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Optimal wet corn gluten and protein levels in steam-flaked corn-based finishing diets for steer calves[1]

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ABSTRACT: A feeding trial evaluated the hypothesis that wet corn gluten feed would improve growth performance of cattle fed steam-flaked corn-based finishing diets and supply required degradable intake protein (DIP). The trial used 360 steer calves (initial BW = 288 ± 11 kg) housed in 36 pens for 166 d in an incomplete 4 × 3 factorial arrangement of treatments. Pens of steers were assigned to treatments according to a completely randomized design (four replicates per treatment combination). Treatments were wet corn gluten feed (0, 20, 30, or 40% of dietary DM) and CP (13.0, 13.7, or 14.4% of dietary DM) via supplemental urea as DIP. The 0% wet corn gluten feed treatment included only the 13.7% CP diet, and the 40% wet corn gluten feed treatment included only the 13.7 and 14.4% CP diets. Final dietary DIP concentration was 9.0% for 0% wet corn gluten feed; 8.7, 9.5, and 10.2% for 20% wet corn gluten feed; 9.0, 9.7, and 10.3% DIP for 30% wet corn gluten feed; and 10.0 and 10.6% for 40% wet corn gluten feed. Hot carcass weight, ADG, DMI, and G:F responded quadratically ($P \leq 0.05$) to wet corn gluten feed. The 20, 30, and 40% wet corn gluten feed treatments increased ADG by 7, 6, and 3% and increased DMI by 4, 5, and 5%, respectively, relative to the 0% wet corn gluten feed treatment. Feed efficiency was 102, 101, and 98% of the 0% wet corn gluten feed treatment for 20, 30, and 40% wet corn gluten feed, respectively. Hot carcass weight, ADG, and G:F increased linearly ($P \leq 0.05$) in response to increased DIP. Nonlinear analysis for DIP over the combined 20 and 30% wet corn gluten feed treatments indicated a DIP requirement of 9.6% of DM for ADG and 9.2% of DM for G:F, corresponding to 14.6 and 14.3% CP for 20% wet corn gluten feed and 14.8 and 14.5% CP for 30% wet corn gluten feed, respectively. Fat thickness, marbling, LM area, and USDA yield grade were not affected (P = 0.12 to 0.99) by wet corn gluten feed or CP. These results show that the inclusion rate of wet corn gluten feed for maximizing ADG and G:F in steam-flaked corn-based finishing diets is approximately 20% of DM. The DIP requirement determined in this trial averaged 9.4% of DM.

Key Words: Beef Cattle, Protein, Steam-Flaked Corn, Wet Corn Gluten Feed

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Introduction

Steam-flaking corn gelatinizes the starch and increases enzyme accessible space and degradation rate (Theurer, 1986), ruminal organic acid load and acidosis risk (Huntington, 1988), and microbial protein synthesis (Zinn, 1990). Cooper et al. (2002a,b) found higher degradable intake protein (**DIP**) requirements for steam-flaked corn diets than for dry-rolled corn diets because of increased ruminal starch digestion. Wet corn gluten feed, a mix of corn bran and steep liquor, with possible inclusion of germ meal, distillers solubles, and corn screenings (Stock et al., 2000), has value as a DIP source (Scott et al., 1997).

Addition of wet corn gluten feed to dry-rolled corn diets replaces starch with fiber, thereby increasing pH and reducing the incidence of acidosis (Herold et al., 1998; Sindt et al., 2002; Montgomery et al., 2004). Steep liquor in wet corn gluten feed contains lactate (Krehbiel et al., 1995), which improves lactic acid metabolism (Fron et al., 1995), prevents lactate accumulation in the rumen (Nisbet and Martin, 1994; Kung and Hession, 1995), and reduces acidosis risk. Acidosis reduction may increase microbial efficiency, energy yield, and DIP requirement (Russell et al., 1992; NRC, 1996).

Stock et al. (2000) reported that the NE value of wet corn gluten feed is 93 to 101% or 113 to 115% of dry-rolled corn, depending on the source of wet corn gluten

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feed. Scott et al. (2003) and Macken et al. (2004) reported that G:F did not differ between steers fed steam-flaked corn or steam-flaked corn with wet corn gluten feed diets, implying similar NE values. Scott et al. (2003) reported wet corn gluten feed has 25.3% more NE when fed with steam-flaked corn compared with being fed in dry-rolled corn-based diets, suggesting that wet corn gluten feed energy value may interact with corn processing. The objective of this experiment was determination of optimal inclusion levels for wet corn gluten feed and DIP in steam-flaked corn-based finishing diets.

Materials and Methods

Animal care for this experiment complied with procedures approved by the University of Nebraska Institutional Animal Care and Use Committee.

Experimental Design and Animals

From November 8, 2000 to April 23, 2001 (166 d), a cattle finishing trial conducted at the University of Nebraska research feedlot (Mead, NE) evaluated wet corn gluten feed (Sweet Bran; Cargill Inc., Blair, NE) and protein concentrations in steam-flaked corn-based finishing diets. The trial used 360 crossbred British breed steer calves (initial BW = 288 ± 11 kg) stratified by BW and assigned randomly to 36 open lot pens. Each pen was then assigned randomly to one of nine treatments in a completely randomized design with an incomplete 4 × 3 factorial arrangement of treatments (four replications per treatment). Treatments were wet corn gluten feed (0, 20, 30, or 40% of dietary DM) and CP (13.0, 13.7, or 14.4% of dietary DM) achieved by the addition of urea. The 0% wet corn gluten feed treatment included only 13.7% CP, as this concentration was comparable with the DIP requirements for steam-flaked corn finishing diets reported by Cooper et al. (2002a). The 40% wet corn gluten feed treatment included only 13.7 and 14.4% CP, as the protein content of feed ingredients rendered a 13.0% CP diet infeasible.

Adaptation to final diets (Table 1) involved feeding corn silage at 70% of dietary DM (30 and 40% wet corn gluten feed treatments had corn silage at 65 and 55% of dietary DM, respectively) for 3 d, followed by alfalfa hay at 45, 35, 25, and 15% of dietary DM for 3, 4, 8, and 7 d, respectively. In each adaptation diet, steam-flaked corn replaced corn silage or alfalfa hay. Steam-flaked corn was processed to a flake thickness of 2.12 mm and a bulk density of 0.35 kg/L at a commercial feedlot (Mead Cattle Company, Mead, NE).

All diets contained 33 mg of monensin (Elanco Animal Health, Indianapolis, IN)/kg and 11 mg of tylosin (Elanco Animal Health)/kg with once daily feeding to allow steers ad libitum intake. Vaccination for respiratory disease with Pyramid (Fort Dodge Animal Health, Overland Park, KS), treatment for internal and external parasites with Cydectin (Fort Dodge Animal Health), and implantation with Synovex-S (Fort Dodge Animal Health) occurred on d 1 of the feeding trial. On d 70, steers were retreated for external parasites with Saber (Schering-Plough Animal Health, Union, NJ) and implanted with Revalor-S (Intervet Inc., Millsboro, DE). During the course of the trial, injury or illness resulted in the removal of seven steers.

Feed Samples and Chemical Analysis

Feed ingredient composites consisted of weekly feed ingredient samples combined on an equal weight basis after drying at 60°C in a forced-air oven and ground to pass a 1-mm screen of a Wiley mill (Thomas Scientific, Swedesboro, NJ). Composite sample analysis included DM, ash, and Dumas CP (AOAC, 1999) using a combustion-type N analyzer (Leco FP-528 Nitrogen Autoanalyzer, St. Joseph, MI). Published DIP values (Stock et al., 1995; NRC, 1996; Herold, 1999) and measured CP for dietary feed ingredients allowed calculation of diet DIP content. Neutral detergent fiber (Van Soest et al., 1991) analysis used heat-stable α-amylase (Ankom Technology, Macedon, NY) at 0.01 mL/mL of NDF solution (Midland Scientific, Omaha, NE). Attempts to determine the NDF content of steam-flaked corn resulted in unreasonably high values approaching 30% of DM, presumably because of insoluble zein proteins and starch contamination; consequently, published values for the NDF content of corn (10% of DM; NRC, 1996) replaced measured NDF content. Starch analysis used an enzymatic hydrolysis (α-amylase, A-3403; amyloglucosidase, A-3042; Sigma-Aldrich Corp., St. Louis, MO) and glucose oxidase procedure (Fleming and Reichert, 1980) without prior extraction of soluble sugars. Feed refusals were collected periodically throughout the trial as needed (weighing, rain events, etc.), subsampled, and dried at 60°C in a forced-air oven to correct DMI.

Data Collection

Initial steer BW was the average of BW taken on two consecutive days before feeding. Hot carcass weights recorded at slaughter and a common dressing percentage of 64.58% (overall average dressing percentage in this experiment) were used to calculate final BW and ADG. Liver scoring in accordance with Elanco Products Company (1974) system occurred at slaughter. After a 24-h chill, fat thickness over the 12th rib, LM area, USDA marbling score, and USDA yield grade were recorded. Pen averages and climatic data were used in estimating the NE_g value of the diets based on NRC model equations (NRC, 1996).

Economic Evaluation

Economic evaluation for wet corn gluten feed inclusion used a partial budget approach; evaluation of profitability was relative to the 0% wet corn gluten feed level. Effects of treatment on change in diet composition and feed intake on subsequent feed costs and change

Table 1. Feed ingredient and nutrient composition of diets fed to steer calves. Treatment definitions reflect percentages of DM

	Treatment								
	0% wet corn gluten feed	20% wet corn gluten feed			30% wet corn gluten feed			40% wet corn gluten feed	
Item	14.1% CP	14.0% CP	14.7% CP	15.4% CP	14.3% CP	15.0% CP	15.6% CP	15.4% CP	16.0% CP
Ingredient	(% of dietary DM)								
Steam-flaked corn	85	65	65	65	55	55	55	45	45
Wet corn gluten feed	0	20	20	20	30	30	30	40	40
Corn silage	10	10	10	10	10	10	10	10	10
Fine ground corn	0.26	1.87	1.62	1.36	2.54	2.29	2.04	2.61	2.43
Limestone	1.72	1.68	1.68	1.68	1.66	1.66	1.66	1.85	1.84
Urea	1.83	0.62	0.87	1.13	0.15	0.40	0.65	0.00	0.19
NaCl	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
KCl	0.65	0.29	0.29	0.29	0.11	0.11	0.11	0.00	0.00
Tallow	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral premix[a]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Ionophore premix[b]	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Antibiotic premix[c]	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Vitamin premix[d]	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Nutrient									
OM	95.7	95.1	95.1	95.1	94.1	94.8	94.8	94.3	94.3
CP	14.1	14.0	14.7	15.4	14.3	15.0	15.6	15.4	16.0
Degradable intake protein	9.0	8.7	9.5	10.2	9.0	9.7	10.3	10.0	10.6
NDF[e]	12.8	20.6	20.5	20.5	24.4	24.4	24.4	28.3	28.2
Starch	66.0	54.2	54.1	53.9	48.3	48.1	47.9	41.9	41.8
Ca	0.73	0.74	0.74	0.74	0.74	0.74	0.74	0.83	0.83
P	0.28	0.42	0.42	0.42	0.48	0.48	0.48	0.55	0.55
K	0.71	0.69	0.69	0.69	0.68	0.68	0.68	0.70	0.70

[a]Trace mineral premix contained 14% Ca, 12% Zn, 8% Mn, 10% Fe, 1.5% Cu, 0.2% I, and 0.1% Co.
[b]Ionophore premix supplied monensin (Elanco Animal Health, Indianapolis, IN) at 33 mg/kg of dietary DM.
[c]Antibiotic premix supplied tylosin (Elanco Animal Health) at 11 mg/kg of dietary DM.
[d]Vitamin premix contained (/g of premix) 15,000 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of vitamin E.
[e]The NDF content of corn was taken as 10% of DM.

in final weight on return were taken into account. Diet costs were calculated using 10-yr (1992-2002) average corn ($104.92/Mg of DM) and alfalfa hay ($77.69/Mg of DM) prices for Nebraska reported by the USDA (2002a). Supplement costs as billed at the University of Nebraska feedmill were $263.29/Mg of DM for the 0% wet corn gluten feed level; $165.67, $183.21, and $200.74/Mg of DM for the 14.75, 15.44, and 16.16% DIP levels of the 20% wet corn gluten feed level, respectively; $133.56, $147.81, and $162.06/Mg of DM for the 15.04, 15.73, and 16.42% DIP levels of the 30% wet corn gluten feed level, respectively; and $112.88 and $124.77/Mg of DM for the 16.18 and 16.71% DIP levels of the 40% wet corn gluten feed level, respectively. The prices of wet corn gluten feed and steam-flaked corn were equal to corn price with addition of processing costs for a 5,000-animal feedlot ($9.29/Mg of DM) as indicated by Cooper et al. (2001) for steam-flaked corn. Pricing of corn silage ($73.20/Mg of DM) was based on corn price according to Guyer and Duey (1986). Returns from cattle sales used 10-yr (1992-2001) average choice steer (499 to 590 kg) prices ($1.52/kg of final BW) from the Nebraska direct market (USDA, 2002b).

Statistical Analysis

Excluded treatment combinations confounded statistical evaluation of experimental results. To account for confounding effects of the incomplete factorial arrangement of treatments, the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC) was used to test for linear and quadratic effects of DIP and linear interaction of DIP with wet corn gluten feed after accounting for linear, quadratic, and lack-of-fit effects of wet corn gluten feed. Similarly, testing for linear, quadratic, and lack-of-fit effects of wet corn gluten feed and linear interaction of wet corn gluten feed with DIP occurred after accounting for linear and quadratic effects of DIP. Testing for lack-of-fit DIP by lack-of-fit wet corn gluten feed interaction was conducted last in each case. The overall statistical model was

$$y_{ijkl} = \mu + \beta_1 x_1 + \beta_2 x_1^2 + \beta_3 x_2 + \beta_4 x_2^2 + \beta_5 x_1 x_2 + W_j + (WD)_{jk} + e_{ijkl},$$

where

y_{ijkl} = individual pen observation,
μ = overall mean,

$\beta_1 x_1$ = linear effect of wet corn gluten feed,
$\beta_2 x_1^2$ = quadratic effect of wet corn gluten feed,
$\beta_3 x_2$ = linear effect of DIP,
$\beta_4 x_2^2$ = quadratic effect of DIP,
$\beta_5 x_1 x_2$ = linear interaction of wet corn gluten feed and DIP,
W_j = lack-of-fit effect of wet corn gluten feed,
$(WD)_{jk}$ = interaction of lack-of-fit effect of wet corn gluten feed and lack-of-fit effect of DIP, and
e_{ijkl} = error term.

The GLM procedure of SAS was used to fit linear and quadratic regression equations to experimental results when DIP or wet corn gluten feed had an effect ($P \leq 0.05$). Setting the first derivative of quadratic regressions to zero allowed determination of local minima or maxima responses. Horizontal extension of local minima or maxima to interception of 95% confidence intervals for predicted responses determined 95% fiducial intervals for estimates of local minima or maxima (Draper and Smith, 1998).

Investigation of DIP requirement for cattle fed steam-flaked corn and wet corn gluten feed diets involved break-point analysis of ADG and G:F using the NLIN procedure of SAS across the pooled 20 and 30% wet corn gluten feed levels. Determination of protein balances for experimental diets used microbial protein efficiency based on break-point analysis of ADG and G:F for DIP requirement. When DIP requirement was equal to the DIP provided at the breakpoint, microbial efficiency could be calculated with known dietary TDN values.

Results and Discussion

Experimental Diets

Experimental diets had greater CP concentrations than targeted (Table 1) because steam-flaked corn and corn silage contained nearly one percentage unit more CP than anticipated and because wet corn gluten feed contained nearly two percentage units more CP than anticipated. The 0% wet corn gluten feed diet contained 66% of dietary DM as starch, whereas the 40% wet corn gluten feed diets contained only 42% of dietary DM as starch.

Feedlot Performance

Dry matter intake, ADG, G:F, estimated NE_g, and HCW of steers responded quadratically ($P \leq 0.05$) to wet corn gluten feed (Table 2). This response is in contrast to Macken et al. (2004), where no effect of wet corn gluten feed level in steam-flaked corn-based diets on ADG or G:F was observed, but DMI tended to increase linearly. However, Scott et al. (2003) found wet corn gluten feed inclusion into steam-flaked corn-based diets tended to increase DMI and ADG with no effect on G:F.

The fitted regression equation relating DMI to wet corn gluten feed inclusion rate suggests maximum DMI occurred at 37% wet corn gluten feed. Predicted DMI at 37% wet corn gluten feed was 9.44 kg/d with a 95% confidence interval of 9.30 to 9.59 kg/d. The 95% fiducial interval for the 9.44-kg/d DMI ranged from 17 to >40% wet corn gluten feed. The relationship between wet corn gluten feed and ADG (Figure 1) predicts a maximal ADG of 1.66 kg at 23% wet corn gluten feed. The 95% confidence and fiducial intervals ranged from 1.62 to 1.70 kg and 7 to 37% wet corn gluten feed, respectively. For G:F, the regression equation (Figure 2) predicted a maximum G:F of 0.178 at 17% wet corn gluten feed. The 95% confidence and fiducial intervals for G:F were 0.175 to 0.181 and <0 to 30% wet corn gluten feed, respectively. The relationship of HCW to wet corn gluten feed inclusion rate paralleled the response observed with ADG and predicted a maximum HCW of 364 kg at 23% wet corn gluten feed. The 95% confidence and fiducial intervals were 360 to 368 kg and 7 to 36% wet corn gluten feed, respectively.

Quadratic responses to wet corn gluten feed inclusion into steam-flaked corn-based finishing diets indicate an interaction or associative effect. A decrease in feed intake with high-grain diets is symptomatic of acidosis (Huntington, 1988). Therefore, the increase in DMI observed with inclusion of wet corn gluten feed into the diets might be attributed to a reduction of acidosis. The decline in rate at which DMI increased with increasing inclusion rate of wet corn gluten feed may be attributed to a decreasing benefit from reduced incidence and severity of acidosis.

Maximum ADG was observed at a lower inclusion rate of wet corn gluten feed than for maximum DMI, which indicates that the energy value of wet corn gluten is dependent on inclusion rate. If wet corn gluten feed had the same energy value as steam-flaked corn, ADG would be affected only by changes in DMI and the predicted maximum ADG would have occurred at the wet corn gluten feed inclusion rate that maximized DMI. Similarly, G:F would have been affected only through alteration of the portion of intake available for gain, and G:F would be increased as long as feed intake increased. However, ADG decreased relative to maximum ADG when wet corn gluten feed concentrations were >23% of DM, despite increased DMI. Therefore, the marginal energy value of wet corn gluten feed was less than steam-flaked corn and declined with increasing inclusion. Predicted ADG was not expected to decrease below that expected for a steam-flaked corn diet without wet corn gluten feed until wet corn gluten feed levels increase to 46% of DMI, suggesting increased DMI compensated for the decreasing dietary energy value.

Evaluation of wet corn gluten feed energy values was more complex with wet corn gluten feed concentration below those that maximized ADG. Over this range of wet corn gluten feed inclusion rate, both DMI and ADG were increasing, indicating that if wet corn gluten feed energy values decreased, those decreases were more

Table 2. Effects of wet corn gluten feed and protein on feedlot performance and carcass characteristics of steer calves. Treatment definitions reflect percentages of DM

	Treatment									
	0% wet corn gluten feed	20% wet corn gluten feed			30% wet corn gluten feed			40% wet corn gluten feed		
Item	14.1% CP	14.0% CP	14.7% CP	15.4% CP	14.3% CP	15.0% CP	15.6% CP	15.4% CP	16.0% CP	SE[a]
Initial BW, kg	288	288	288	287	287	287	288	287	288	1
DMI,[b] kg/d	8.97	9.10	9.34	9.55	9.33	9.66	9.33	9.38	9.48	0.13
ADG,[c] kg	1.55	1.61	1.67	1.72	1.56	1.71	1.65	1.59	1.62	0.04
G:F[d]	0.173	0.177	0.179	0.180	0.168	0.177	0.177	0.170	0.171	0.003
NE_g[b]	1.41	1.43	1.43	1.42	1.36	1.40	1.42	1.37	1.38	0.02
HCW,[f] kg	352	359	365	370	353	368	364	357	360	4
Fat thickness, mm	12.3	11.9	11.6	12.8	11.8	13.1	12.3	11.2	13.0	0.6
LM area, cm^2	85.3	88.6	86.5	88.5	84.6	87.0	86.9	87.6	86.8	1.4
Marbling[g]	529	539	522	541	529	548	522	503	540	13
USDA yield grade	2.23	2.27	2.21	2.30	2.30	2.57	2.23	2.13	2.44	0.11

[a]Pooled standard error of the least squares means (df = 27).
[b]Quadratic response to wet corn gluten feed, $P = 0.05$.
[c]Quadratic response to wet corn gluten feed, $P < 0.01$; linear response to protein, $P < 0.01$.
[d]Quadratic response to wet corn gluten feed, $P < 0.01$; linear response to protein, $P = 0.05$.
[e]Quadratic response to wet corn gluten feed, $P < 0.01$; linear response to protein, $P = 0.01$.
[f]Quadratic response to wet corn gluten feed, $P = 0.03$.
[g]Marbling score: 500 = small (low choice); 600 = modest (average choice).

than offset by increased DMI. However, maximum G:F at 17% wet corn gluten feed suggests that wet corn gluten feed had similar or greater energy than steam-flaked corn when fed at lower inclusion rates. Based on the regression analysis on estimated dietary NE_g, NE_g would be maximized at 11.9% wet corn gluten feed inclusion, which supports the theory that the initial benefit to wet corn gluten feed inclusion is through both increased dietary energy and DMI. The 95% confidence

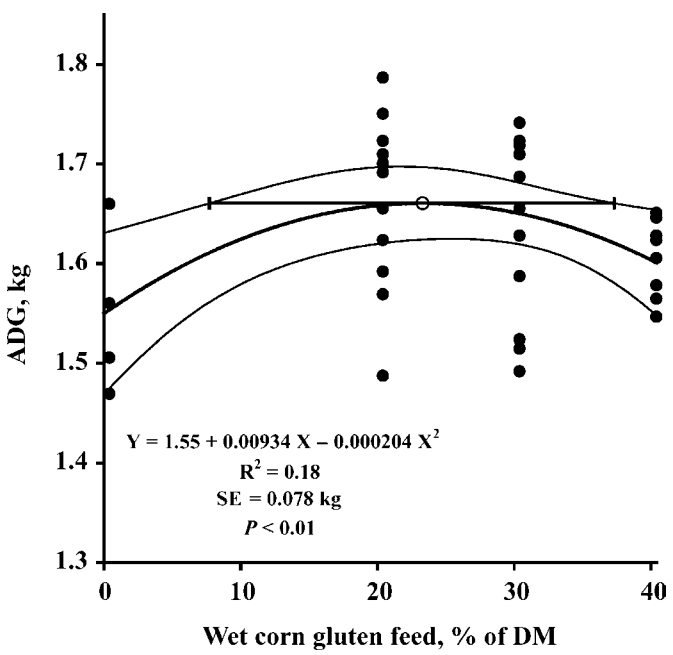

Figure 1. Effect of wet corn gluten feed on ADG. Observed pen ADG (solid circles) and 95% confidence intervals (thin flanking curves) for ADG predicted from the quadratic relationship between ADG and wet corn gluten feed (thick central curve). Maximum ADG (open circle) and fiducial interval (horizontal error bar) are also indicated.

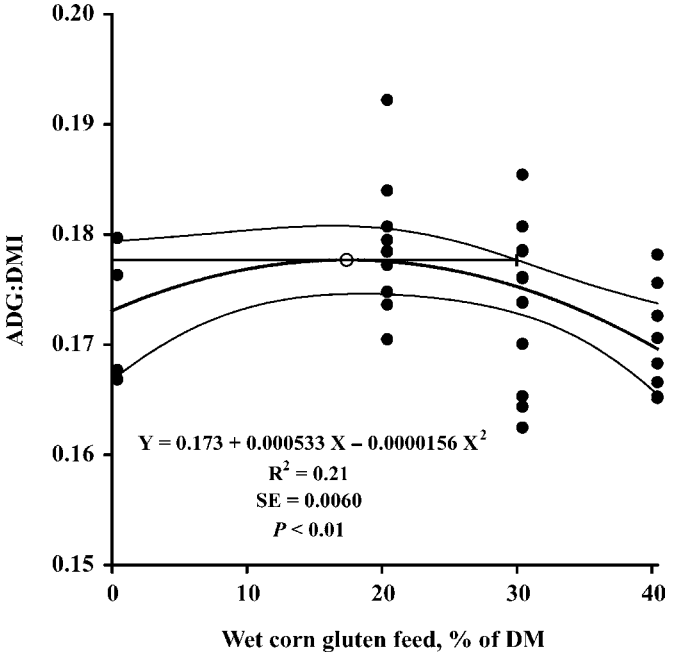

Figure 2. Effect of wet corn gluten feed on G:F. Observed pen average feed efficiency (solid circles) and 95% confidence intervals (thin flanking curves) for feed efficiency predicted from the quadratic relationship between G:F and wet corn gluten feed (thick central curve). Maximum G:F (open circle) and fiducial interval (horizontal error bar) are also indicated.

and fiducial intervals were 1.41 to 1.45 Mcal/kg of NE_g and 0 to 26.5% wet corn gluten feed, respectively. Either the energy content of wet corn gluten feed energy changed across inclusions or wet corn gluten feed concentration influenced other feed ingredient energy values, such as steam-flaked corn.

Other experiments evaluating similar wet corn gluten feed (Macken et al., 2004) indicated that animal performance was not influenced when wet corn gluten feed was included in steam-flaked corn-based finishing diets. Based on observations and calculated NE_g from Macken et al. (2004), wet corn gluten feed had the same energy value as steam-flaked corn. Additionally, Scott et al. (2003) reported the NE_g of wet corn gluten feed was 25.3% higher in a steam-flaked corn-based diet than in a dry-rolled corn-based diet. This indicates that the energy value of wet corn gluten feed is dependent on the diet into which it is included. The variable energy values might be attributed to a positive interaction between wet corn gluten feed and steam-flaked corn in reducing the deleterious impacts of acidosis. The resulting improvements in feed digestion, energy yield, and animal performance were independent of the impact of wet corn gluten feed on DMI.

The ADG, G:F, and HCW of steers fed steam-flaked corn finishing diets containing wet corn gluten feed responded to DIP linearly ($P \leq 0.05$; Table 2). Nonlinear, break-point analysis of ADG data from the pooled 20 and 30% wet corn gluten feed levels indicated an increase in ADG of 0.176 ± 0.024 kg for each additional 1% DIP until ADG reached a plateau at 1.69 ± 0.02 kg. The breakpoint, or DIP requirement, calculated from ADG was 9.6% DIP (Figure 3). Similar analysis of G:F data indicated an increase in efficiency of 0.0193 ± 0.0003 for each additional 1% DIP until efficiency reached a plateau at 0.178 ± 0.002. The DIP requirement calculated from G:F was 9.2% DIP.

Cooper et al. (2002a) reported DIP requirements for a steam-flaked corn-based finishing diet to be between 7.1 and 9.5% of DM, although the 9.5% requirement was not supported by differences in estimated bacterial CP flow. However, the 9.5% value compares well with the average 9.4% DIP requirement determined from this experiment and suggests that wet corn gluten feed inclusion in steam-flaked corn-based finishing diets results in similar or only slightly higher DIP requirements than those observed for steam-flaked corn diets without wet corn gluten feed.

Calculated dietary energy values and a DIP requirement for steam-flaked corn and wet corn gluten feed based finishing diets of approximately 9.4% allowed use of the NRC (1996) model to determine protein balances for the experimental diets. Protein balance determination was based on average BW of steers over the course of the trial and observed DMI, ADG, and BW of steers for each treatment combination. A microbial efficiency of 10.4% of dietary TDN resulted in a DIP balance of zero when a diet of 25% wet corn gluten feed (average of the 20 and 30% wet corn gluten feed levels) formulated for 9.4% DIP was evaluated. Ruminal digestion of carbohydrate is the most accurate estimator of microbial efficiency (NRC, 1996); however, limited data on ruminal carbohydrate digestion has resulted in use of TDN as a predictor of microbial efficiency with level 1 of the NRC (1996) model. The NRC (1996) model uses a default value of 13% for estimating microbial efficiency with a 2.2% decrease for every 1% the dietary effective NDF is <20% to account for effects of low ruminal pH on microbial turnover (Russell et al., 1992). For the diet containing 85% corn and 10% corn silage, predicted microbial efficiency is 7.4%. Differences between this predicted value and the predicted 10.4% microbial efficiency determined in this trial are attributed to increased ruminal carbohydrate digestion with steam-flaked corn (Cooper et al., 2002b) and reduced acidosis with wet corn gluten feed inclusion (Herold et al., 1998; Scott et al., 2003).

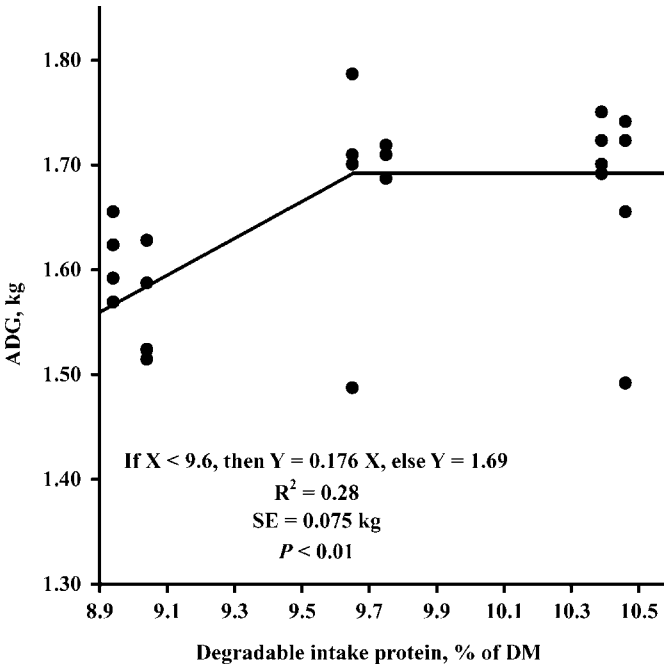

Figure 3. Nonlinear analysis of effect of degradable intake protein (DIP) on ADG. Observed pen ADG (solid circles) and the nonlinear, breakpoint relationship between ADG and DIP (line) are indicated.

Increased microbial efficiency resulted in NRC (1996) model metabolizable protein (**MP**) balances that were in excess of requirements for all experimental diets. Evaluation of MP balances during the first week after adaptation to the final finishing diet when MP requirements can be expected to be greatest also resulted in MP levels that were in excess of requirements for all experimental diets (data not shown) with a minimum surplus of 113 g of MP/d. Given surplus MP, responses to DIP must result from improvements in microbial fermentation and total energy yield to the cattle, not from increased supply of microbial protein.

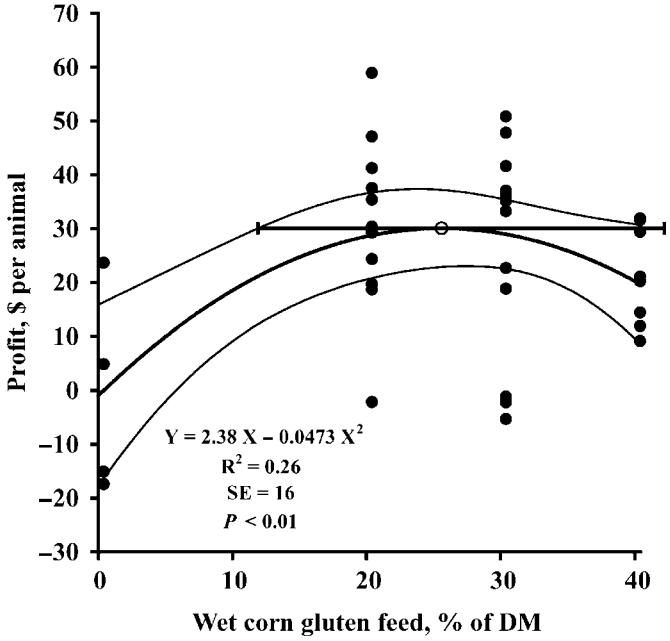

Figure 4. Effect of wet corn gluten feed on profitability relative to steam-flaked corn diets without wet corn gluten feed. Observed pen average profitability above the 0% wet corn gluten feed diet (solid circles) and 95% confidence intervals (thin flanking curve) for profitability predicted from the quadratic relationship between profitability and wet corn gluten feed (thick central curve). Maximum profitability (open circle) and fiducial interval (horizontal error bars) are also indicated.

Carcass Characteristics

Neither DIP level nor wet corn gluten feed inclusion into steam-flaked corn-based finishing diets affected (P = 0.12 to 0.99) fat thickness evaluated at the 12th rib, LM area, or marbling (Table 2).

Economic Evaluation

Inclusion of wet corn gluten feed into steam-flaked corn-based finishing diets was found to be economically favorable with a quadratic response ($P < 0.01$). Diminishing returns exist, although expected profitability relative to steam-flaked corn diets without wet corn gluten feed remained positive for all levels of wet corn gluten feed evaluated in this study (Figure 4). The fitted regression equation predicted a maximum economic return of $30.05 per animal above the 0% wet corn gluten feed level at 25% wet corn gluten feed; the 95% confidence and fiducial intervals for maximum economic return were $22.88 to $37.21 per animal and 11 to >40% wet corn gluten feed inclusion, respectively. With this study, the economically optimal level of wet corn gluten feed to include in steam-flaked corn-based finishing diets increased in response to decreases in finished cattle prices and greater price spreads between steam-flaked corn and wet corn gluten feed. The economically optimal wet corn gluten feed inclusion level also shifted in response to changes in finished cattle prices. Elevated prices placed increased emphasis on ADG or HCW, which was predicted to be maximal at 23% wet corn gluten feed.

Implications

Wet corn gluten feed inclusion into steam-flaked corn-based finishing diets for steers will increase dry matter intake, likely through reducing acidosis, and will improve daily gain with little impact on gain:feed. Steers fed steam-flaked corn and wet corn gluten feed-based finishing diets that contain surplus metabolizable protein benefit from supplemental degradable intake protein, presumably through improvements in microbial fermentation and subsequent total energy yield. The requirement for degradable intake protein in steam-flaked corn and wet corn gluten feed based finishing diets for steers was comparable with previously observed requirements for steam-flaked corn-based finishing diets for steers that did not contain wet corn gluten feed.

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