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Postruminal Flow of Glutamate Linearly Increases Small Intestinal Starch Digestion in Cattle

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Postruminal flow of glutamate linearly increases small intestinal starch digestion in cattle[1]

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SUMMARY

Improving performance and efficiency among cattle fed corn-based diets could have large benefit to cattle production in the United States. Starch escaping ruminal fermentation is not efficiently digested in the small intestine; however, postruminal flows of casein (i.e., milk protein) or glutamate (an amino acid or building block of protein) increase small intestinal starch digestion in cattle. The objective of this study was to determine responses of small intestinal starch digestion in cattle to increasing amounts of postruminal glutamate. Increasing amounts of duodenal glutamate linearly increased small intestinal and postruminal starch digestion. These data indicate that postruminal glutamate can provide benefit to cattle fed corn-based diets.

INTRODUCTION

Cattle performance is often first limited by energy (Lofgreen and Garrett, 1968; NRC, 2000). Thus, cattle are often fed diets with appreciable amounts of cereal grains that provide energy as starch (Vasconcelos and Galyean, 2007). Small intestinal starch digestion (SISD) can provide up to 42% more energy than ruminal fermentation of starch (Owens et al., 1986); however, extent of SISD is less compared to ruminal fermentation. Consequently, cattle are typically fed diets with large amounts of ruminally fermentable starch. Unfortunately, increases in ruminally fermentable energy are associated with reductions in dry matter intake and increases in metabolic disorders (Owens et al., 1998). Increases in SISD may provide large benefits to cattle.

Greater postruminal flows of high quality protein (i.e., casein) or glutamate increase SISD in cattle (Richards et al., 2002; Brake et al., 2014b). Our objective was to quantify effects of increasing amounts of postruminal glutamate flow on SISD. We hypothesized that small increases in postruminal glutamate flow would increase SISD.

MATERIALS AND METHODS

Five ruminally, duodenally, and ileally cannulated Jersey × Limousin steers (BW = 773 ± 24 lb) were placed in a 5 × 5 Latin square with 12-d periods. Steers were housed in individual pens in a temperature-controlled room under 16 h of light and 8 h of darkness. Cattle were moved to metabolism stalls 1 d before sample collection. Every 12 h, steers were fed a low-starch diet (Table 1; 11.3 ± 0.13 lbs DM/d, about 1.5 × NE_m; NRC, 2000). The diet was formulated to provide adequate ruminally available N and only moderate amounts of ruminally undegradable protein.

[1] This project is a contribution from the South Dakota Agricultural Experiment Station, Brookings.

Treatments were continuous duodenal infusions of raw cornstarch (1507 ± 18 g[2] DM/d) and either 0 (control), 30.9 ± 0.59, 62.4 ± 1.16, or 120.4 ± 3.39 g glutamate/d, or casein (a positive control; 387.9 ± 18.34 g DM/d). Glutamate infusions delivered 39.9, 80.6, and 155.5% of glutamate provided by casein. Additionally, glutamate infusions provided 3.35 ± 0.06, 6.77 ± 0.13, and 13.06 ± 0.37 g of N/d, compared to casein which provided 56.36 ± 2.73 g of N/d.

Periods consisted of 8 d of adaptation and 4 d of sample collection. Diet and ort samples were collected on d 8 to 11 to correspond to the ileal and fecal samples collected on d 9 to 12. Ileal and fecal spot samples were collected every 4 h between 12-h feeding intervals on d 9 to 12 and composited. Sampling time was delayed 1 h each subsequent d so that composites were representative of each h in a 12-h period.

Ileal, fecal, and feed samples were analyzed for DM, OM, and starch. Additionally, ileal and fecal samples were analyzed for ethanol-soluble starch (i.e., short chain starch).

Data were analyzed using the Mixed procedure of SAS (SAS Inst. Inc., Cary, NC). Fixed effects were treatment and period; steer was a random effect. Linear, quadratic, and cubic contrasts were used to determine responses to greater flows of glutamate. The positive control (casein) was compared to the negative control by a *t*-test. Differences were declared when $P \leq 0.05$, and tendencies were considered at $0.05 < P \leq 0.15$.

RESULTS AND DISCUSSION

Results are summarized in Table 2. By design, amount of starch infused was not affected by glutamate (*Linear* = 0.46) or casein ($P = 0.45$). Casein increased SISD ($P = 0.05$) compared to control. Furthermore, casein tended ($P = 0.07$) to decrease ileal starch flow and decreased ($P = 0.01$) fecal starch flow compared to control. Brake et al. (2014b) infused similar amounts of postruminal starch and casein and reported increased SISD. Similarly, these authors (Brake et al., 2014a, 2014b) observed decreased ileal and fecal starch flow.

Greater flows of glutamate increased SISD (*Linear* = 0.02) and postruminal starch digestion (*Linear* = 0.05; *Cubic* = 0.03). Ileal DM flow (*Quadratic* = 0.14) and ethanol-soluble starch flow (*Linear* = 0.16) tended to decrease with greater infusion of glutamate. Ileal (*Linear* = 0.04) and fecal (*Linear* = 0.04; *Cubic* = 0.04) starch flow decreased with greater infusion of glutamate. When Brake et al. (2014a) duodenally infused casein (400 g/d) they observed increased ($P < 0.01$) SISD and decreased ($P < 0.01$) ileal starch flow, but found increased flows of ethanol-soluble starch at the ileum ($P = 0.05$).

Increased SISD with greater postruminal flows of glutamate could provide large benefit to cattle. When cattle were postruminally infused with 120.4 g/d glutamate, SISD was 49.6% compared to 37.2% when cattle received no postruminal glutamate or casein. Previous data indicate that starch digested in the small intestine provides 42% more NE than ruminally-fermented starch (Owens et al., 1986). McLeod et al. (2001) reported that retained energy from postruminally digested starch was 1.75 kcal/g of starch digested. A 33% increase in SISD can contribute to appreciable increases in retained energy. For example, a feedlot steer fed a dry rolled corn-based diet will typically consume about 5,000 g (11 lb) of starch/d (Theurer, 1986), and nearly 1,500 g (3.3 lb) will flow to the small intestine (Owens et al., 1986; Theurer, 1986). These data indicate increased postruminal flow of glutamate could increase retained

[2] 100 g = 0.22 lb

energy from diet to 0.32 Mcal/d because of increased SISD. In a 900 lb steer expected to finish at 1350 lb with a small marbling score, this additional retained energy would result in an approximate increase 0.22 lb of ADG.

In order to fully optimize SISD in cattle, it is necessary to understand response of SISD to postruminal glutamate. Clearly, postruminal glutamate increases SISD; it is possible that greater amounts of glutamate would further improve SISD.

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Table 1. Composition of soybean hull-based diet

Ingredient	**% DM**
Soybean hulls	72.4
Brome hay	20.0
Corn steep liquor	6.0
Limestone	1.0
Salt	0.5
Mineral and vitamin premix[1]	0.1
Nutrient concentration	
NE_m, Mcal/cwt[2]	78.5
CP, % DM[3]	13.1
Undegradable intake protein, % CP[2]	40.8
Starch, % DM[3]	0.8

[1]Designed to provide to diet (DM basis) 100 ppm Fe, 40 ppm Mn, 60 ppm Zn, 20 ppm Cu, 1 ppm I, 0.2 ppm Se, 0.2 ppm Co, 1,000 IU of vitamin A/lb, 125 IU of vitamin D/lb, and 23 IU of vitamin E/lb.

[2]Predicted from tabular values (NRC, 2000).

[3]Analyzed value.

Table 2: Effect of duodenal infusion of glutamate on ileal and fecal nutrient flows and small and large intestinal starch disappearance in steers receiving 3.3 lb duodenally-infused raw cornstarch

		Glutamate, g/d					***P*-value for contrasts**			
Item	**Control**	**30.9**	**62.4**	**120.4**	**Casein**	**SEM**	**Linear**	**Quadratic**	**Cubic**	**Control vs. casein**
No. of observations	4	5	5	4	5					
Duodenal starch infused, g/d[1]	1531	1516	1534	1479	1483	49	0.46	0.68	0.66	0.45
Nutrient flow to ileum, g/d										
DM	2716	2596	2367	2538	2681	201	0.33	0.14	0.43	0.84
Starch	965	844	801	752	801	68	0.04	0.33	0.74	0.07
Ethanol soluble starch	154	132	119	119	171	27	0.16	0.30	0.99	0.42
Glucose	3	20	14	7	1	6	1.00	0.08	0.21	0.81
Small intestinal starch digestion[2]	37.2	44.4	47.9	49.6	46.1	3.3	0.02	0.16	0.83	0.05
Nutrient flow to feces, g/d										
DM	3965	4170	3709	3434	3642	453	0.27	0.76	0.49	0.56
Starch	490	570	383	355	278	74	0.04	0.82	0.04	0.01
EtOH soluble starch	71	70	66	73	48	10	0.90	0.68	0.78	0.10
Glucose	47	56	46	43	46	11	0.64	0.73	0.49	0.97
Postruminal starch digestion[2]	68.0	62.2	75.1	76.3	80.9	4.9	0.05	0.85	0.03	0.02

[1]100 g = 0.22 lb

[2]% of infusion