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Effect of Energy Source and Escape Protein on Receiving and Finishing Performance and Health of Calves[1]

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ABSTRACT: Two receiving and two finishing trials evaluated energy source and escape protein supplementation for calves. In receiving Trial 1, 398 calves (257 ± 24 kg BW) were used in a 2 × 2 factorial arrangement of treatments. Energy sources were dry-rolled corn (DRC) and wet corn gluten feed (WCGF); each was fed without or with supplemental escape protein (EP). Calves fed WCGF gained slower ($P < .05$) and consumed less DM ($P < .01$) than calves fed DRC. Feed efficiency improved ($P < .10$) with EP supplementation. In finishing Trial 1, 240 calves (305 ± 21 kg BW) were used. The arrangement of treatments was the same as in receiving Trial 1. Calves fed DRC/WCGF tended ($P = .15$) to be more efficient and consumed less DM ($P < .05$) than calves fed DRC. In receiving Trial 2, 315 calves (252 ± 23 kg BW) were fed diets similar to those fed in receiving Trial 1. Calves fed WCGF consumed less DM ($P < .01$), gained similarly ($P > .15$), and were more efficient ($P < .10$) than calves fed DRC. In finishing Trial 2, 320 calves (298 ± 23 kg BW) were fed diets containing DRC, DRC/WCGF, high-moisture corn (HMC), HMC/WCGF, and DRC/HMC; each was fed without or with supplemental EP. An energy source × protein supplement interaction was detected for gain ($P < .05$) and efficiency ($P < .01$). Results suggest that WCGF has a NE_g greater than DRC in receiving diets and a NE_g similar to that of DRC but lower than that of HMC in finishing diets.

Key Words: Maize, Gluten Feed, Protein, Cattle

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Introduction

Large-framed calves are well suited to an intensive production system in which finishing begins shortly after weaning. Compared with yearlings, weaned calves are less mature and deposit more lean tissue relative to fat when placed in the feedlot. Therefore, the relative need for metabolizable protein (**MP**) is greater with calves, especially during the first 30 d of finishing (Sindt et al., 1994).

Wet corn gluten feed (**WCGF**), a fibrous by-product of the corn wet milling industry, is an excellent energy source in beef cattle diets (Ham et al., 1995; Richards et al., 1997). Compared with dry-rolled corn (**DRC**), WCGF is higher in CP (approximately 16 vs 9%) but lower in escape protein (26% of CP [Firkins et al., 1984] vs 66% of CP [Sindt et al., 1993a]).

High-moisture corn (**HMC**) is used widely in finishing diets. Like WCGF, the escape protein potential of HMC is lower than that of DRC (38% of CP [Sindt et al., 1993b]). Unless the CP in these feeds is captured and made usable as microbial protein, the lower escape protein potential of WCGF and HMC may create a deficiency in MP and increase the need for escape protein supplementation. The objectives of this research were to determine the energy value of WCGF and the interaction of WCGF and addition of escape protein on performance and health of receiving and finishing calves and to determine the interaction of WCGF and corn source (DRC or HMC) on finishing performance.

Experimental Procedures

Receiving Trial 1. Steer calves (n = 398; 257 ± 24 kg BW) were received at the University of Nebraska Agricultural Research and Development Center, Mead, during the fall of 1993. Calves were processed on the same day as they were received. Calves were vaccinated (bovine respiratory syncytial virus [killed]; *Haemophilus somnus* [killed]; infectious bovine rhinotracheitis [modified-live]; bovine viral diarrhea [modified-live]; and parainfluenza-3 [modified-live]), identified with ear tags, and weighed individually.

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Table 1. Composition of diets in receiving Trial 1 (% on a DM basis)

Item	DRC/U[a]	DRC/EP[a]	WCGF[a]	WCGF/EP[a]
Dry-rolled corn	44.91	44.91	—	—
Wet corn gluten feed	—	—	52.00	52.00
Alfalfa hay	45.00	45.00	45.00	45.00
Molasses	6.09	6.09	—	—
Dry supplement	4.00	4.00	3.00	3.00
Finely ground corn	2.40	.79	2.21	.50
Urea	.73	.64	—	—
Feather meal	—	1.36	—	1.36
Blood meal	—	.35	—	.35
Tallow	.06	.06	.06	.06
Limestone	—	—	.36	.36
Dicalcium phosphate	.23	.21	—	—
Potassium chloride	.31	.32	—	—
Sodium chloride[b]	.21	.21	.30	.30
Vitamin premix[c]	.01	.01	.01	.01
Thiamin premix[d]	—	—	.01	.01
Trace mineral premix[e]	.05	.05	.05	.05
Nutrient composition[f]				
CP	13.0	14.2	15.3	16.7
DIP	8.8	8.9	11.4	11.8
Ca	.73	.73	.80	.80
P	.35	.35	.54	.54
K	1.30	1.30	1.55	1.55

[a]DRC = dry-rolled corn; U = urea; EP = escape protein (80% feather meal:20% blood meal, CP basis); WCGF = wet corn gluten feed.

[b]Molasses contributes .09% sodium chloride.

[c]15,000 IU of vitamin A, 3,000 IU of vitamin D, and 3.75 IU of vitamin E/g premix.

[d]18 g of thiamin/kg of premix.

[e]10% Mg, 6% Zn, 4.5% Fe, 2% Mn, .5% Cu, .3% I, and .05% Co.

[f]The CP for dry-rolled corn, wet corn gluten feed, alfalfa hay, and molasses was based on analyzed (AOAC, 1975) values. The CP for urea, feather meal, and blood meal was based on tabular (NRC, 1984) values. Degradable intake protein (DIP) based on analyzed and tabular CP values and referenced (Table 5) DIP (100 − UIP) values. The Ca, P, and K were based on tabular values (NRC, 1984).

Additionally, calves were given booster vaccinations (bovine respiratory syncytial virus and *Haemophilus somnus*), vaccinated against *Clostridia* species (seven-way), and treated for internal parasites on d 14. Calves were assigned randomly to one of four dietary treatments. Calves were received in four groups and assigned to seven replications. All calves came from sale barns and were of mixed origin. Group 1 (replications 1 and 2; 88 calves, 11 calves/pen) was transported approximately 970 km; group 2 (replications 3 and 4; 160 calves, 20 calves/pen) was transported approximately 180 km; group 3 (replication 5; 67 calves, 16 to 17 calves/pen) was transported approximately 970 km; and group 4 (replications 6 and 7; 83 calves, 10 to 11 calves/pen) was transported approximately 480 km. Groups 1, 3, and 4 were processed shortly after arrival and had no access to feed or water before processing. Group 2 had access to grass hay and water for approximately 2 h before processing.

A 2 × 2 factorial arrangement of treatments was used in which factors were energy source (DRC or WCGF [Minnesota Corn Processors, Columbus, NE; 16.1% CP, 48.5% NDF]) and protein supplement (no supplemental escape protein or supplemental escape protein). Urea (**U**) was the source of supplemental CP in diets with no supplemental escape protein. Supplemental escape protein (**EP**) was provided by an 80% feather meal (**FTH**):20% ring-dried blood meal (**BM**) blend (CP basis). Diets (Table 1) were formulated to contain a minimum of (DM basis) 9.2% degradable intake protein (**DIP**), which would supply sufficient NH_3 for maximal microbial protein synthesis (Burroughs et al., 1974) in calves fed high-forage diets. Additionally, diets were formulated to contain a minimum of .35% P and 1.30% K (DM basis).

Calves were observed daily for sickness. Sick calves were moved from their pens to respective hospital pens, maintained on their dietary treatments, treated with antibiotics, and returned to their original pens when health was restored. Sick calves were included in the data set for performance analysis. Calves from groups 1, 2, 3, and 4 were fed 25, 33, 31, and 21 d, respectively. Final weights were determined as the average of two consecutive days' weights, shrunk 2% to account for gut fill.

Finishing Trial 1. Calves (n = 240; 305 ± 21 kg BW) representing the 60 heaviest calves from each receiving treatment were used in finishing Trial 1. Calves were blocked by weight (six pens/treatment) and assigned randomly, within block, to one of four pens (10 calves/pen). All calves were maintained on their receiving dietary treatment.

Table 2. Composition of diets in finishing Trial 1 (% on a DM basis)

Item	DRC/U[a]	DRC/EP[a]	DRC/WCGF[a]	DRC/WCGF/EP[a]
Dry-rolled corn	79.91	77.91	42.00	40.00
Wet corn gluten feed	—	—	45.00	45.00
Alfalfa hay	5.00	5.00	5.00	5.00
Corn silage	5.00	5.00	5.00	5.00
Molasses	6.09	6.09	—	—
Dry supplement	4.00	6.00	3.00	5.00
Finely ground corn	.96	1.33	1.07	1.44
Urea	1.07	1.07	—	—
Feather meal	—	1.28	—	1.28
Blood meal	—	.32	—	.32
Tallow	.08	.12	.06	.10
Limestone	1.37	1.38	1.49	1.48
Dicalcium phosphate	.09	.06	—	—
Potassium chloride	.15	.16	—	—
Sodium chloride[b]	.21	.21	.30	.30
Vitamin premix[c]	.01	.01	.01	.01
Thiamin premix[d]	—	—	.01	.01
Trace mineral premix[e]	.03	.03	.03	.03
Rumensin premix[f]	.02	.02	.02	.02
Tylan premix[g]	.01	.01	.01	.01
Nutrient composition[h]				
CP	11.2	12.5	11.9	13.1
DIP	6.8	6.8	8.0	8.1
Ca	.70	.70	.70	.70
P	.35	.35	.53	.53
K	.70	.70	.95	.95

[a]DRC = dry-rolled corn; U = urea; EP = escape protein (80% feather meal:20% blood meal, CP basis); WCGF = wet corn gluten feed.
[b]Molasses contributes .09% sodium chloride.
[c]15,000 IU of vitamin A, 3,000 IU of vitamin D, and 3.75 IU of vitamin E/g premix.
[d]18 g of thiamin/kg of premix.
[e]10% Mg, 6% Zn, 4.5% Fe, 2% Mn, .5% Cu, .3% I, and .05% Co.
[f]132 g of monensin/kg of premix.
[g]88 g of tylosin/kg of premix.
[h]The CP for dry-rolled corn, wet corn gluten feed, alfalfa hay, corn silage, molasses, and feather meal was based on analyzed (AOAC, 1975) values. The CP for urea and blood meal was based on tabular (NRC, 1984) values. Degradable intake protein (DIP) was based on analyzed and tabular CP values and referenced (Table 5) DIP (100 − UIP) values. The Ca, P, and K were based on tabular values (NRC, 1984).

Treatments were arranged the same as in receiving Trial 1. Supplemental EP was provided by an 80% FTH:20% BM blend (CP basis). Calves were adapted to final finishing diets using three adaptation diets containing (DM basis) 35, 25, and 15% forage. Each adaptation diet was fed for 7 d. Final finishing diets (Table 2) were formulated to contain a minimum of (DM basis) 6.8% DIP, which would meet the requirement for maximal microbial protein synthesis (Russell et al., 1992) in calves fed finishing diets. Additionally, diets were formulated to contain a minimum of .70% Ca, .35% P, and .70% K (DM basis).

Calves were vaccinated against *Leptospirosis*, treated for external parasites, implanted with Revalor®-S (Hoechst-Roussel Agri-Vet, Somerville, NJ) initially and on d 84, and fed for an average of 168 d. Final weights were estimated from hot carcass weight assuming a 62% dressing percentage. Livers were scored with the following system (Stock et al., 1990): 0 = healthy liver; 1 = one to four small abscesses; 2 = one to four medium abscesses; 3 = one or more large abscesses; and 4 = adherence of abscess to diaphragm or digestive tract. Additionally, USDA quality and yield grades and fat thickness at the 12th rib were collected after a 48-h chill.

Receiving Trial 2. Calves (n = 315; 252 ± 23 kg BW) were received during the fall of 1994. Processing procedures were the same as described for receiving Trial 1 except calves were not vaccinated or treated for internal parasites on d 14. Calves were assigned randomly to one of four dietary treatments. Calves were received in three groups and were assigned to four replications. Group 1 (replication 1; 69 calves, 17 to 18 calves/pen) came from a sale barn, was of mixed origin, and was transported approximately 970 km. Group 2 (replications 2 and 3; 164 calves, 20 to 21 calves/pen) came directly from a single ranch and was transported approximately 1,820 km. Group 3 (replication 4; 82 calves, 20 to 21 calves/pen) came from a sale barn, was of mixed origin, and was transported

Table 3. Composition of diets in receiving Trial 2 (% on a DM basis)

			d 1 to 7		d 8 to end	
Item	DRC/U[a]	DRC/EP[a]	WCGF[a]	WCGF/EP[a]	WCGF[a]	WCGF/EP[a]
Dry-rolled corn	44.91	43.91	19.50	19.12	—	—
Wet corn gluten feed	—	—	32.50	31.88	52.00	51.00
Alfalfa hay	45.00	45.00	45.00	45.00	45.00	45.00
Molasses	6.09	6.09	—	—	—	—
Dry supplement	4.00	5.00	3.00	4.00	3.00	4.00
Finely ground corn	2.07	1.09	2.37	1.15	2.37	1.15
Urea	1.00	.77	—	—	—	—
Feather meal	—	1.76	—	1.76	—	1.76
Blood meal	—	.45	—	.45	—	.45
Tallow	.12	.15	.09	.12	.09	.12
Limestone	—	—	.19	.17	.19	.17
Dicalcium phosphate	.25	.21	—	—	—	—
Potassium chloride	.31	.32	—	—	—	—
Sodium chloride[b]	.21	.21	.30	.30	.30	.30
Vitamin premix[c]	.01	.01	.01	.01	.01	.01
Thiamin premix[d]	—	—	.01	.01	.01	.01
Trace mineral premix[e]	.03	.03	.03	.03	.03	.03
Nutrient composition[f]						
CP	15.1	16.3	15.5	17.3	17.3	19.0
DIP	10.5	10.3	10.8	11.2	12.8	13.2
Ca	.73	.73	.72	.73	.72	.73
P	.35	.35	.43	.53	.44	.54
K	1.30	1.30	1.30	1.55	1.31	1.54

[a]DRC = dry-rolled corn; U = urea; EP = escape protein (80% feather meal:20% blood meal, CP basis); WCGF = wet corn gluten feed.
[b]Molasses contributes .09% sodium chloride.
[c]15,000 IU of vitamin A, 3,000 IU of vitamin D, and 3.75 IU of vitamin E/g premix.
[d]18 g of thiamin/kg of premix.
[e]10% Mg, 6% Zn, 4.5% Fe, 2% Mn, .5% Cu, .3% I, and .05% Co.
[f]The CP for dry-rolled corn, wet corn gluten feed, alfalfa hay, and molasses based on analyzed (AOAC, 1975) values. The CP for urea, feather meal, and blood meal was based on tabular (NRC, 1984) values. Degradable intake protein (DIP) was based on analyzed and tabular CP values and referenced (Table 5) DIP (100 − UIP) values. The Ca, P, and K were based on tabular values (NRC, 1984).

approximately 640 km. Groups 1 and 3 had access to grass hay and water for approximately 1 h before processing. Group 2 had no access to feed or water before processing.

Arrangement of treatments was the same as in receiving Trial 1. Supplemental EP was provided by an 80% FTH:20% BM blend (CP basis). In an effort to increase DMI during the 1st wk of the receiving period, DRC was included in WCGF diets for the first 7 d (Table 3). Diet formulation constraints were the same as described for receiving Trial 1.

Procedures for sick calves were the same as described for receiving Trial 1. Calves from groups 1, 2, and 3 were fed 32, 28, and 20 d, respectively. Final weights were determined as the average of two consecutive days' weights, shrunk 2% (groups 1 and 3) or 4% (group 2) to minimize weight differences due to incoming shrink.

Finishing Trial 2. Calves (n = 320; 298 ± 23 kg BW; the heaviest 258 calves from receiving Trial 2 and 62 calves similar in weight and breeding) were used in the finishing Trial 2. Calves were blocked by weight (four pens/treatment) and assigned randomly, within block, to one of 10 pens (eight calves/pen).

A 5 × 2 factorial arrangement of treatments was used in which factors were energy source (DRC, DRC/WCGF, HMC, HMC/WCGF, and DRC/HMC) and protein supplement (no supplemental EP or supplemental EP). The HMC was easily harvested (25.3% moisture), ground, and stored in an oxygen-limiting structure. Supplemental EP was provided by an 80% FTH:20% BM blend (CP basis). Calves were adapted to final finishing diets using four adaptation diets containing (DM basis) 45, 35, 25, and 15% forage. Adaptation diets were fed for 2, 6, 7, and 7 d, respectively. Diet formulation constraints for final finishing diets (Table 4) were the same as described for finishing Trial 1.

Calves were vaccinated against *Leptospirosis*, treated for internal and external parasites, implanted with Revalor®-S initially and on d 83, and fed for an average of 164 d. Estimation of final weights and collection of carcass data were the same as described for finishing Trial 1.

Evaluation of Protein Nutrition. Degradable intake protein supplies and requirements and metabolizable protein (**MP**) supplies and requirements for all trials were estimated using the NRC (1996) model, Level 1.

Table 4. Composition of diets in finishing Trial 2 (% on a DM basis)

	No supplemental escape protein					Supplemental escape protein				
Item	DRC[a]	DRC/ WCGF[a]	HMC[a]	HMC/ WCGF[a]	DRC/ HMC[a]	DRC[a]	DRC/ WCGF[a]	HMC[a]	HMC/ WCGF[a]	DRC/ HMC[a]
Dry-rolled corn	78.91	42.00	—	—	36.91	77.91	40.00	—	—	37.91
Wet corn gluten feed	—	45.00	—	45.00	—	—	45.00	—	45.00	—
High-moisture corn	—	—	78.91	42.00	42.00	—	—	77.91	40.00	40.00
Alfalfa hay	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Corn silage	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Molasses	6.09	—	6.09	—	6.09	6.09	—	6.09	—	6.09
Dry supplement	5.00	3.00	5.00	3.00	5.00	6.00	5.00	6.00	5.00	6.00
Finely ground corn	1.77	1.04	1.77	1.04	1.77	.58	.79	.58	.79	.58
Urea	1.17	—	1.17	—	1.17	1.15	—	1.15	—	1.15
Feather meal	—	—	—	—	—	1.76	1.76	1.76	1.76	1.76
Blood meal	—	—	—	—	—	.45	.45	.45	.45	.45
Tallow	.15	.09	.15	.09	.15	.18	.15	.18	.15	.18
Limestone	1.36	1.49	1.36	1.49	1.36	1.37	1.47	1.37	1.47	1.37
Dicalcium phosphate	.11	—	.11	—	.11	.07	—	.07	—	.07
Potassium chloride	.16	—	.16	—	.16	.16	—	.16	—	.16
Sodium chloride[b]	.21	.30	.21	.30	.21	.21	.30	.21	.30	.21
Vitamin premix[c]	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
Thiamin premix[d]	—	.01	—	.01	—	—	.01	—	.01	—
Trace mineral premix[e]	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
Rumensin premix[f]	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
Tylan premix[g]	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
Nutrient composition[h]										
CP	10.3	10.7	10.8	11.0	10.6	12.1	12.6	12.6	12.8	12.4
DIP	6.6	7.3	8.1	8.1	7.4	6.6	7.4	8.1	8.2	7.4
Ca	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70
P	.35	.53	.35	.53	.35	.35	.53	.35	.53	.35
K	.70	.94	.70	.94	.70	.70	.94	.70	.84	.70

[a]DRC = dry-rolled corn; WCGF = wet corn gluten feed; HMC = high-moisture corn.
[b]Molasses contributes .09% sodium chloride.
[c]15,000 IU of vitamin A, 3,000 IU of vitamin D, and 3.75 IU of vitamin E/g premix.
[d]18 g of thiamin/kg of premix.
[e]10% Mg, 6% Zn, 4.5% Fe, 2% Mn, .5% Cu, .3% I, and .05% Co.
[f]176 g of monensin/kg of premix.
[g]88 g of tylosin/kg of premix.
[h]The CP for dry-rolled corn, wet corn gluten feed, high-moisture corn, alfalfa hay, corn silage, and molasses was based on analyzed (AOAC, 1975) values. The CP for urea, feather meal, and blood meal was based on tabular (NRC, 1984) values. Degradable intake protein (DIP) was based on analyzed and tabular CP values and referenced (Table 5) DIP (100 − UIP) values. The Ca, P, and K were based on tabular values (NRC, 1984).

The CP (AOAC, 1975), DIP, undegradable intake protein (**UIP**), TDN, and effective NDF (**eNDF**) values used to calculate MP and DIP supplies are provided in Table 5.

The efficiency of microbial protein synthesis used in the NRC model is affected by pH, as predicted by dietary effective NDF (eNDF). Therefore, establishing an eNDF value for WCGF was important. Ham et al. (1995) observed that ruminal pH increased by .09 unit when WCGF replaced 40% of the DRC in a DRC-based finishing diet, whereas Richards (1996) observed a .21-unit increase in ruminal pH when WCGF replaced 45% of the DRC in a DRC-based finishing diet. From these data, the average increase in ruminal pH resulting from inclusion of 45% WCGF in a DRC-based finishing diet would be .16 unit. Assigning WCGF an eNDF value of 18% (percentage of NDF) in the NRC model resulted in a .16-unit increase in pH, compared with the DRC diet. Thus, WCGF was assumed to contain 18% eNDF (Table 5).

Ruminal digestibility, and resulting ruminal pH, of the energy sources evaluated differed. An increased ruminal digestibility results in greater energy available for microbial protein synthesis. However, lower ruminal pH decreases microbial protein synthesis. An accurate accounting for differences attributable to these factors is difficult. Therefore, we assumed that all energy sources contained 90% TDN (Table 5).

Evaluation of Net Energy. Net energy for gain of each diet for all trials was calculated using procedures described by Larson et al. (1993). The net energy required for daily gain (**NE_gR**) was calculated with the equation $NE_gR = .0557\ BW^{.75}\ (ADG^{1.097})$, where NE_gR (Mcal/d) is the net energy required for daily weight gain (ADG, kg/d) and BW (kg) is the mean BW (NRC, 1984). Net energy required for maintenance (**NE_mR**, Mcal/d) was calculated with the equation $NE_mR = .077\ BW^{.75}$ (NRC, 1984). The NE content of the diet (Mcal/kg) for gain and maintenance was assumed to fit the relationship NE_g =

Table 5. Crude protein, degradable intake protein, undegradable intake protein, TDN, and effective NDF values used to calculate metabolizable protein and degradable intake protein supplies

Item	Trial 1 CP[a]	Trial 2 CP[a]	DIP[b]	UIP[c]	TDN[d]	eNDF[e]
Receiving trials						
Dry-rolled corn	8.3	7.7	48.1	51.9	90	0
Wet corn gluten feed	16.2	17.0	81.0	19.0	90	18
Alfalfa hay[f]	14.9	18.4	66.8	33.2	58	100
Alfalfa hay[g]	14.9	18.4	61.2	38.8	58	100
Molasses	5.3	5.3	100.0	0.0	57	0
Urea	287.0	287.0	100.0	0.0	0	0
Feather meal	91.3	91.3	32.9	67.1	70	0
Blood meal	89.8	89.8	6.7	93.3	66	0
Finishing trials						
Dry-rolled corn	8.4	6.9	39.6	60.4	90	0
Wet corn gluten feed	16.0	15.0	81.8	18.2	90	18
High-moisture corn	—	7.5	62.0	38.0	90	0
Alfalfa hay	13.6	14.9	58.0	42.0	58	100
Corn silage	7.3	6.4	76.8	23.2	70	71
Molasses	5.3	5.3	100.0	0.0	57	0
Urea	287.0	287.0	100.0	0.0	0	0
Feather meal	70.8	91.3	8.3	91.7	70	0
Blood meal	89.8	89.8	6.7	93.3	66	0

[a]% of DM. The CP for dry-rolled corn, wet corn gluten feed, high-moisture corn, alfalfa hay, corn silage, molasses, and feather meal (finishing Trial 1) are analyzed (AOAC, 1975) values. The CP for urea, feather meal (receiving Trials 1 and 2 and finishing Trial 2) and blood meal are tabular (NRC, 1984) values.
[b]DIP = degradable intake protein (% of CP).
[c]UIP = undegradable intake protein (% of CP). References: dry-rolled corn (receiving trials), McCoy, 1996; dry-rolled corn (finishing trials), Richards, 1996; wet corn gluten feed (receiving trials), McCoy, 1996; wet corn gluten feed (finishing trials), Richards, 1996; high-moisture corn, Sindt et al., 1993b; alfalfa hay (receiving trials, dry-rolled corn diets), McCoy, 1996; alfalfa hay (receiving trials, wet corn gluten feed diets), McCoy, 1996; alfalfa hay (finishing trials), Richards, 1996; corn silage, Sindt et al., 1993a; molasses and urea, assumed; feather meal (receiving trials), Herold et al., 1996; feather meal (finishing trials), Sindt et al., 1993a; and blood meal, Sindt et al., 1993a.
[d]% of DM. The TDN for corn, alfalfa hay, feather meal, and blood meal are tabular (NRC, 1984) values. Wet corn gluten feed was assumed to be equal to corn. The TDN for molasses was provided by the supplier.
[e]eNDF = effective NDF (% of NDF).
[f]Dry-rolled corn diets.
[g]Wet corn gluten feed diets.

.877 NE_m − .41 (derived from NRC, 1984; Zinn, 1989). By the process of iteration, the NE_g and NE_m contents of diets were calculated to fit the equation DMI (kg/d) = (NE_gR/NE_g) + (NE_mR/NE_m). The NE_g content of DRC, WCGF, and HMC was calculated by substitution, assuming basal ingredients possessed the same energy value (NRC, 1984) across all diets.

Statistical Analysis. Data from receiving trials were analyzed as a completely randomized design (Ott, 1988) using the GLM procedure of SAS (1989). Pen was the experimental unit, and the model included energy source, protein supplement, energy source × protein supplement interaction, and replication. Data from finishing trials were analyzed as a randomized complete block design (Ott, 1988) using the GLM procedure of SAS (1989). Pen was the experimental unit, and the model included energy source, protein supplement, energy source × protein supplement interaction, and block. For finishing Trial 2, means for energy source were separated with the protected Least Significant Difference method when a significant (P < .10) treatment F-test was detected.

Results and Discussion

Receiving Trial 1. There were no energy source × protein supplement interactions (P > .15); thus, data were pooled across energy source and across protein supplement. Calves fed WCGF consumed less DM (P < .01) and gained slower (P < .05) than calves fed DRC (Table 6). Feed efficiency was not affected (P > .15) by energy source but was improved (P < .10) with EP supplementation. The efficiency response to EP supplementation in DRC diets was small (2%); the majority of improvement in efficiency was observed in calves fed WCGF diets (18%). Daily gain and DMI were not affected (P > .15) by protein supplement. The MP supply for calves fed DRC was higher (P < .01) than that for calves fed WCGF and

Table 6. Effect of dietary treatment on receiving performance and health in Trial 1

Item	DRC/U[a]	DRC/EP[a]	WCGF[a]	WCGF/EP[a]	SEM
Number of calves	101	100	99	98	—
DMI, kg/d[b]	5.71	5.65	5.20	5.03	.10
Daily gain, kg[cd]	1.11	1.13	.91	1.03	.05
Daily gain, kg[be]	1.12	1.17	.95	1.00	.05
Gain/feed[df]	.195	.199	.176	.207	.009
MP supply, kg/d[bgh]	.54	.58	.50	.53	.01
DIP supply, kg/d[bi]	.50	.50	.57	.57	.01
DIP requirement, kg/d[i]	.54	.53	.51	.49	—
Morbidity, %[j]	20.0	17.6	24.8	21.7	2.5
Mortality, %	0.0	1.4	0.0	0.0	.7
NE_g, Mcal/kg[fk]	1.35	1.37	1.32	1.46	.05

[a]DRC = dry-rolled corn; U = urea; EP = escape protein (80% feather meal:20% blood meal, CP basis); WCGF = wet corn gluten feed.
[b]DRC vs WCGF ($P < .01$).
[c]DRC vs WCGF ($P < .05$).
[d]Excludes dead calves.
[e]Calves never treated for sickness.
[f]No supplemental EP vs supplemental EP ($P < .10$).
[g]No supplemental EP vs supplemental EP ($P < .01$).
[h]MP (metabolizable protein) requirement of a 274-kg steer (average trial BW) gaining 1.13 kg/d (maximal trial gain) = .59 kg/d; NRC (1996).
[i]DIP (degradable intake protein) requirement (TDN × .13), in absolute terms (kg/d), varies with intake; NRC, 1996.
[j]DRC vs WCGF ($P < .10$).
[k]NE_g of diet. Calculated from animal performance.

higher ($P < .01$) for calves fed supplemental EP than for calves not fed supplemental EP. Although no treatment provided a MP supply sufficient to meet the estimated MP requirement for maximal gain observed in this trial (.59 kg/d), MP supply of calves fed DRC was closer to the requirement than MP supply of calves fed WCGF. The DIP supply for calves fed WCGF was higher ($P < .01$) than that for calves fed DRC. Calves fed WCGF had sufficient DIP for maximal microbial protein synthesis, but calves fed DRC were deficient in DIP. This deficiency was the result of unexpectedly low CP levels in alfalfa hay. The NRC model assumes that there is no net recycling of N. We assumed that the slight deficiencies in DIP were alleviated by recycled N.

Less morbidity was observed in calves fed DRC ($P < .10$) than in calves fed WCGF, but the difference was small. A negative correlation ($r = -.61$; $P < .01$) was observed between MP supply and morbidity, indicating that increased MP supply may improve health. Mortality was not affected ($P > .15$) by energy source or protein supplement. Daily gains of calves never treated for sickness were higher ($P < .01$) for calves fed DRC than for calves fed WCGF.

Dietary NE_g was not affected ($P > .15$) by energy source; however, increased ($P < .10$) dietary NE_g in response to EP supplementation indicates a MP deficiency in diets without supplemental EP. With supplemental EP, the NE_g of WCGF was 103% that of DRC (1.59 vs 1.55 Mcal/kg).

Finishing Trial 1. There were no energy source × protein supplement interactions ($P > .15$); thus, data were pooled across energy source and across protein supplement. Daily gain was not affected ($P > .15$) by energy source, but final weights were heavier ($P < .05$) for calves fed DRC than for calves fed DRC/WCGF (Table 7). In the receiving trial, calves fed DRC gained faster ($P < .05$) and had heavier ($P < .05$) final weights than calves fed WCGF. These heavier weights were maintained through finishing. Ham et al. (1995) also observed no difference in daily gain when 52.5% WCGF was included in a DRC-based finishing diet. In contrast, Firkins et al. (1985) and Richards et al. (1997) observed increased daily gains when 50% WCGF was included in DRC-based finishing diets. Additionally, daily gain was not affected ($P > .15$) by protein supplement. Similarly, Krehbiel et al. (1995) observed no response to supplemental escape protein in yearling steers fed diets including up to 94.5% WCGF. However, Trenkle (1993) observed improved gains in yearling cattle fed approximately equal portions of DRC and dry corn gluten feed when the diet was supplemented with a combination of urea and soybean meal, compared with urea alone.

Calves fed DRC/WCGF tended to be more efficient ($P = .15$) than calves fed DRC, but the difference was small. Richards et al. (1997) also observed improved feed efficiency, but Ham et al. (1995) observed no difference. Protein supplement had no effect ($P > .15$) on feed efficiency, which agrees with the results of Richards et al. (1997).

The DMI of calves fed DRC was higher ($P < .05$) than that of calves fed DRC/WCGF. In contrast, Ham et al. (1995) observed no differences in DMI and

Table 7. Effect of dietary treatment on finishing performance in Trial 1

Item	DRC/U[a]	DRC/EP[a]	DRC/WCGF[a]	DRC/WCGF/EP[a]	SEM
Number of calves	60	60	60	60	—
Final weight, kg[b]	599	601	583	589	5
DMI, kg/d[b]	10.31	10.21	9.83	9.96	.14
Daily gain, kg	1.73	1.74	1.69	1.72	.02
Gain/feed[c]	.168	.170	.172	.173	.001
MP supply, kg/d[de]	.84	.92	.84	.93	.01
DIP supply, kg/d[fg]	.71	.70	.80	.81	.01
DIP requirement, kg/d[g]	.74	.74	.83	.84	—
Quality grade[bh]	18.3	18.6	18.0	18.0	.2
Yield grade[b]	2.61	2.73	2.34	2.50	.09
Fat thickness, cm[b]	1.03	1.06	.91	.95	.04
Liver score	.07	.00	.02	.13	.06
NE_g, Mcal/kg[i]	1.47	1.50	1.49	1.50	.02

[a]DRC = dry-rolled corn; U = urea; EP = escape protein (80% feather meal:20% blood meal, CP basis); WCGF = wet corn gluten feed.
[b]DRC vs WCGF (P < .05).
[c]DRC vs WCGF (P = .15).
[d]No supplemental EP vs supplemental EP (P < .01).
[e]MP (metabolizable protein) requirement of a 449-kg steer (average trial BW) gaining 1.74 kg/d (maximal trial gain) = .80 kg/d; NRC, 1996.
[f]DRC vs WCGF (P < .01).
[g]DIP (degradable intake protein) requirement (TDN × .081), in absolute terms (kg/d), varies with intake; NRC, 1996.
[h]18.0 = high Select; 19.0 = low Choice.
[i]NE_g of diet. Calculated from animal performance.

Firkins et al. (1985) noted increased DMI when similar diets were fed.

As would be expected, MP supply of calves supplemented with EP was greater (P < .01) than that of calves not supplemented with EP. However, MP supply for all treatments exceeded the requirement for maximal gain observed in this trial (.80 kg/d). Degradable intake protein supplies of calves fed WCGF were higher (P < .01) than those of calves fed DRC. However, all treatments supplied DIP below the requirement. The DIP deficiencies were attributable to the CP value of DRC (8.4%, DM basis) being lower than expected. In addition, if WCGF increased ruminal pH, and consequently increased efficiency of microbial protein synthesis, DIP requirements would also increase. Strobel and Russell (1986) showed, using in situ experiments, that mixed ruminal bacteria produced 50% less protein at pH 5.7 than at 6.7. In the Cornell Net Carbohydrate and Protein System (Russell et al., 1992), efficiency of microbial protein synthesis is affected using pH, as predicted by dietary eNDF. We assumed that the slight deficiencies in DIP were alleviated with recycled N.

Quality grade, yield grade, and fat thickness were greater (P < .05) for calves fed DRC than for calves fed DRC/WCGF, but the differences were small. Liver score was not affected (P > .15) by dietary treatment.

Dietary NE_g was not affected (P > .15) by energy source or protein supplement. On average, the NE_g of WCGF was 98% that of DRC (1.52 vs 1.55 Mcal/kg). This is in agreement with results of Ham et al. (1995), who fed similar diets and similar WCGF and observed similar NE_g between DRC and WCGF. However, Richards et al. (1997) indicated that WCGF, from a different processing plant, had 20% more NE_g than DRC when included at 50% of the DM in a DRC-based finishing diet. Wet corn gluten feed is composed of corn fiber (bran) and a liquid fraction. The liquid fraction contains steep liquor and may include condensed solubles from ethanol production. The proportions of bran and liquid that go into WCGF can vary widely among mills. These differences in composition seem to affect energy content.

Receiving Trial 2. There were no energy source × protein supplement interactions (P > .15); thus, data were pooled across energy source and across protein supplement. Calves fed WCGF consumed less DM (P < .01), gained similarly (P > .15), and were more efficient (P < .10) than calves fed DRC (Table 8). The MP supply of calves fed DRC was higher (P < .01) than that of calves fed WCGF and higher (P < .05) for calves fed supplemental EP than for calves not fed supplemental EP. However, all treatments provided a MP supply sufficient to meet the estimated MP requirement for maximal gain observed in this trial (.58 kg/d).

On average, calves in receiving Trials 1 and 2 gained the same (1.05 kg/d), but calves in receiving Trial 1 consumed 15.9% less DM than calves in receiving Trial 2. Calves in receiving Trial 2 had higher intake; this contributed to the fact that all treatments provided sufficient MP for maximal gain. Additionally, inclusion of DRC in WCGF diets for the first 7 d increased MP supply in calves fed WCGF diets. In each treatment, DIP supply was sufficient to support maximal microbial protein synthesis.

Table 8. Effect of dietary treatment on receiving performance and health in Trial 2

Item	DRC/U[a]	DRC/EP[a]	WCGF[a]	WCGF/EP[a]	SEM
Number of calves	79	78	79	79	—
DMI, kg/d[b]	6.80	6.67	5.89	5.66	.15
Daily gain, kg[c]	1.08	1.00	1.12	1.00	.06
Daily gain, kg[d]	1.10	1.01	1.12	1.05	.07
Gain/feed[ce]	.151	.143	.189	.176	.016
MP supply, kg/d[bfg]	.66	.72	.60	.64	.02
DIP supply, kg/d[h]	.71	.68	.71	.70	.02
DIP requirement, kg/d[h]	.63	.62	.58	.55	—
Morbidity, %	8.89	6.47	7.14	10.08	1.71
Mortality, %	.00	.00	1.19	.00	.60
NE_g, Mcal/kg[ij]	1.05	1.02	1.35	1.29	.11

[a]DRC = dry-rolled corn; U = urea; EP = escape protein (80% feather meal:20% blood meal, CP basis); WCGF = wet corn gluten feed.
[b]DRC vs WCGF (P < .01).
[c]Excludes dead calves.
[d]Calves never treated for sickness.
[e]DRC vs WCGF (P < .10).
[f]No supplemental EP vs supplemental EP (P < .05).
[g]MP (metabolizable protein) requirement of a 266-kg steer (average trial BW) gaining 1.12 kg/d (maximal trial gain) = .58 kg/d; NRC, 1996.
[h]DIP (degradable intake protein) requirement (TDN × .13), in absolute terms (kg/d), varies with intake; NRC, 1996.
[i]DRC vs WCGF (P < .05).
[j]NE_g of diet. Calculated from animal performance.

Morbidity, mortality, and daily gain of calves never treated for sickness were not affected (P > .15) by energy source or protein supplement. However, a negative correlation (r = –.91; P < .01) was observed between MP supply and morbidity, indicating that increased MP supply may improve health.

Dietary NE_g was higher (P < .05) for WCGF diets than for DRC diets. On average, the NE_g of WCGF was 139% that of DRC (2.15 vs 1.55 Mcal/kg). Similarly, Ham et al. (1995) observed that WCGF was 13% higher in NE_g than DRC when WCGF replaced DRC and(or) corn silage in growing diets for calves. Corn fiber has been characterized as highly and rapidly digested (DeHaan, 1983). Thus, replacing starch (corn) with a rapidly digestible fiber source such as WCGF may reduce negative effects, thereby increasing fiber digestion (Green et al., 1987).

Finishing Trial 2. An energy source × protein supplement interaction (Table 9) was detected for daily gain (P < .10), final weight (P < .15), feed efficiency (P < .01), and NE_g (P < .10). The biological explanation for these interactions is unclear. Escape protein supplementation improved performance of calves fed HMC. Because calves fed HMC with no supplemental EP were predicted to be deficient in MP (.71 kg/d), a response to EP supplementation in HMC diets would be expected. However, calves fed DRC with no supplemental EP were predicted to be sufficient in MP (.82 kg/d) but still responded to EP supplementation. These results disagree with the results of Sindt et al. (1993b, 1994) in which gain and feed efficiency of calves fed DRC finishing diets were not affected by the supplementation of escape protein. Calves fed HMC/WCGF or DRC/HMC were predicted to be deficient in MP when not supplemented with EP (.76 and .70 kg/d, respectively); however, they did not respond to EP supplementation. Sindt et al. (1993b) observed that performance of calves, finished immediately after weaning and fed HMC finishing diets, was not affected by supplementation of a FTH:BM combination. However, calves that grazed cornstalks for 74 d after weaning and then finished on HMC diets gained faster and more efficiently when their diet was supplemented with a FTH:BM combination. Richards et al. (1997) supplemented 25% WCGF diets with urea or a combination of urea, soybean meal, FTH, and BM; steer performance was similar.

With no supplemental EP, daily gain and final weight were not affected (P > .15) by energy source. Feed efficiency was highest with calves fed DRC/HMC; intermediate with calves fed DRC/WCGF, HMC, or HMC/WCGF; and lowest with calves fed DRC (P < .10). Dietary NE_g was highest (P < .10) for DRC/HMC; intermediate for DRC/WCGF, HMC, and HMC/WCGF; and lowest for DRC. With supplemental EP, daily gain was highest with calves fed DRC or HMC, intermediate with calves fed DRC/HMC, and lowest with calves fed DRC/WCGF or HMC/WCGF (P < .10). Efficiency was highest with calves fed HMC, intermediate with calves fed DRC or DRC/HMC, and lowest with calves fed DRC/WCGF or HMC/WCGF (P < .10). Dietary NE_g was highest (P < .10) for HMC, intermediate for DRC and DRC/HMC, and lowest for DRC/WCGF and HMC/WCGF.

On average, the NE_g of WCGF was 101% that of DRC (1.57 vs 1.55 Mcal/kg) when fed in DRC/WCGF diets. The NE_g of HMC was 103% that of DRC (1.60 vs 1.55 Mcal/kg). The NE_g of WCGF was 97% that of

Table 9. Effect of energy source and protein supplement on finishing daily gain, final weight, gain/feed, and NE_g in Trial 2

	No supplemental escape protein					Supplemental escape protein					
Item	DRC[a]	DRC/WCGF[a]	HMC[a]	HMC/WCGF[a]	DRC/HMC[a]	DRC[a]	DRC/WCGF[a]	HMC[a]	HMC/WCGF[a]	DRC/HMC[a]	SEM
Daily gain, kg[b]	1.61	1.65	1.61	1.58	1.63	1.70^{c}	1.59^{d}	1.70^{c}	1.57^{d}	1.63^{cd}	.03
Final weight, kg[e]	562	568	561	557	566	577^{c}	560^{d}	578^{c}	557^{d}	567^{cd}	5
Gain/feed[f]	$.151^{g}$	$.160^{h}$	$.155^{gh}$	$.162^{h}$	$.169^{i}$	$.164^{cd}$	$.160^{c}$	$.168^{d}$	$.160^{c}$	$.163^{cd}$	.003
NE_g, Mcal/kg[bj]	1.29^{g}	1.37^{h}	1.33^{gh}	1.39^{hi}	1.45^{i}	1.41^{cd}	1.37^{c}	1.44^{d}	1.37^{c}	1.40^{cd}	.03

[a]DRC = dry-rolled corn; WCGF = wet corn gluten feed; HMC = high-moisture corn.
[b]Energy source × protein supplement interaction ($P < .10$).
[c,d]Means within supplemental escape protein and within a row with different superscripts differ ($P < .10$).
[e]Energy source × protein supplement interaction ($P < .15$).
[f]Energy source × protein supplement interaction ($P < .01$).
[g,h,i]Means within no supplemental escape protein and within a row with different superscripts differ ($P < .10$).
[j]NE_g of diet. Calculated from animal performance.

HMC (1.55 vs 1.60 Mcal/kg) when fed in HMC/WCGF diets. The NE_g of DRC/HMC was 106% that of DRC (1.65 vs 1.55 Mcal/kg) and 103% that of HMC (1.65 vs 1.60 Mcal/kg).

Dry matter intake was highest for calves fed DRC, intermediate for calves fed DRC/WCGF or HMC, and lowest for calves fed HMC/WCGF or DRC/HMC ($P < .10$; Table 10). Metabolizable protein supply was highest for calves fed DRC or DRC/WCGF, intermediate for calves fed HMC/WCGF, and lowest for calves fed HMC or DRC/HMC. Calves fed HMC or DRC/HMC were predicted to be deficient in MP supply, but the gain data do not indicate a deficiency. Degradable intake protein supply was highest for calves fed HMC and lowest for calves fed DRC ($P < .10$). Calves fed DRC, DRC/WCGF, or HMC/WCGF were deficient in DIP. Deficiencies in DIP were attributable to the fact that the CP value of DRC (6.9%, DM basis) was lower than expected and the efficiency of microbial protein synthesis in diets including WCGF was greater. Quality grade, yield grade, fat thickness, and liver score were not affected ($P > .15$) by energy source.

Dry matter intake was not affected ($P > .15$) by protein supplement (Table 11). As would be expected, calves fed supplemental EP had a higher ($P < .01$) MP supply than calves not fed supplemental EP. Degradable intake protein, quality grade, yield grade, fat thickness, and liver score were not affected ($P > .15$) by protein supplement.

In summary, the MP supply of calves fed WCGF-alfalfa hay receiving diets was near the calculated requirement. When MP supply was predicted to be sufficient, calves fed WCGF-alfalfa hay receiving diets gained similarly and were more efficient than calves fed DRC-alfalfa hay receiving diets. When MP was predicted to be sufficient, the NE_g of WCGF in receiving diets was 139% that of DRC, presumably because of a reduction in negative associative effects. Escape protein supplementation of finishing diets including HMC gave inconsistent results. On average, the NE_g of WCGF in finishing diets was 100% that of DRC and 97% that of HMC.

Table 10. Effect of energy source on DMI, metabolizable protein supply, degradable intake protein supply, and carcass characteristics in Trial 2

Item	DRC[a]	DRC/WCGF[a]	HMC[a]	HMC/WCGF[a]	DRC/HMC[a]	SEM
Number of calves	64	64	64	64	64	—
DMI, kg/d	10.51^{b}	10.16^{c}	10.23^{bc}	9.81^{d}	9.83^{d}	.12
MP supply, kg/d[f]	$.88^{b}$	$.90^{b}$	$.77^{c}$	$.83^{d}$	$.79^{c}$	.01
DIP supply, kg/d[g]	$.71^{b}$	$.75^{c}$	$.84^{d}$	$.80^{e}$	$.73^{bc}$	.01
DIP requirement, kg/d[g]	.77	.86	.75	.83	.72	—
Quality grade[h]	19.0	18.7	18.7	18.5	18.6	.1
Yield grade	2.69	2.48	2.59	2.58	2.65	.07
Fat thickness, cm	1.30	1.14	1.23	1.16	1.23	.04
Liver score	.03	.13	.03	.23	.13	.09

[a]DRC = dry-rolled corn; WCGF = wet corn gluten feed; HMC = high-moisture corn.
[b,c,d,e]Means within a row with unlike superscripts differ ($P < .10$).
[f]MP (metabolizable protein) requirement of a 432-kg steer (average trial BW) gaining 1.70 kg/d (maximal trial gain) = .80 kg/d; NRC, 1996.
[g]DIP (degradable intake protein) requirement (TDN × .081), in absolute terms (kg/d), varies with intake; NRC, 1996.
[h]18.0 = high Select; 19.0 = low Choice.

Table 11. Effect of protein supplement on DMI, metabolizable protein supply, degradable intake protein supply, and carcass characteristics in Trial 2

Item	No supplemental EP[a]	Supplemental EP[a]	SEM
Number of calves	160	160	—
DMI, kg/d	10.15	10.07	.08
MP supply, kg/d[bc]	.77	.90	.01
DIP supply, kg/d[d]	.76	.77	.01
Quality grade[e]	18.7	18.7	.1
Yield grade	2.59	2.61	.04
Fat thickness, cm	1.24	1.18	.03
Liver score	.08	.14	.06

[a]EP = escape protein.
[b]No supplemental EP vs supplemental EP ($P < .01$).
[c]MP (metabolizable protein) requirement of a 432-kg steer (average trial BW) gaining 1.70 kg/d (maximal trial gain) = .80 kg/d.
[d]DIP = degradable intake protein.
[e]18.0 = high Select; 19.0 = low Choice.

Implications

Inclusion of wet corn gluten feed in receiving diets can improve the feed efficiency of calves, provided the metabolizable protein requirement is met. Escape protein supplementation or inclusion of dry-rolled corn are potential means of increasing metabolizable protein supply. In finishing diets, wet corn gluten feed has an energy value similar to that of dry-rolled corn and 3% less than that of high-moisture corn.

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