Influence of Protein Supplementation on the Feeding Value of Dry Rolled and Steam-Flaked Corn in Diets for Feedlot Cattle

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ABSTRACT: Eighty medium-framed yearling crossbreed heifers (357 kg) were used in a 110-d trial to evaluate the influence of dietary protein level (11 vs 14%) on the feeding value of dry rolled (DRC) and steam-flaked corn (SFC). All diets contained 1% urea, cottonseed meal (CSM) was the source of supplemental UIP. Steam flaking corn reduced DMI (9%, P < .10), and increased (P < .01) feed efficiency (14%), dietary NE_m (13%) and NE_g (15%). Steam flaking increased the NEm and NEg values of corn by 17 and 19%, respectively. Supplemental CSM decreased (P < .10) feed efficiency (7%), and dietary NE_m (4%) and NE_g (6%). There were no treatment effects (P > .10) on carcass characteristics. Steam flaking corn increased (P < .05) fecal pH and reduced (P < .01) fecal starch. Supplemental CSM increased (P < .01) fecal pH and reduced (P < .01) fecal starch. Four Holstein steers (413 Kg) were used in a 4 x 4 Latin square experiment to evaluate treatment effects on digestive function. Steam flaking corn increased (P < .05) flow of nonammonia N (11%, P < .05) and microbial N (15%, P < .01) to the duodenum. Supplemental CSM increased the flow of microbial N (6%, P < .01), feed N (21%, P < .10), and nonammonia N (12%, P < .05) to the duodenum. The UIP value of CSM was 28% for the DRC diet and 52% for the SFC diet. Steam flaking corn increased (P < .01) ruminal starch digestion (26%), and total tract digestibility of OM (17%), N (15%), starch (19%), and GE (17%). Steam flaking increased the DE value of corn 21%. Supplemental CSM did not influence (P > .10) postruminal or total tract starch digestion. Supplemental CSM decreased (7%, P < .10) the DE value of the diet. We conclude that increasing postruminal protein supply of a corn-based finishing diet beyond that provided by urea supplementation, alone, will not enhance intestinal starch digestion or the energy value of the diet.

Introduction

Reduced starch digestibility constitutes the primary basis for the lower feeding value of dry rolled corn (**DRC**)vs steam-flaked corn (**SFC**)in diets for feedlot cattle. Although both ruminal and postruminal starch digestion are lower for DRC than for SFC, differences in postruminal starch digestion accounts for most of the variation in total tract starch digestion (Zinn et al., 1995). Karr et al. (1966) suggested that variation in postruminal starch digestion may be due to limitations in amylolytic capacity. Because pancreatic amylase secretion and activity is enhanced by increasing protein supply to the small

intestine (Magee, 1961; Johnson et al.,1977), it has been hypothesized (Huntington, 1995) that increasing dietary protein level may augment postruminal starch digestion. The objective of this study was to evaluate the influence of dietary protein level on the comparative feeding value of DRC and SFC in finishing diets for feedlot cattle.

Experimental Procedure

Trial 1. Eighty medium-framed yearling crossbreed heifers (approximately 25% Brahman breeding with the remainder of Hereford, Angus, Shorthorn, Gelvieh, and Charolais breeds in various proportions) with an average initial weight of 357 kg were used in a 110-d feeding trial. Heifers were blocked by weight and randomly allotted to 16 pens. Pens were 43 m^2 with 22 m^2 overhead shade, automatic waterers and 2.4 m fence-line feed bunks. The trial was initiated November 2, 1995. Average daily minimum and maximum air temperature during the trial was 8.4 and 25.0°C, respectively. There was .06 cm precipitation, and average daily relative humidity was 50%. Two corn grain processing treatments (DRC and SFC) and two protein levels (11 and 14%) were compared in a factorial arrangement of treatments. The dietary CP requirement of heifers in this trial was 8.8% (NRC, 1984). Ingredient composition of the dietary treatments is shown in Table 1. The SFC was prepared as follows. A chest situated directly above the rollers (46 x 61 cm corrugated) was filled with 441 kg of yellow corn and then brought to a constant temperature of 102 °C at atmospheric pressure using steam. The grain was steamed for 20 min before starting the rollers. Approximately 454 kg of the initial steam-processed grain that exited the rollers during the warm-up (of the rollers) was set aside and not fed to the cattle on this study. Tension of the rollers was adjusted to provide a flake density of .31 kg/L (24 lbs/bushel). The retention time in the steam chamber was approximately 30 min. The SFC was allowed to air-dry before use in diet preparation. The DRC was prepared by rolling corn in the absence of steam with a tension of rollers to provide a density of.57 kg/L (44 lbs/bushel). Upon initiation of the trial and at d-56 heifers were implanted with Synovex-H (Syntex, Des Moines, IA). Diets were prepared at weekly intervals and stored in plywood boxes located front of each pen. Heifers were allowed free access to dietary treatments. Fresh feed was provided twice daily. At weeks 2, 4, 6, 8, and 10 fecal grab samples were taken from each pen. Fecal pH was determinated by mixing 50 g of fecal sample with 50 g of deionized water and inserting a general purpose pH electrode (Haaland et al., 1982). Fecal samples were analyzed for starch (Zinn, 1990a). Hot carcass weight were obtained from all heifers at time of slaughter and liver abscess were recorded. After the carcass were chilled for 48 h , the

following measurements were obtained: 1) longissimus muscle area, measured by direct grid reading of the longissimus muscle at the 12th rib; 2) subcutaneous fat over the longissimus muscle at the 12th rib taken at a location 3/4 the lateral length from the chine bone end; kidney, pelvic, and heart fat (KPH) as a percentage of carcass weight, and 4) marbling score (USDA, 1965). Initial and final weights were obtained with cattle on full feed. Weights were reduced by 4% to account for digestive tract fill. Energy retention (**ER**, megacalories) was derived from measures of live weight (**LW**, kilograms) and ADG (kilograms/day) according to the following equation: Heifers ER = (.0686 $LW^{.75}$) $ADG^{1.119}$ (NRC, 1984). Net energy content of the diet for maintenance and gain was calculated assuming a constant fasting heat production (**MQ**) of .077 $LW^{.75}$ Mcal/d (Lofgreen and Garrett, 1968). From estimates of ER and MQ the NE_m and NE_g values of the diets were obtained by process of iteration (Zinn, 1987) to fit the relationship NE_g = (.877 NE_m) - .41 (NRC, 1984). This trial was analyzed as a randomized complete block design experiment with a 2 x 2 factorial arrangement of treatments (Hicks, 1973), using pens as the experimental unit.

Trial 2. Four Holstein steers (413 Kg) with cannulas in the rumen and proximal duodenum (Zinn and Plascencia, 1993) were used to evaluate treatment effects on digestive function. Steers were maintained in individual slotted-floor pens (3.9 m^2) with automatic drinkers. Pens were washed with water daily. Dietary treatments were the same as in Trial 1 with the inclusion of .4% of chromium oxide as a digesta marker. Diets were fed in equal proportion at 0800 and 2000 daily. Individual feed intake was restricted to 6.6 kg/d (DM basis). After a 10-d treatment adjustment period, duodenal and fecal samples were taken from respective steers twice daily during a period of four successive days. The time sequence for sampling steers during the collection periods was as follows: d 1, 1050 and 1650; d 2, 0900 and 1500; d 3, 0750 and 1350; and d 4, 0600 and 1200. Individual samples consisted of approximately 500 mL of duodenal chyme and 200 g (wet basis) of fecal material. Fecal samples represented a composite of fecal material that accumulated on the floor slots during a collection interval. Duodenal and fecal samples from each steer and within each period were composited (equal weight, wet basis) for analysis. During the final day of each collection period, ruminal samples were obtained via the ruminal cannula from each steer at 1, and 4 h postprandial. Ruminal fluid pH was determinated by insertion of pH electrode into the freshly collected sample. The ruminal fluid sample was divided in two parts: 40 mL were placed into a plastic bag, placed in ice bath and carried to laboratory for determination of ammonia N in fresh ruminal fluid (Fawcett and Scott, 1960). The remainder was strained through four layer of cheesecloth. Ten milliliters of

freshly prepared 25% (wt/vol) metaphosphoric acid was added to 40 mL of strained ruminal fluid and stored at -20°C for VFA analysis. Upon completion of the trial, ruminal fluid was obtained from all steers and composited for isolation of ruminal bacteria, via differential centrifugation (Bergen et al., 1968). The microbial isolates were prepared for analysis by oven drying at 70°C and then grinding with mortar and pestle. Feed, duodenal and fecal samples were prepared for analysis by oven drying at 70°C and then grinding in a laboratory mill (Micro-Mill, Bel-Arts Products, Pequannock, NJ). Samples were then oven drying at 105°C until no further weight loss and stored in tightly sealed glass jars. Samples were subjected to all or part of the following analyses: Ash, Kjeldahl N, ammonia N (AOAC, 1975); starch (Zinn, 1990a): purines (Zinn and Owens, 1986); VFA in rumen fluid (gas chromatography), GE (adiabatic bomb calorimetry), and chromic oxide (Hill and Anderson, 1958). Microbial organic matter (MOM) and N (MN) leaving the abomasum were calculated using purines as a microbial marker (Zinn and Owens, 1986). Organic matter fermented in the rumen (OMF) was considered equal to OM intake minus the difference between the amount of total OM reaching the duodenum and MOM reaching the duodenum. Feed N escape to the small intestine was considered equal to total N leaving the abomasum minus ammonia N and MN and, thus, includes any endogenous contributions. This trial was analyzed as 4 x 4 Latin square design experiment (Hicks, 1973) with a factorial 2 x 2 arrangement.

Implications

Corn processing method is the primary factor that influences the site and extent of starch digestion. Increasing postruminal protein supply of a corn-based finishing diet beyond that provided by urea supplementation, alone, will not enhance intestinal starch digestion or the energy value of the diet. Current feeding standards markedly underestimate the improvement in net energy value of corn due to steam flaking. Measures of fecal starch are a practical means for evaluating the efficiency of corn grain processing.

Table 1. Composition of the diets used in trials 1 and 2.

	Dry rolled corn		Steam flaked corn	
Item	Urea	CSM[a]	Urea	CSM[a]
Dry rolled corn	74.05	64.05	-	-
Steam flaked corn	-	-	74.05	64.05
Cottonseed meal	-	10.0	-	10.0
Urea	0.8	0.8	0.8	0.8
Alfalfa hay	6	6	6	6
Sudangrass hay	6	6	6	6
Yellow grease	3	3	3	3
Sugarcane Molasses	8.0	8.0	8.0	8.0
Limestone	1.5	1.5	1.5	1.5
TM Salt[b]	.5	.5	.5	.5
Magnesium oxide	.15	.15	.15	.15
Calculated analysis (DM basis)[c]				
CP, %	11.35	14.96	11.35	14.96
DE, Mcal/Kg	3.79	3.75	3.93	3.86
NEm, Mcal/Kg	2.13	2.10	2.23	2.19
NEg, Mcal/Kg	1.46	1.43	1.55	1.51
Ca, %	0.70	0.71	0.70	0.71
P, %	0.30	0.30	0.30	0.30

[a]CSM = Cottonseed meal
[b]TM salt,contain: $CoSO_4$,.068%; $CuSO_4$, 1.04%; $FeSO_4$,. 3.57%; ZnO, .75%; $MnSO_4$, 1.07%; KI, .052%; and NaCl 93.4%.
[c]Calculated from tabular values (NRC, 1996).

Table 2. Influence of corn processing method and dietary protein level on growth performance of heifers (Trial 1).

	DRC[a]		SFC[a]		
Item	Urea	CSM[b]	Urea	CSM[b]	SEM
CP, % [c]	11	14	11	14	
D1-End					
Pen replicates, n	4	4	4	4	
Days in trial	110	110	110	110	
Initial Body wt., kg	356	357	359	358	2.84
Final Body wt., Kg	476	468	488	474	9.09
ADG, kg	1.10	1.01	1.19	1.08	0.06
DMI, Kg [d]	8.41	8.02	7.56	7.49	0.28
DMI/ADG [ef]	7.64	7.94	6.37	7.03	0.21
Diet NEm, Mcal/Kg[ef]	2.08	2.06	2.41	2.27	0.03
Diet NEg, Mcal/Kg[ef]	1.47	1.40	1.71	1.58	0.03
NE observed/Expected					
NEm [f]	0.97	0.98	1.08	1.03	0.02
NEg [f]	0.97	0.97	1.10	1.05	0.02

[a]DRC = Dry rolled corn, SFC = Steam-flaked corn.
[b]CSM = Cottonseed meal.
[c]Dietary crude protein level (DM basis).

[c]Corn processing effect, P < .10.
[e]Protein level effect, P < .10.
[f]Corn processing effect, P < .01.

Table 3. Influence of corn processing method and dietary protein level on carcass characteristics of heifers (Trial 1).

	DRC[a]		SFC[a]		
Item	Urea	CSM[b]	Urea	CSM[b]	SEM
CP, %[c]	11	14	11	14	
Pen replicates, n	4	4	4	4	
Final Body wt., Kg	476	468	488	474	9.09
Carcass wt., kg	307	298	315	306	4.87
Dressing percentage,%[d]	64.26	62.67	62.87	63.58	0.45
KPH fat, % [df]	2.13	1.75	2.25	2.76	0.18
Fat thickness, cm	1.21	1.02	1.19	1.23	0.13
Loin eye area, cm^2	79.89	80.84	79.58	77.16	1.22
Marbling score [e]	3.92	3.56	3.70	3.73	0.11
Retail grade, %	50.50	51.40	50.30	49.86	0.51
Liver abscess, % [dg]	5.00	0.00	5.00	25.00	5.13

[a]DRC = Dry rolled corn, SFC = Steam-flaked corn.
[b]CSM = Cottonseed meal.
[c]Dietary crude protein level (DM basis).
[d]Code: Minimum slight = 3, minimum small 4, etc.
[d]Corn processing x Protein effect, P < .10.
[f]Corn processing effect, P < .05.

[g]Corn processing effect, P < .10.

Table 4. Influence of corn processing method and dietary protein level on fecal pH and fecal starch content of heifers fed finishing diets (Trial 1).

	DRC[a]		SFC[a]		
Item	Urea	CSM[b]	Urea	CSM	SEM
CP, %[c]	11	14	11	14	
Pen replicates, n	4	4	4	4	
Fecal pH					
Week 2 [de]	5.63	6.11	6.02	6.30	.12
Week 4 [f]	5.70	5.71	5.88	6.19	.10
Week 6 [d]	5.74	5.92	5.70	6.17	.09
Week 8	5.93	6.05	5.95	5.95	.09
Week 10 [eg]	5.69	5.89	5.76	6.37	.10
Mean [fg]	5.73	5.93	5.06	6.20	.05
Fecal starch, %					
Week 2 [h]	20.28	17.10	4.46	5.67	2.37
Week 4 [hi]	24.04	19.13	6.21	2.94	1.77
Week 6 [h]	23.28	21.47	5.23	5.51	2.22

Week 8 [hij]	28.34	17.59	4.00	3.38	2.12
Week 10 [dh]	28.47	20.33	6.83	2.39	1.89
Mean [ghk]	24.88	19.22	5.35	3.98	0.48

[a]DRC = Dry rolled corn, SFC = Steam flaked corn.
[b]CSM = Cottonseed meal.
[c]Dietary crude protein level (DM basis).
[d]Protein level effect, P < .05.
[e]Corn processing effect, P < .10.
[f]Corn processing effect, P < .05.
[g]Protein level effect, P < .01
[h]Corn processing effect, P < .01.
[i]Protein level effect, P < .10.
[j]Corn processing x Protein effect, P < .10.
[k]Corn processing x Protein effect, P < .01.

Table 5. Effect of corn processing method and dietary protein level on characteristics of OM, starch, GE, and N digestion (Trial 2).

	DRC[a]		SFC[a]		
Item	Urea	CSM[c]	Urea	CSM	SEM
CP, %[c]	11	14	11	14	
Replicates	4	4	4	4	
Intake, g/d					
DM	8237	8304	8270	8251	
OM	7749	7762	7811	7738	
N	140	187	140	186	
Starch	3823	3538	4063	3558	
Flow to duodenum, g/d.					
OM	5026	4998	4731	4781	351
NAN [ab]	159	179	177	202	6.0
MN [c]	79	89	96	97	5.6

Feed N [d]	80	90	81	105	7.2
Starch [a]	1840	1702	1287	985	180
Rumen digestion, % of intake.					
OM	45.3	47.0	56.8	50.8	4.6
Feed N	42.8	51.7	42.3	43.7	4.0
Starch [e]	51.8	51.7	68.4	72.5	4.9
Microbial efficiency	24.1	25.5	25.2	28.4	3.9
Protein efficiency [af]	1.14	0.96	1.27	1.08	0.5
Postrumen digestion, % of flow to duodenum					
OM [e]	51.8	47.8	75.0	68.7	3.3
N [e]	62.7	60.1	74.6	73.8	1.2
Starch [e]	56.8	54.7	95.0	95.0	5.5
Total tract digestion, % of intake					
OM [e]	69.8	67.6	83.7	81.8	1.0
N [be]	56.9	61.5	67.6	71.3	1.2
Starch [e]	80.8	79.4	98.5	98.7	1.2
DE, Mcal/Kg [de]	3.54	3.41	4.26	3.86	0.6

[a] DRC = Dry rolled corn, SFC = Steam-flaked corn.
[b]CSM = Cottonseed meal.
[c]Dietary crude protein level (DM basis).
[d]Corn processing effect, P < .05.
[e]Protein level effect, P < .05.
[f]Corn processing effect, P < .10.
[g]Protein level effect, P < .10.
[h]Corn processing effect, P < .01.
[i]Protein level effect, P < .01

Table 6 . Influence of corn processing method and dietary protein level on ruminal pH, and concentrations of ammonia and VFA (Trial 2).

	DRC[a]		SFC[a]		
Item	Urea	CSM[b]	Urea	CSM	SEM
CP, %[c]	11	14	11	14	
Rumen pH					
1 h [d]	6.40	6.27	6.09	6.15	0.9
4 h	6.4	6.05	6.08	6.03	0.2
Ammonia mg/dL					
1 h	6.0	6.6	5.2	6.5	0.7
4 h [e]	2.8	5.4	1.9	4.2	0.6

VFA mmol/dL					
1 h [f]	77.0	84.7	104.9	104.2	9.7
4 h	75.0	86.8	90.6	81.4	4.2
VFA mol/100 mol					
Acetate					
1 h	57.3	54.8	56.1	56.2	1.4
4 h	60.5	55.9	63.8	55.8	4.2
Propionate					
1 h	24.4	25.2	25.8	25.1	2.7
4 h	21.3	25.0	27.4	24.0	3.0
Butirate					
1 h	11.6	12.2	11.9	11.3	0.5
4 h	11.8	13.8	11.8	10.5	0.9
Acetate/Propionate					
1 h	2.4	2.4	2.0	2.3	0.2
4 h [d]	3.2	2.5	2.1	2.1	0.3

[a] DRC = Dry rolled corn, SFC = Steam-flaked corn.
[b] CSM = Cottonseed meal.
[c] Dietary crude protein level (DM basis).
[d]Corn processing effect P < .05.
[e]Protein level effect P < .10.
[f]Corn processing effect P < .10.