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Effects of concentration and composition of wet corn gluten feed in steam-flaked corn-based finishing diets¹

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ABSTRACT: Two finishing experiments were conducted to determine the effects of concentration (Exp. 1) and composition of wet corn gluten feed (Exp. 2) in steam-flaked corn-based diets on feedlot steer performance. In Exp. 1, 192 English × Continental crossbred steer calves (299 ± 0.6 kg) were used in a completely randomized design with six dietary treatments (four pens per treatment). Treatments were six concentrations of wet corn gluten feed (Sweet Bran, Cargill Inc., Blair, NE; 0, 10, 20, 25, 30, and 35%) replacing steam-flaked corn (DM basis). All diets contained 10% corn silage, 5% supplement, and 3.5% tallow (DM basis). Gain efficiency and ADG were similar ($P > 0.25$) among treatments. Dry matter intake was lower ($P < 0.10$) with 0% wet corn gluten feed than with concentrations of 20, 25, and 35% WCGF. Dry matter intake did not differ among treatments containing wet corn gluten feed. In Exp. 2, 160 English × Continental crossbred steer calves (315 ± 0.6 kg) were used in a completely randomized design with five dietary treatments (four pens/treatment). Treatments were assigned based on four ratios of steep to corn bran/germ meal mix in wet

corn gluten feed plus a negative control (CON). Wet corn gluten feed was fed at 25% of the dietary DM and was made by mixing steep and corn bran/germ meal into the diet. The four concentrations of steep in wet corn gluten feed that comprised the ratios were 37.5, 41.7, 45.8, and 50% (DM basis), with the remaining proportion being the bran/germ meal mix. Bran/germ meal mix was comprised of 60% dry corn bran, 24% germ meal, and 16% fine-cracked corn (DM basis). All diets contained 10% corn silage, 5% supplement, and 3.5% tallow (DM basis). Daily gain did not differ ($P = 0.18$) among treatments. Gain efficiency did not differ between CON and 50% steep; however, G:F was decreased ($P < 0.05$) for concentrations of 37.5, 41.7, and 45.8% steep compared with CON. A linear improvement ($P < 0.05$) was observed for G:F as concentration of steep increased as a proportion of wet corn gluten feed. These data suggest that wet corn gluten feed can be used at concentrations up to 35% of the dietary DM without adversely affecting performance, and that steep has more energy than bran/germ meal in steam-flaked corn-based diets.

Key Words: Corn Gluten Feed, Finishing Cattle, Steam Flaking

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Introduction

Wet corn gluten feed (WCGF) is a by-product of the corn wet milling industry and is comprised primarily of steep liquor (liquid resulting from steeping corn) and corn bran. However, depending on wet milling plant capabilities, WCGF may also contain distiller solubles, germ meal, and kernel screenings (Stock et al., 2000). Feeding WCGF in dry-rolled corn (DRC)-based finish-

ing diets has been shown to increase intake and gain, while maintaining or improving feed efficiency (Stock et al., 2000). The energy concentration of WCGF can vary and has been associated with the proportion of steep in WCGF (Stock et al., 2000). Steep contains more energy than corn bran (Scott et al., 1997b) and germ meal (Herold et al., 1998), the other components of WCGF, when fed in DRC based finishing diets.

The majority of the research conducted with WCGF and its components has been in DRC-based diets. Cattle efficiency responses to WCGF in steam-flaked corn (SFC)-based finishing diets (Sindt et al., 2002) have differed from responses shown in DRC-based diets (Ham et al., 1995; Scott et al., 1997a). However, in Sindt et al. (2002), 0, 30, and 60% of diet DM were evaluated, and replacing 30% of SFC was equal to SFC diets alone. However, only three concentrations were evaluated.

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Table 1. Finishing diet ingredient composition, DM basis (Exp. 1)

Ingredient, %	Treatments ^a					
	0%	10%	20%	25%	30%	35%
Steam-flaked corn	81.5	71.5	61.5	56.5	51.5	46.5
Wet corn gluten feed	—	10.0	20.0	25.0	30.0	35.0
Corn silage	10.0	10.0	10.0	10.0	10.0	10.0
Tallow	3.5	3.5	3.5	3.5	3.5	3.5
Dry meal supplement	5.0	5.0	5.0	5.0	5.0	5.0
Urea	1.81	1.38	0.96	0.75	0.53	0.32
Limestone	1.73	1.72	1.71	1.71	1.71	1.70
Potassium chloride	0.47	0.34	0.20	0.14	0.07	—
Ammonium sulfate	0.40	0.29	0.17	0.11	0.06	—
Sodium chloride	0.30	0.30	0.30	0.30	0.30	0.30
Tallow	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral premix ^b	0.05	0.05	0.05	0.05	0.05	0.05
Fine ground milo	0.05	0.73	1.42	1.75	2.09	2.44
Rumensin-80 premix ^c	0.02	0.02	0.02	0.02	0.02	0.02
Tylan-40 premix ^d	0.01	0.01	0.01	0.01	0.01	0.01
Vitamin premix ^e	0.01	0.01	0.01	0.01	0.01	0.01
Analyzed composition						
DM, %	73.5	71.0	68.8	67.7	66.6	65.6
CP, % ^f	14.1	14.3	14.5	14.6	14.7	14.7

^aConcentration of WCGF inclusion (DM basis).

^bContained (g/kg of premix): 130 Ca, 10 Co, 15 Cu, 2 I, 100 Fe, 80 Mn, and 120 Zn.

^cDiet formulated to contain 34 mg/kg of monensin (176 g of monensin/kg of premix).

^dDiet formulated to contain 11 mg/kg of tylosin (88 g of monensin/kg of premix).

^eContained 29.9 million IU of vitamin A, 6.0 million IU of vitamin D, and 7,000 IU of vitamin E/kg of premix.

^fCP values were analyzed and equal for both Phases 1 and 2. The only change was replacing the urea and feather meal: blood meal combination.

Therefore, the objectives of these studies were 1) to determine the optimal concentration of WCGF and 2) to evaluate the interaction of steep and corn bran/germ meal concentration of WCGF in SFC-based diets fed to finishing cattle.

Materials and Methods

Experiment 1

One hundred ninety-two English × Continental crossbred steer calves (299 ± 0.6 kg) were stratified by BW (eight BW strata) and assigned randomly to one of 24 open-lot pens (eight steers per pen). Pens were assigned randomly to one of six dietary treatments (four pens per treatment). Treatments were assigned based on six concentrations of Sweet Bran (Cargill Inc., Blair, NE) WCGF in SFC-based diets. Concentrations were 0, 10, 20, 25, 30, and 35% WCGF (DM basis), and WCGF replaced SFC in the diets. Steam-flaked corn was processed to a flake density of 0.34 kg/L (26 lb/bushel) at a commercial feedlot (Mead Cattle Co., Mead, NE) and delivered twice per week. Flake density was measured by flake thickness (Zinn, 1990). All diets contained 3.5% tallow and 10% corn silage (DM basis). Steers were adapted to finishing diets in 29 d using SFC to replace alfalfa hay (35% alfalfa hay for 7 d, 25% for 8 d, 15% for 7 d, and 5% for 7 d, DM basis). Feed ingredients were sampled on a weekly basis to correct DM in the diets. Supplements were fed in two phases to supply

undegraded intake protein (**UIP**) early in the finishing stage when calves may be deficient in metabolizable protein (**MP**). In Phase 1, UIP was supplemented to calves using feather and blood meal (50:50 ratio) at 1% of dietary DM. In Phase 2, UIP was replaced with urea when cattle were estimated to weigh 398 kg. This occurred on d 41 of the feeding period. Diets (Table 1) were formulated (DM basis) to contain a minimum of 14.0% CP, 0.70% Ca, 0.51% P, 0.65% K, 34 mg/kg of monensin (Elanco Animal Health, Indianapolis, IN), and 11 mg/kg of tylosin (Elanco Animal Health). Diets were formulated to meet protein requirements using the 1996 NRC beef cattle model at two stages: the beginning of Phases 1 and 2 (Table 2). Protein analysis was determined on feeds from total N analysis by combustion method using a N analyzer (Leco FP428, Leco Corp., St. Joseph, MI). Bacterial protein efficiency was increased 20% for the proportion of SFC that was included in the diet, based on the data of Cooper et al. (2002).

Steers were vaccinated with Pyramid MLV 4 (Fort Dodge Animal Health, Overland Park, KS), Presponse HM (Fort Dodge Animal Health), and Vision 7 with somnus (Intervet, Millsboro, DE) and poured with Cydectin (Fort Dodge Animal Health) upon arrival to the feedlot (35 to 50 d before initiation of the trial). Steers were implanted initially (0 d) with Synovex-C (10 mg of estradiol benzonate and 100 mg of progesterone; Fort Dodge Animal Health) and reimplanted with Revalor-S (24 mg of estradiol and 120 mg of trenbolone acetate;

Table 2. The NRC (1996) beef cattle model formulated metabolizable protein balances for Phases 1 and 2 of protein supplementation (Exp. 1)

Item	Treatments ^a					
	0%	10%	20%	25%	30%	35%
Phase 1 ^b						
MP ^c						
Supplied, g/d	761	767	771	771	774	776
Required, g/d	764	764	764	764	764	764
Balance, g/d	-3	3	7	7	10	12
DIP ^c						
Supplied, g/d	694	692	689	688	686	685
Required, g/d	667	671	671	672	674	676
Balance, g/d	27	22	18	16	12	9
Phase 2 ^d						
MP						
Supplied, g/d	843	849	855	858	860	863
Required, g/d	776	776	776	776	776	776
Balance, g/d	67	73	79	82	84	87
DIP						
Supplied, g/d	871	866	861	859	856	854
Required, g/d	778	762	785	787	788	789
Balance, g/d	93	84	76	72	68	65

^aConcentration of wet corn gluten feed inclusion (DM basis).

^bSupplied UIP from feather meal and blood meal (50:50) and fed for the first 40 d. Inputs for cattle entered into the model were: BW = 318 kg; ADG = 1.63 kg; DMI = 8.0 kg/d; and final BW = 591 kg.

^cMP = metabolizable protein, DIP = degraded intake protein, and UIP = undegraded intake protein.

^dUrea replaced the UIP supplementation and fed for the last 111 d. Inputs for cattle entered into the model were: BW = 523 kg; ADG = 1.63 kg; DMI = 9.3 kg/d; and final BW = 591 kg.

Intervet) on d 53. Steers were fed for 151 d. Steers were fed once daily between 0800 and 1100 using a Roto-Mix 420-12 mixer with a 0.45-kg scale break and allowed ad libitum access to feed and water.

Initial BW were obtained on individual steers with a scale break of 0.45 kg on two consecutive days after being limit fed at 2% (DM basis) of BW for 5 d to minimize ruminal fill differences. Final weight was calculated from hot carcass weight divided by 63%. Daily gain, DMI, and G:F were calculated on a pen basis. Hot carcass weights were collected on all steers at the time of slaughter, whereas other carcass traits were collected following a 24-h chill. Dietary NE_g concentrations were calculated, based on performance, using the iterative procedure described by Owens et al. (2002).

Data were analyzed as a completely randomized design using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC), with pen as experimental unit. Treatment was used in the model statement. Least squares means were separated using the LSD method when a significant ($P < 0.05$) overall F -test was detected. Linear, quadratic, and cubic effects were tested for concentration of WCGF using regression procedures in the MIXED procedure for unequally spaced treatments. Procedures for the study had been reviewed and accepted by the University of Nebraska Institutional Animal Care Program.

Experiment 2

One hundred sixty English × Continental crossbred steer calves (315 ± 0.6 kg) were stratified by BW (eight

BW strata) and assigned randomly to one of 20 open-lot pens (eight steers per pen). Pens were assigned randomly to one of five dietary treatments (four pens per treatment). Treatments were assigned based on four ratios of steep liquor plus distiller solubles (steep) to a corn bran/germ meal mix (**B/GM**) in WCGF, plus a negative control (**CON**) without WCGF. Wet corn gluten feed was fed at 25% of dietary DM and was made by mixing steep and B/GM into the diet. The B/GM was mixed weekly and added to the diet as one ingredient. The B/GM mix was 60% corn dry bran, 24% germ meal, and 16% fine-cracked corn (DM basis). The B/GM and steep were mixed into the diet as separate ingredients to produce four concentrations of steep in the WCGF: 37.5% steep; 41.7% steep; 45.8% steep; and 50.0% steep (DM basis, Table 3). Steam-flaked corn was processed to a flake density of 0.34 kg/L (26 lb/bushel) at a commercial feedlot (Mead Cattle Co.) and delivered twice per week. All diets fed contained 3.5% tallow and 10% corn silage (DM basis). Steers were adapted to finishing diets in 21 d using SFC to replace alfalfa hay (35% alfalfa hay for 3 d, 25% for 4 d, 15% for 7 d, and 5% for 7 d, DM basis). Feed ingredients were sampled on a weekly basis to correct DM in the diets. Supplements were fed in two phases similar to Trial 1 and switched when cattle were estimated to weigh 432 kg. This occurred on d 65 of the feeding period. Diets (Table 3) were formulated (DM basis) to contain a minimum of 14.0% CP, 0.70% Ca, 0.51% P, 0.65% K, 34 mg/kg of monensin, and 11 mg/kg tylosin. Formulation of MP balances and protein analysis were similar to Exp. 1.

Table 3. Finishing diet ingredient composition, DM basis (Exp. 2)

Ingredient, %	Treatments ^a				
	CON	37.5% ST	41.7% ST	45.8% ST	50.0% ST
Steam-flaked corn	81.5	56.5	56.5	56.5	56.5
Corn silage	10.0	10.0	10.0	10.0	10.0
Tallow	3.5	3.5	3.5	3.5	3.5
Steep	—	9.4	10.4	11.5	12.5
Bran/GM mix ^b					
Bran	—	9.4	8.8	8.1	7.5
Germ meal	—	3.8	3.5	3.3	3.0
Fine-cracked corn	—	2.5	2.3	2.2	2.0
Dry meal supplement	5.0	5.0	5.0	5.0	5.0
Urea	1.81	0.89	0.83	0.78	0.72
Limestone	1.73	1.71	1.71	1.71	1.71
Potassium chloride	0.47	—	—	—	—
Ammonium sulfate	0.40	0.14	0.12	0.10	0.08
Sodium chloride	0.30	0.30	0.30	0.30	0.30
Tallow	0.15	0.15	0.15	0.15	0.15
Trace mineral premix ^c	0.05	0.05	0.05	0.05	0.05
Fine ground milo	0.05	1.72	1.80	1.87	1.95
Rumensin-80 premix ^d	0.02	0.02	0.02	0.02	0.02
Tylan-40 premix ^e	0.01	0.01	0.01	0.01	0.01
Vitamin premix ^f	0.01	0.01	0.01	0.01	0.01
Analyzed composition					
DM, %	73.5	69.0	68.5	67.9	67.5
CP, %	14.1	14.6	14.6	14.7	14.7

^aCON = 0% wet corn gluten feed (WCGF), 37.5% ST = 25% WCGF made with 37.5% steep, 41.7% ST = 25% WCGF made with 41.7% steep, 45.8% ST = 25% WCGF made with 45.8% steep, and 50.0% ST = 25% WCGF made with 50.0% steep.

^bThe ratio of corn bran, germ meal, and fine-cracked corn was constant (60, 24, and 16% DM basis; respectively)

^cContained (g/kg of premix): 130 Ca, 10 Co, 15 Cu, 2 I, 100 Fe, 80 Mn, and 120 Zn.

^dFormulated to contain 34 mg/kg of monensin (176 g of monensin/kg of premix).

^eFormulated to contain 11 mg/kg of tylosin (88 g of monensin/kg of premix).

^fContained 29.9 million IU of vitamin A, 6.0 million IU of vitamin D, and 7,000 IU of vitamin E/kg of premix.

Steers were vaccinated as in Exp. 1, but initiation of Exp. 2 was 42 d after the initiation of Exp. 1. Steers were implanted initially (0 d) with Synovex C (Fort Dodge Animal Health) and reimplanted with Revalor-S (Intervet) on d 46. Steers were fed for 132 d. Steers were fed once daily between 0800 and 1100 using a Roto-Mix 420-12 mixer with a 0.45-kg scale break and were allowed ad libitum access to feed and water. Response criteria and measurements for cattle performance and carcass characteristics were similar to Exp. 1.

Data were analyzed as a completely randomized design using the MIXED procedure of SAS with pen as the experimental unit. Treatment was used in the model statement. Least squares means were separated using the LSD method when a significant ($P < 0.05$) overall F -test was detected. Linear, quadratic, and cubic effects were tested for concentration of steep. Procedures for the studies were reviewed and approved by the University of Nebraska Institutional Animal Care Program.

Results and Discussion

Experiment 1

Final weights, ADG, and G:F did not differ ($P > 0.25$) among treatments (Table 4) resulting in similar ($P =$

0.29) dietary NE_g concentrations. However, a tendency for a linear effect was observed ($P = 0.07$) for DMI, such that DMI increased in response to increasing concentration of WCGF. The linear effect on inclusion concentration of WCGF on DMI is consistent with previous reports using SFC- (Block et al., 2002; Sindt et al., 2002) and DRC-based diets (Scott et al. 1997a). Block et al. (2002) reported a quadratic effect for ADG and feed efficiency for concentrations of WCGF of 0, 20, 30, and 40% of diet DM, optimizing in the range of 20 to 30% inclusion. These concentrations differed slightly from the concentrations fed in our study (0, 10, 20, 25, 30, and 35%). Potentially, the difference in concentrations may account for differences across experiments. The 10% concentration of WCGF in our study seems to have had some negative effect on feed efficiency and dietary NE_g . Feeding 40% WCGF (DM basis) in SFC-based diets decreased G:F (Parsons et al. 2001; Block et al. 2002; Sindt et al. 2002) compared with no inclusion of WCGF in finishing diets. With these considerations, feeding 10% concentration and not feeding a 40% concentration may explain the lack of quadratic response. Hot carcass weight, marbling, fat thickness, LM area, and USDA yield grade did not differ ($P > 0.47$) among treatments (Table 4). These data would suggest that

Table 4. Effect of WCGF concentration in steam-flaked corn-based diets on cattle performance and carcass characteristics (four pens per treatment)

Item	Treatments ^a						SEM	P-value ^b
	0%	10%	20%	25%	30%	35%		
Days on feed	151	151	151	151	151	151	—	—
Initial BW, kg	299	299	300	298	300	299	1	0.22
Final BW, kg ^c	596	601	615	604	599	603	7	0.47
DMI, kg/d	9.11	9.44	9.70	9.46	9.41	9.71	0.14	0.07
ADG, kg	1.97	1.99	2.09	2.03	1.98	2.01	0.04	0.47
G:F	0.216	0.211	0.215	0.214	0.210	0.207	0.003	0.25
Dietary NE _g , Mcal/kg of DM	1.58	1.54	1.57	1.56	1.53	1.51	0.02	0.29
Carcass wt, kg	376	378	387	381	377	380	4	0.47
Marbling score ^d	524	526	514	517	528	534	14	0.92
Fat thickness, cm	1.38	1.36	1.47	1.43	1.42	1.48	0.08	0.87
LM area, cm ²	84.0	84.5	85.8	85.8	86.8	85.5	1.7	0.88
Yield grade	2.81	2.69	2.74	2.75	2.87	2.82	0.1	0.81

^aConcentration of wet corn gluten feed inclusion (DM basis).

^bOverall *F*-test.

^cFinal weight calculated as hot carcass weight divided by 0.63.

^dMarbling score: 400 = Slight 0, 450 = Slight 50, 500 = Small 0, 550 = Small 50, etc.

concentrations up to 35% WCGF can be fed with steam-flaked corn-based diets.

Experiment 2

Cattle fed steep and B/GM (25% of diet DM) had greater ($P < 0.05$) DMI compared with the cattle fed CON (Table 5). The response at this concentration of inclusion is similar to results observed in Trial 1 and results previously reported (Block et al., 2002; Sindt et

al., 2002) when WCGF replaced SFC in finishing diets. Within steep and B/GM, a quadratic response ($P < 0.05$) was observed for DMI, with DMI being greatest for the 41.7 and 45.8% steep concentrations. Herold (1999) reported a quadratic response to the ratio of steep to bran and a linear response to the ratio of steep to B/GM in DRC-based finishing diets. The range of steep percentage in the Herold (1999) study (20 to 50%, DM basis) was greater than the range used in our study (37.5 to 50%, DM basis), and the range in steep may

Table 5. Cattle performance and carcass characteristics with different steep to corn bran/germ meal ratios in wet corn gluten feed (WCGF) added to steam-flaked corn-based diets (four pens per treatment)

Item	Treatments ^a					SEM	P-value ^b
	CON	37.5% ST	41.7% ST	45.8% ST	50.0% ST		
Days on feed	132	132	132	132	132		
Initial BW, kg	315	314	316	314	315	1	0.12
Final BW, kg ^c	601	598	611	610	610	5	0.19
DMI, kg/d ^d	9.58 ^g	10.30 ^h	10.46 ^h	10.48 ^h	10.19 ^h	0.10	<0.01
ADG, kg	2.16	2.15	2.24	2.24	2.24	0.04	0.18
G:F ^e	0.226 ^g	0.208 ⁱ	0.214 ^{hi}	0.214 ^{hi}	0.220 ^{gh}	0.003	0.02
Dietary NE _g , Mcal/kg of DM ^e	1.64 ^g	1.51 ⁱ	1.55 ^{hi}	1.55 ^{hi}	1.59 ^{gh}	0.02	0.02
Carcass wt, kg	379	377	385	384	385	3	0.18
Marbling score ^f	516	533	531	538	528	9	0.55
Fat thickness, cm	1.25 ^g	1.42 ^{gh}	1.48 ^h	1.60 ^h	1.47 ^h	0.07	0.03
LM area, cm ²	107.0	100.8	103.7	100.5	103.9	1.5	0.06
Yield grade	2.38 ^g	2.85 ^h	2.81 ^h	2.83 ^h	2.82 ^h	0.11	0.04

^aCON = 0% WCGF, 37.5 ST = 25% WCGF made with 37.5% steep, 41.7 ST = 25% WCGF made with 41.7% steep, 45.8 ST = 25% WCGF made with 45.8% steep, and 50.0 ST = 25% WCGF made with 50.0% steep.

^bOverall *F*-test.

^cFinal weight calculated as hot carcass weight divided by 0.63.

^dQuadratic effect of steep percentage of WCGF ($P < 0.05$).

^eLinear effect of steep percentage of WCGF ($P < 0.05$).

^fMarbling score: 400 = Slight 0, 450 = Slight 50, 500 = Small 0, etc.

^{g,h,i}Means within a row with different superscripts differ ($P < 0.05$).

explain the different response between this study and other experiments.

Daily gain did not differ ($P = 0.18$) among treatments, although there was a linear trend ($P = 0.09$) for ADG to increase as steep concentration increased. Compared with the CON, feeding wet milling by-products did not affect ($P = 0.18$) ADG, which was similar to the response observed in Exp. 1. Gain efficiency did not differ between CON and 50.0% steep. A linear improvement ($P < 0.05$) in G:F was detected as the percentage of steep increased, suggesting that steep has a higher energy value than B/GM meal in SFC-based diets. This response is similar to the response observed in DRC-based diets (Herold 1999). Scott et al. (1997b) and Herold et al. (1998) reported that the energy value of steep was greater than that of corn bran and germ meal, respectively, in DRC-based finishing diets.

Hot carcass weight, LM area, and marbling score did not differ among treatments. Cattle fed CON had less ($P < 0.05$) fat and lower USDA yield grades than did those fed steep and B/GM, suggesting that the CON cattle were not finished to the same end point as the steep and B/GM cattle. Presumably, G:F for the CON cattle would have been less if they had been fed to the same fat thickness as the cattle fed the by-products. Therefore, it is unclear from the G:F data as to whether CON cattle were more efficient due to diet energy or composition of gain. It also is unclear how one might correct for such composition of gain effects on feed efficiency.

Implications

Replacing steam-flaked corn with wet corn gluten feed up to 35% of diet DM had minimal effects on finishing cattle performance. Steep liquor plus distiller solubles content of wet corn gluten feed can affect the feeding value of wet corn gluten feed in finishing cattle diets. A higher percentage of steep in wet corn gluten feed increased energy value and improved cattle performance. Therefore, knowing the composition of wet corn gluten feed is important to determine the response that will be observed with the replacement of steam-flaked

corn with wet corn gluten feed in finishing beef cattle diets.

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