion. If significant quadratic relationships were observed for level of coproduct blend inclusion, then a first-order derivative was calculated from the best-fit quadratic equation (Microsoft Excel, Microsoft Corporation, Redmond, WA) to determine the inclusion level when the response (ADG, DMI, or G:F) was maximized.

Effects of WDGS inclusion in combination with 30% WCGF (DM basis) in Exp. 3 were analyzed using orthogonal polynomials. Coefficients were obtained using PROC ILM of SAS due to unequal spacing of WDGS level. A single degree of freedom contrast between the control treatment and the 30% WCGF with no WDGS treatment was included in the analysis. If significant quadratic relationships were observed for level of WDGS inclusion, then a first-order derivative was calculated to determine the inclusion level when the response was maximized similar to Exp. 2.

Table 4. Cattle performance when fed coproducts alone or in combinations to finishing steers in Exp. 1

	Treatment[1]						*P*-value[3]
Item	Con	30WCGF	30WDGS	30Blend	60Blend	SEM[2]	*F*-test
Performance							
Initial BW, kg	342	342	342	343	342	0.4	0.70
Final BW,[4] kg	577^{a}	599^{bc}	610^{c}	601^{c}	588^{ab}	4.0	<0.01
Final BW,[5] kg	573^{a}	596^{c}	608^{d}	602^{cd}	585^{b}	3.9	<0.01
DMI, kg/d	10.8^{a}	11.9^{c}	11.4^{b}	11.5^{bc}	10.8^{a}	0.2	<0.01
ADG, kg	1.85^{a}	2.03^{c}	2.12^{d}	2.07^{cd}	1.94^{b}	0.03	<0.01
G:F[6]	0.172^{a}	0.171^{a}	0.187^{c}	0.179^{b}	0.179^{b}	0.003	<0.01
Carcass characteristic							
HCW, kg	360^{a}	375^{c}	382^{d}	379^{cd}	368^{b}	2.5	<0.01
Dressing %	62.6	62.2	62.7	63.1	62.6	0.4	0.58
Marbling score[7]	481	507	487	496	477	8.5	0.14
12th-rib fat, cm	1.19	1.30	1.42	1.32	1.32	0.01	0.14
LM area, cm^2	85.2	83.9	83.2	85.2	84.5	0.8	0.35
Yield grade[8]	2.84^{a}	3.12^{bc}	3.35^{c}	3.12^{bc}	3.07^{ab}	0.08	<0.01

[a–d] Means in the same row without a common superscript differ ($P < 0.05$).

[1] Where Con = 0% coproduct, 30WCGF = 30% wet corn gluten feed (WCGF), 30Blend = 15% WCGF + 15% wet distillers grains plus solubles (WDGS), 30WDGS = 30% WDGS, 60Blend = 30% WCGF + 30% WDGS (DM basis); inclusion of coproducts replaces a 1:1 ratio of dry-rolled and high-moisture corns.

[2] Each treatment mean represents 5 pens (n).

[3] Significance for *F*-test effect between treatments.

[4] Calculated with a 4% shrink from BW.

[5] Calculated from HCW, adjusted to a 63% dressing percentage.

[6] Calculated as total BW gain over total DMI.

[7] 400 = Slight^0, 500 = Small^0.

[8] USDA yield grade (YG) calculated as 2.50 + [(6.35 × fat thickness, cm) – (2.06 × LM area, cm^2) + (0.2 × KPH, %) + (0.0017 × HCW, kg)]; (Boggs and Merkel, 1993).

RESULTS AND DISCUSSION

Exp. 1

Steers fed the coproduct treatment diets had similar or greater ADG, DMI, and G:F than steers fed the corn-based control diet (Table 4). Feeding 30% WCGF increased DMI ($P < 0.01$) from 10.8 to 11.9 kg compared with the corn-based control diet, and ADG increased ($P < 0.01$) from 1.85 to 2.03 kg for steers fed 30% WCGF compared with the corn-based control diet. This increase in DMI and ADG when feeding WCGF may be due to potential control of subacute acidosis when feeding WCGF (Stock et al., 2000; Farran et al., 2006). Krehbiel et al. (1995) observed that feeding cattle WCGF allows for rumen pH to increase quicker within 24 h after an acidotic challenge, indicating a reduction in subacute acidosis, compared with feeding DRC. No difference ($P = 0.85$) was observed in G:F of steers fed 30% WCGF compared with the DRC and HMC control diet.

Feeding 30% WDGS resulted in the greatest ($P = 0.02$) G:F compared with any other treatment in this trial. Compared with the control, corn-based diet, feeding 30% WDGS increased ($P < 0.01$) DMI from 10.8 to 11.4 kg, ADG ($P < 0.01$) from 1.85 to 2.12 kg, and G:F ($P < 0.01$) from 0.172 to 0.187. These data agree with Vander Pol et al. (2006) who fed WDGS from 0 to 50% of diet DM, resulting in a quadratic response for ADG and G:F, with optimum WDGS inclusions at 30 to 40% DM. Al-Suwaiegh et al. (2002) observed that increasing WDGS in finishing diets from 0 to 30% of diet DM increased ADG by 10% and G:F by 8%. They attributed the improved cattle performance when feeding WDGS to greater dietary fat, resulting in greater dietary energy content. Klopfenstein et al. (2008) conducted a meta-analysis utilizing 9 experiments that fed WDGS in DRC and HMC diets from 0 to 50% of diet DM. Quadratic effects for DMI and ADG were observed along with a quadratic trend for G:F as WDGS was increased in diets, with the greatest values at about 30% DM, attributing increased performance partially due to additional CP used as energy. The control diets exceeded MP requirements of the cattle (NRC, 1996). Protein in excess of the requirement would be used for energy. There is an energy cost for the animal to excrete excess protein, but that cost may be small (Huntington and Archibeque, 1999) and protein has about 36% more energy than carbohydrate. Ruminally undegraded protein would have more ME than ruminally degraded carbohydrate or protein.

Steers fed the coproduct blend at 30% (DM basis) had intermediate DMI and ADG compared with steers fed 30% WCGF or 30% WDGS alone, and this performance was not different ($P \geq 0.12$) from either coproduct fed alone. Feed efficiency was intermediate and different ($P = 0.02$) for steers fed the coproduct blend at 30% (DM basis) compared with steers fed WCGF or WDGS alone. Peter et al. (2000) compared dry corn gluten feed to dry distillers grains and observed a 10% G:F increase for cattle fed dry distillers grains in addition to dry corn gluten feed when compared with feeding dry corn gluten feed as the only coproduct in the diet. Our data suggest that feeding a 1:1 blend (DM basis) of WCGF and WDGS did not result in associative effects. Cattle fed the coproduct blend at 30% dietary inclusion level (DM basis) had greater DMI ($P < 0.01$), ADG ($P < 0.01$), and G:F ($P = 0.02$) than cattle fed the control corn-based diet, indicating improved steer performance for feeding a coproduct blend compared with a blend of DRC and HMC.

Feeding the 60% coproduct blend resulted in decreased ($P < 0.01$) DMI and decreased ($P < 0.01$) ADG compared with feeding the 30% coproduct blend treatment, but G:F was similar ($P = 0.85$). Although DMI did not differ ($P = 0.83$) between steers fed 60% coproduct blend and the control corn-based diet, ADG ($P = 0.04$) and G:F ($P = 0.02$) were greater for steers fed 60% coproduct blend compared with steers fed the control diet. These results indicate that feeding a WCGF and WDGS combination at 60% of diet DM has a greater energy value than the DRC and HMC control diet. The data from Vander Pol et al. (2006) suggest that DMI and ADG decrease when WDGS is fed at 50% inclusion compared with 30 or 40%, but is similar to feeding a DRC- and HMC-based diet. However, results from this experiment suggest greater than 50% DM inclusion of coproducts can be fed (up to 60% DM) and improves cattle performance when WDGS is fed with WCGF. The greater DMI observed for steers fed the 60% blend could be attributed to less combined dietary fat or S (due to less fat and S in WCGF) when compared with a diet containing 50% WDGS. Vander Pol et al. (2009) reported decreased DMI for feeding increased levels of WDGS or corn oil when dietary fat was above 8%, suggesting fat may be depressing intakes. Zinn (1988) supplemented 0 and 4% added fat and also observed decreased DMI with added fat. Likewise, increasing dietary S from 0.15 to 0.25% using mineral forms of S resulted in a linear decrease in DMI (Zinn et al., 1997). Additionally, Bolsen et al. (1973) used ammonium sulfate to increase diet S levels from 0.12 to 0.41% in finishing diets and reduced DMI for cattle by 32% at the greatest level of S.

Dressing percentage was not affected by dietary treatment ($P = 0.58$) and averaged 62.6%. As a result, final BW mimicked final BW calculated from HCW. Steers fed coproducts had heavier carcass weights ($P < 0.01$) than steers fed the control diet. Dietary treatment tended ($P = 0.14$) to affect marbling scores, with the greatest numerical scores for steers fed 30% WCGF or 30% coproduct blend. A trend ($P = 0.14$) was observed for 12th-rib fat thickness, with the greatest numerical fat thickness for cattle consuming 30% WDGS and the least for the control-fed cattle, likely due to ADG. No differences ($P = 0.35$) were observed for LM area. Yield grade was greater ($P < 0.01$) for cattle fed coproduct diets than cattle fed the corn-based diet. No incidences of PEM were observed for cattle consuming any of the dietary treatments in Exp. 1.

Exp. 2

No interactions were observed ($P \geq 0.39$) for any of the feedlot performance measurements between coproduct blend and alfalfa hay inclusion level (Table 5). Therefore, only main effects of coproduct blend and alfalfa hay inclusions are discussed. A trend ($P = 0.06$) was observed for greater DMI in the diets that included 7.5% alfalfa hay (DM basis) compared with diets with less alfalfa hay. Reduced DMI or variability in intake has been identified as one of the more typical symptoms of subacute acidosis (Cooper et al., 1999; Scott et al., 2003). This suggests that cattle would eat more feed to compensate for less NE_g in the diets with greater alfalfa hay inclusions or subacute acidosis is offset by the alfalfa hay. However, the numerically greater DMI of diets that included 7.5% alfalfa level (DM basis) did not result ($P = 0.86$) in greater ADG. Furthermore, no differences ($P = 0.21$) in G:F were observed by reducing the alfalfa hay inclusion, which implies that acidosis was not a problem. Farran et al. (2006) observed a linear improvement in G:F when reducing alfalfa levels from 7.5 to 0% DM in diets that included 35% WCGF (Archer Daniels Midland Company, Columbus, NE), containing proportionally more corn bran and less steep liquor than Sweet Bran produced by Cargill. In the current study, no differences were observed for final BW ($P = 0.85$) or HCW ($P = 0.87$) by reducing alfalfa hay level within coproduct blend level.

Feeding a coproduct blend at increasing inclusion levels resulted in a quadratic response ($P < 0.01$) for ADG, DMI, and G:F (Table 6), with greater DMI, ADG, and G:F for cattle fed coproduct blend inclusions of 25 and 50% of diet DM. When the coproduct blend was fed at 75% (DM basis), ADG, DMI, and G:F were similar to cattle fed the control DRC and HMC based diet (0% coproduct). First derivative of the regression equation resulted in maximum ADG at a coproduct combination level of 36.6% DM, and maximum G:F at inclusion level of 39.4% DM. Similarly, Hussein and Berger (1995) fed heifers WCGF at 0, 25, 50, and 75% (DM basis) in HMC-based diets and observed a quadratic response for ADG with the greatest values at intermediate WCGF levels. These authors reported only a 3.5% decrease in cattle G:F when WCGF inclusion levels were increased from 25 to 50% (DM basis) and an 11.4% decrease in G:F when comparing the 75% WCGF inclusion to the 25% (DM basis). Stock et al. (2000) summarized 5 studies that fed WCGF (Sweet Bran, Cargill) at typical feedlot inclusions of 20 to 60% DM. On average, across that range of inclusion, DMI increased 5.4%, ADG increased 11.4%, and G:F improved 5.1% compared with corn control diets in those studies. Block et al. (2005) also observed a similar quadratic response in ADG, when feeding steam-flaked corn finishing diets containing 0, 20, 30, and 40% WCGF (DM basis); however, they predicted a maximum ADG and G:F with inclusions of 23 and 17% WCGF (DM basis), respectively.

Table 5. Simple effects of feeding increased inclusion levels of a coproduct blend containing wet corn gluten feed (WCGF) and wet distillers grains plus solubles (WDGS; 1:1 DM basis) and 0 to 7.5% alfalfa hay, which replaced dry-rolled and high-moisture corns, to yearling steers in Exp. 2

	Treatment								P-value[2]		
	0 CB[3]	25 CB[3]		50 CB[3]		75 CB[3]					
Item	7.5 AH[4]	5 AH[4]	7.5 AH[4]	2.5 AH[4]	7.5 AH[4]	0 AH[4]	7.5 AH[4]	SEM[1]	Cop × Alf	Cop	Alf
Performance											
Initial BW, kg	370	370	370	371	370	370	369	0.6	0.51	0.38	0.26
Final BW,[5] kg	579	617	610	610	611	572	575	6.1	0.71	<0.01	0.85
DMI, kg/d	11.0	11.9	12.0	11.5	11.9	10.4	10.7	0.2	0.79	<0.01	0.06
ADG, kg	1.81	2.13	2.07	2.07	2.07	1.75	1.78	0.05	0.63	<0.01	0.86
G:F[6]	0.164	0.179	0.172	0.179	0.174	0.167	0.166	0.004	0.39	0.03	0.21
Carcass characteristic											
HCW, kg	365	388	384	384	385	360	362	4	0.71	<0.01	0.87
Calculated YG[7]	1.85^{a}	2.43^{b}	2.31^{b}	1.93^{a}	2.25^{b}	1.94^{a}	2.28^{b}	0.01	0.03	0.01	0.03
Marbling score[8]	532^{bcd}	522^{bc}	520^{bc}	539^{cd}	496^{ab}	468^{a}	477^{a}	10	0.03	<0.01	0.12
12th-rib fat, cm	0.94	1.19	1.12	1.12	1.24	0.94	0.97	0.05	0.14	<0.01	0.21
LM area, cm^2	93.4	93.2	92.3	91.4	91.1	90.8	92.6	1.7	0.72	0.65	0.86

[a–d] Means in the same row without a common superscript differ ($P < 0.05$).

[1] Each treatment mean represents 5 pens (n).

[2] Cop × Alf = interaction between coproduct blend level and alfalfa hay level; Cop = main effect for coproduct blend level; Alf = main effect for alfalfa hay level.

[3] Coproduct blend (CB) was a 1:1 ratio blend of wet distillers grains and wet corn gluten feed (% DM basis).

[4] Alfalfa hay (AH) expressed on a percent of diet DM basis.

[5] Calculated from HCW, adjusted to a 63% dressing percentage.

[6] Calculated as total BW gain over total DMI.

[7] USDA yield grade (YG) calculated as 2.50 + [(6.35 × fat thickness, cm) – (2.06 × LM area, cm^2) + (0.2 × KPH, %) + (0.0017 × HCW, kg)]; (Boggs and Merkel, 1993).

[8] 400 = Slight^0, 500 = Small^0.

Additionally, Klopfenstein et al. (2008) and Vander Pol et al. (2006) observed quadratic responses for ADG and DMI when WDGS was fed in finishing diets from 0 to 50% DM with the greatest values at 30 to 40%. Maximum G:F, DMI, and ADG were observed when the diet contained 30 to 40% WDGS (DM basis). Furthermore, Larson et al. (1993) and Ham et al. (1994) observed an increase in G:F of 20 and 18%, respectively, when diets included 40% WDGS (DM basis) compared with a DRC-based control diet.

Hot carcass weights were 5% heavier for the 25 and 50% coproduct blend (DM basis) compared with the

Table 6. Main effect of a 1:1 blend of wet corn gluten feed (WCGF) and wet distillers grains plus solubles (WDGS) in replacement of dry-rolled and high-moisture corn in finishing diets fed to yearling steers in Exp. 2

	Coproduct blend[1]					P-value[2]	
Item	0	25	50	75	SEM	Lin	Quad
Performance							
Initial BW, kg	370	370	371	370	0.41	0.90	0.84
Final BW,[3] kg	579	615	611	575	3.98	0.35	<0.01
DMI, kg/d	11.0	12.0	11.7	10.6	0.2	<0.01	<0.01
ADG, kg	1.81	2.10	2.07	1.77	0.03	0.34	<0.01
G:F[4]	0.164	0.175	0.176	0.167	0.002	0.32	<0.01
Carcass characteristic							
HCW, kg	366	387	385	362	2.51	0.35	<0.01
Calculated YG[5]	1.85	2.37	2.08	2.10	0.08	0.27	<0.01
Marbling score[6]	532	521	518	473	8.71	<0.01	0.08
12th-rib fat, cm	0.94	1.14	1.17	0.97	0.05	0.60	<0.01
LM area, cm^2	93.5	92.9	91.0	91.6	1.3	0.32	0.66

[1] Coproduct blend was a 1:1 blend of WCGF and WDGS in replacement of a 1:1 blend of dry-rolled and high-moisture corns (DM basis).

[2] Lin = linear effect for coproduct blend level; Quad = quadratic effect for coproduct blend level.

[3] Calculated from HCW, adjusted to a 63% dressing percentage.

[4] Calculated as total BW gain over total DMI.

[5] USDA yield grade (YG) calculated as 2.50 + [(6.35 × fat thickness, cm) – (2.06 × LM area, cm^2) + (0.2 × KPH, %) + (0.0017 × HCW, kg)]; (Boggs and Merkel, 1993).

[6] 400 = Slight^0, 500 = Small^0.

0% (control, DM basis) and the 75% coproduct blend (quadratic, $P < 0.01$). Hussein and Berger (1995) reported an increase in HCW when diets included 25% WCGF (DM basis). However, when the inclusion of WCGF was at 50% of the diet (DM basis), Hussein and Berger (1995) reported that HCW were not different from steers fed a DRC-based control diet. There was a trend ($P = 0.14$) for an interaction between alfalfa hay level and coproduct blend for 12th-rib backfat thickness (Table 5). The decrease in alfalfa concentrations did not affect ($P = 0.21$) 12th-rib backfat thickness, but fat thickness was affected ($P < 0.01$) by coproduct blend inclusion levels (Table 6). The LM area was not affected by dietary coproduct blend level ($P = 0.65$) or reduction of alfalfa hay dietary levels ($P = 0.72$). Interactions (Table 5) were observed for marbling score ($P = 0.03$) and USDA calculated yield grade ($P = 0.03$) for alfalfa hay and coproduct blend inclusion levels. Marbling scores were similar in diets that included 25% coproduct blend at either alfalfa hay inclusion, whereas marbling scores were decreased by the inclusion of 7.5% alfalfa hay in diets formulated with a coproduct blend inclusion of 50% (DM basis). When the diets included 75% of the coproduct blend, marbling scores were similar in diets including 7.5 or 0% alfalfa hay. Calculated yield grade decreased with the greater level of alfalfa hay in diets that included 25% coproduct blend, whereas calculated yield grade increased with increased alfalfa hay level in the diets that included the coproduct blend at 50 and 75% (DM basis).

Twelve cattle were diagnosed with PEM symptoms in Exp. 2. All of these cattle consumed the diet containing 75% coproduct blend with 0% alfalfa hay. These cattle died or were removed from the experiment and were not included in the performance summary of this experiment. No cases of PEM were observed for cattle consuming any of the other treatments. The suggested maximum tolerable diet S level is 0.40% (NRC, 1996). However, in a more recent summary, the maximum tolerable S level was 0.30% in diets containing more than 85% concentrate and was 0.50% S in diets with more than 40% forage (NRC, 2005). Vanness et al. (2009) summarized several experiments consisting of 4,143 cattle finished in coproduct studies with varying inclusions of coproducts and dietary S concentrations (not including Exp. 2). The authors evaluated incidence of PEM relative to dietary S. Only 0.14% of the cattle fed diets equal to or less than 0.46% S experienced PEM symptoms, 0.53% of the cattle had PEM symptoms with diet S of 0.47 to 0.56%, and 6.06% cattle fed diets containing greater than 0.56% S experienced PEM symptoms. These data suggest S tolerance levels may be greater than previously reported, at least when the source of S is corn milling coproducts. Based on the incidence of PEM in Exp. 2, it appears that forage inclusion in finishing diets interacts with incidence of PEM, which is likely driven by rumen pH (Vanness et al., 2009). Therefore, these data suggest that forages should not be entirely removed from diets containing more than 0.4% S.

Exp. 3

Steers fed the diet containing 30% WCGF with no WDGS had greater DMI ($P = 0.01$), ADG ($P < 0.01$), and 4.7% greater G:F ($P = 0.04$) compared with steers fed the DRC- and HMC-based control diet (Table 7). The positive response in DMI, ADG, and G:F with the inclusion of 30% WCGF is in agreement with previous research (Scott et al., 2003; Block et al., 2005; Farran et al., 2006), but the G:F improvement in Exp. 3 is different than in Exp. 1. The effect of feeding WCGF on DMI has been attributed to the control of subacute acidosis (Krehbiel et al., 1995). The improvements in ADG and G:F could also result from replacing starch in corn with readily fermentable fiber in WCGF (Hannah et al., 1990).

Increasing WDGS in diets with 30% WCGF tended ($P = 0.12$) to result in a quadratic effect on DMI. Dry matter intake was 5.2% greater for the diet that contained 15% WDGS (DM basis) when compared with 0% WDGS (both diets contain 30% WCGF). Cattle fed the 30% WDGS with 30% WCGF diet consumed the same amount of DM ($P = 0.20$) as cattle fed the DRC- and HMC-based control diet. A positive quadratic ($P = 0.04$) response in ADG resulted from increasing levels of WDGS, with the greatest values observed in treatments containing 15 and 20% WDGS (DM basis). Although the numerically greatest values of G:F were observed with 15 to 20% WDGS inclusion (DM basis), there was not a significant linear ($P = 0.72$) or quadratic ($P = 0.41$) relationship for G:F as WDGS inclusion increased.

Dressing percentage was not significantly affected by adding WDGS to 30% WCGF based diets and averaged 62.0%. There was a different response in final BW whether measured with BW or using HCW. Presumably due to gut fill, final BW shrunk 4% was not affected as WDGS was added to WCGF. However, a quadratic response was observed for HCW and final BW calculated from HCW ($P = 0.03$). Therefore, the more appropriate measure is HCW that is not affected by gut fill. Dressing percentage and the difference between final BW and carcass-adjusted final BW was most noticeably affected with the control diet and greater concentrations of WDGS added in combination with WCGF. In these treatments, final BW was not affected, whereas HCW was decreased relative to other treatments based on the difference between control and 30% WCGF ($P < 0.01$) and the quadratic response observed for final BW adjusted for HCW and not for final BW.

The quadratic response in ADG was similar to the response described by Vander Pol et al. (2006) when WDGS was increased from 0 to 50% of diet DM. Klopfenstein et al. (2008) also observed a quadratic response in ADG in a meta-analysis for feeding increasing levels

Table 7. Effects of different inclusion levels of wet distillers grains with solubles (WDGS) in finishing diets containing 30% wet corn gluten feed (WCGF) fed to yearling steers in Exp. 3

	Treatment[1]										
	0% WCGF	30 % WCGF							*P*-value[3]		
Item	0% WDGS	0% WDGS	10% WDGS	15% WDGS	20% WDGS	25% WDGS	30% WDGS	SEM[2]	Lin	Quad	0 vs. 30% WCGF
Performance											
Initial BW, kg	376	376	376	376	376	373	376	0.4	0.24	0.76	0.88
Final BW,[4] kg	584	595	590	598	599	597	591	2.7	0.90	0.23	0.01
Final BW,[5] kg	569	585	584	590	589	585	579	3.1	0.32	0.03	<0.01
DMI, kg/d	11.5	12.0	12.0	12.1	12.0	11.9	11.7	0.1	0.22	0.12	0.01
ADG, kg	1.63	1.77	1.76	1.81	1.80	1.76	1.71	0.03	0.23	0.04	<0.01
G:F[6]	0.142	0.148	0.147	0.150	0.150	0.148	0.146	0.002	0.72	0.41	0.04
Carcass characteristic											
HCW, kg	358	369	368	372	371	369	365	2	0.32	0.03	<0.01
Dressing %	61.3	62.0	62.3	62.2	61.8	61.9	61.8	0.2	0.29	0.24	0.06
Calculated YG[7]	2.62	2.80	2.93	2.93	2.91	2.70	2.77	0.09	0.42	0.10	0.16
Marbling score[8]	497	506	517	513	497	506	502	9	0.44	0.49	0.48
12th-rib fat, cm	1.14	1.17	1.27	1.30	1.30	1.19	1.17	0.04	0.97	<0.01	0.82
LM area, cm^2	89.7	89.7	89.5	90.3	89.7	90.8	88.5	1.0	0.84	0.42	1.00

[1] WCGF and WDGS = percent included in the diet (DM basis). Inclusion of WCGF and WDGS replaced a 1:1 ratio of dry-rolled and high-moisture corns.

[2] Each treatment mean represents 9 pens (n).

[3] Lin = linear effect for WDGS level; Quad = quadratic effect for WDGS level; 0 vs. 30% WCGF = contrast between treatments with 0 and 30% WCGF with no WDGS.

[4] Calculated with a 4% shrink from BW.

[5] Calculated from HCW, adjusted to a 63% dress.

[6] Calculated as total BW gain over total DMI.

[7] USDA yield grade (YG) calculated as 2.50 + [(6.35 × fat thickness, cm) – (2.06 × LM area, cm^2) + (0.2 × KPH, %) + (0.0017 × HCW, kg)]; (Boggs and Merkel, 1993).

[8] 400 = Slight^0, 500 = Small^0.

of WDGS. Both of these studies reported that maximum ADG and G:F occurred in diets containing between 30 and 40% WDGS (DM basis), which is less total coproduct inclusion than the optimum inclusion in Exp. 3. First derivative calculation of the quadratic regression equation for ADG response to increasing WDGS level in diets containing 30% WCGF (DM basis) indicated that maximum BW gain was achieved at 12.2% inclusion of the WDGS, equaling 42.2% total coproduct inclusion. Feeding steers a diet containing 60% total coproduct with 30% of each WDGS and WCGF (DM basis) resulted in numerically greater ADG and G:F than that of the control corn-based diet. The negative ADG response observed when WDGS inclusion was increased beyond 20% DM in diets containing 30% WCGF was likely related to the intake reduction observed in those diets. The decrease in DMI could have been due to the S content in diets (including water) with increased inclusions of the coproducts (Loneragan et al., 2001). Analyzed S content in Exp. 3 was greater in all of the coproduct treatments than the S content reported by Zinn et al. (1997), for which they observed decreased intakes. However, DMI was only depressed for cattle fed the 60% coproduct inclusion, which contained 0.43% S, compared with cattle fed the other treatments. Cattle may have subclinical challenges related to dietary S that were not physically observed, such as individual animal intake variance or changes in rumen pH.

Including 30% WCGF (DM basis) in diets increased ($P < 0.01$) HCW when compared with cattle fed the control diet. Adding WDGS to 30% WCGF resulted in a quadratic ($P = 0.03$) HCW response, with heavier carcasses obtained from cattle fed diets that included 15 or 20% WDGS. No differences due to treatment were observed for marbling scores ($P = 0.64$) or LM area ($P = 0.70$). A quadratic response ($P = 0.01$) was observed for fat thickness as WDGS increased, similar to the response observed for ADG. There was a tendency ($P = 0.10$) for greater calculated yield grade in the treatments that included 10, 15, and 20% WDGS (DM basis), likely due to differences ($P < 0.01$) observed for 12th-rib fat thickness. A similar quadratic trend ($P = 0.08$) was reported by Vander Pol et al. (2006) in cattle fed increasing levels of WDGS. This effect is most likely related to ADG because cattle were marketed with the same day on trial.

The performance results from Exp. 3 indicate that maximum ADG would be achieved with WDGS inclusion levels ranging from 15 to 20% in diets containing 30% WCGF. Additionally, feeding diets with increased inclusion (60% DM) of combined WCGF and WDGS resulted in similar performance to cattle fed a traditional DRC- and HMC-based finishing diet. No PEM symptoms were observed for cattle fed any of these treatments in Exp. 3.

Combining wet corn gluten feed and wet distillers grains did not result in associative effects. The inclusion of wet corn gluten feed or wet distillers grains at 30% DM in finishing diets will improve DMI and ADG, whereas G:F improvements depend on the dietary inclusion level. Feeding wet corn gluten feed with wet distillers grains at 25 and 50% of DM will improve steer performance compared with feeding no corn milling coproducts. A dietary inclusion of a 1:1 DM ratio of wet corn gluten feed and wet distillers grains at 60 or 75% DM will result in similar or improved cattle performance than a 1:1 blend of DRC- and HMC-based finishing diets, providing an opportunity to decrease the use of corn in finishing diets. However, dietary S needs to be managed because cattle may develop PEM symptoms with dietary coproduct inclusion levels above 60% DM, and diets may require forage inclusion.

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