INFLUENCE OF LEVEL OF FEED INTAKE AND ROUGHAGE ON SMALL INTESTINAL DIGESTION AND PASSAGE IN STEERS

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Story in Brief

Seven steers (730 lb) equipped with ruminal, duodenal and ileal cannulas were fed an 80% concentrate diet at three levels of intake (1,0, 1.6 and 2.2% of body weight) or higher (64%) roughage diets of chopped alfalfa hay or cottonseed hulls at 2.2% of body weight. Transit time through the small intestine, measured by first ileal appearance of duodenally dosed phenol red dye, tended to decrease as feed intake increased. Alfalfa hay decreased transit time but cottonseed hulls did not. Duodenal liquid flow was much greater with added alfalfa hay (47 liter/d) than added cottonseed hulls (17 liter/d) and was closely related to nitrogen flow. Though added roughage tended to reduce total tract digestion of starch, it did not reduce fractional digestion of starch in the small intestine. Added roughage, especially alfalfa hay, shifted starch digestion from the rumen to the small intestine. Results indicate that transit time does not limit starch digestion in the small intestine and is not responsible for the reduced total tract starch digestion often observed with higher roughage diets.

(Key Words: Small Intestinal Passage, Digestion, Retention Time.)

Introduction

When starch is digested in the small intestine instead of being fermented in the rumen, absorbed products provide 30 to 50% more energy for ruminants. But digestion in the small intestine is usually under 70%. Possible factors limiting digestion include physical access of the starch, activity of enzymes digesting starch, and time for digestion within the small intestine. Only one study of the impact of diet on rate of passage through the small intestine of ruminants is available (Gregory et al., 1985). As feed intake of sheep increased from 800 to 1600 g per day, retention time in the small intestine decreased by 29% (from 150 to 106 min). It has been suggested the flow rate through the digestive tract is controlled to regulate protein input to the small intestine, since digesta liquid at the duodenum is surprisingly constant in nitrogen (Zinn et al., 1981). As postruminal protein supply decreases, feed could be retained longer in the rumen for more extensive digestion and more synthesis of microbial protein. In contrast, with a high protein diet, need for ruminal digestion is reduced and ruminal outflow could be accelerated. However, direct comparison of liquid outflow from the rumen against duodenal liquid flow in steers revealed a poor relationship (Doran, 1985). This result suggests that instead of regulating flow from the rumen, protein content of digesta may regulate either fluid absorption by the omasum or secretion by the abomasum. Such regulation may alter input of pepsin and HCl and thereby could alter intestinal digestion.

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The objective of this experiment was to determine the influence of level of feed intake [1.0 (basal), 1.6 and 2.2% of body weight] and roughage supplementation [1.2% of body weight addition of cottonseed hulls (CSH) or chopped alfalfa to the basal diet above] on passage time through and digestibility within the small intestine of growing steers.

Materials and Methods

Seven steers (730 lb) equipped with ruminal, duodenal and ileal cannulas were fed specified levels of each of five diets (Table 1) containing the indigestible marker chromic oxide during 6 different 14- day periods. To measure passage rate through the small intestine, a dye (phenol red) was dosed into the duodenal cannula on days 10, 12 and 14 of each period. Two hours after each dosing, the ileal cannula was opened and digesta was collected continuously. When dye first appeared, the time was recorded and passage time was calculated. Plastic beads dosed with the dye appeared simultaneously but proved more difficult to detect. Total duodenal and ileal liquid flow was calculated from passage of chromic oxide and dry matter of digesta samples. On each sampling day, duodenal, ileal and fecal samples were collected, composited within site, steer and period and analyzed for dry matter, starch and chromium.

Table 1. Diets and feed intake.

Treatment	Concentrate level % of body weight	Roughage level % of body weight	Roughage source
1.0	0.80[a]	0.20	Cottonseed hulls
1.6	1.28	0.32	Cottonseed hulls
2.2	1.76	0.44	Cottonseed hulls
2A	0.80	1.40	Alfalfa hay
2C	0.80	1.40	Cottonseed hulls

[a]Concentrate consisted of 63% rolled corn, 14% cottonseed hulls, 10% soybean meal, 6% dehydrated alfalfa pellets, 5% cane molasses, 0.5% limestone, 0.5% salt, 0.1% dicalcium phosphate, 0.1% urea and 0.2% chromic oxide.

Results and Discussion

As level of daily feed intake was increased from 1.0 to 2.2% of body weight, time for passage through the small intestine tended to decrease (Table 2). Substituting alfalfa for concentrate in the diet fed at 2.2% of body weight decreased transit time by 11%. In contrast, adding a similar level of cottonseed hulls to the diet did not accelerate passage rate through the small intestine. Daily liquid flow at the duodenum was greatly increased by alfalfa, as well. This indicates that these two roughage sources differ in their effects on transit time through the small intestine. The higher protein and mineral contents of alfalfa should exert more osmotic pressure, increase fluidity and bulk and could thereby accelerate passage in a fashion similar to laxatives. Total liquid flow at the duodenum was 2.8 times greater with the alfalfa than the cottonseed hull supplemented diet, but liquid flow at the ileum for the two diets was similar.

Duodenal pH was not altered by diet, but ileal pH declined as intake of concentrate increased. Ileal pH was higher for roughage-supplemented diets. Ileal pH was always considerably above the 6.8 considered ideal for activity of pancreatic amylase for starch digestion.

Fecal pH declined as concentrate intake increased. Alfalfa increased fecal pH but while cottonseed hulls did not. Source and level of roughage altered fecal pH independent of starch concentration in feces. Composition of intestinal contents also varied with intake and roughage source. Dry matter and starch content of duodenal chyme were increased by added roughage, and starch content of ileal material also increased with added roughage.

Starch flows and digestion are presented in Table 2. Though intake of starch was more than doubled at the higher intake levels, flow of starch at the duodenum, ileum and feces was not increased. Starch largely disappeared within the rumen regardless of feed intake level. This agrees with results previously reported with an identical diet by Zinn and Owens (1983).

Addition of alfalfa reduced starch digestibility in the total tract markedly. Most of this depression can be ascribed to reduced ruminal digestion of starch. Added cottonseed hulls depressed ruminal and total tract starch digestion slightly.

Correlations of various factors with residence time in the small intestine across all diets were calculated. The higher the intake of nitrogen and the higher the flow of N at the duodenum, the shorter the transit time through the small intestine (Cr = -.62 and -.36; $P<.01$ and $P<.08$). Also, the greater the ruminal starch digestion, the longer the residence time of digesta in the small intestine ($r = .43$; $P<.03$). Total liquid flows at the duodenum and at the ileum were closely related to nitrogen flow at these points ($r = .79$ and .60; $P<.01$) suggesting that flow is tied somehow to protein content of digesta.

To determine the direct effect of retention time in the small intestine on digestion of starch in the small intestine, correlations across diets were calculated. This relationship proved nonsignificant ($r = -.18$; $P = .47$). Hence, under these test conditions, faster passage through the small intestine did not reduce starch digestibility within the small intestine. Had enzyme activity limited starch digestion in the small intestine, faster passage should have reduced digestibility of starch. With this cracked corn diet, particle size as discussed by Kim and Owens (1985) rather than rate of passage or enzyme activity presumably was the factor which limited starch digestion in the rumen and small intestine.

Table 2. Composition of digesta.

Intake level (% of body weight)	1.0	1.6	2.2	2.2	2.2
Roughage level, %	20	20	20	64	64
Roughage source	CSH	CSH	CSH	Alfalfa	CSH
Time of passage through the small intestine, min	248^{ab}	260^{a}	230^{b}	204^{c}	239^{b}
pH					
Duodenal	3.21	2.94	3.15	3.06	3.03
Ileal	7.60^{a}	7.43^{ab}	7.16^{b}	7.83^{a}	7.66^{a}
Fecal	6.83^{a}	6.38^{b}	6.02^{c}	6.78^{a}	6.02^{c}
Dry matter, %					
Duodenal	4.3^{c}	5.0^{b}	5.9^{bc}	6.3^{ab}	8.0^{a}
Ileal	7.5^{ab}	11.1^{a}	7.2^{ab}	6.1^{b}	7.3^{ab}
Liquid flow, L/day					
Duodenal	21.2^{b}	45.5^{a}	35.2^{ab}	47.0^{a}	16.9^{b}
Ileal	4.6	15.6	13.3	12.0	11.1
Starch, % of DM					
Duodenal	12.8^{ab}	9.4^{a}	8.5^{a}	21.9^{c}	18.3^{bc}
Ileal	8.1^{ab}	3.6^{bc}	2.2^{c}	11.6^{a}	12.2^{a}
Fecal	4.2^{a}	4.5^{a}	3.8^{a}	11.8^{b}	11.0^{b}
Starch, g					
Intake	585	936	1287	742	686
Duodenal	122^{a}	238^{a}	202^{a}	583^{b}	251^{a}
Ileal	37^{ab}	72^{ab}	18^{a}	101^{b}	64^{ab}
Fecal	10.3^{c}	76.0^{ab}	46.8^{bc}	100.4^{a}	39.0^{bc}
Starch digestion, %					
Ruminal	79^{a}	74^{a}	84^{a}	22^{b}	64^{a}
Small intestine	67^{a}	74^{ab}	94^{b}	83^{ab}	79^{ab}
Total tract	98.2^{a}	91.8^{bc}	96.4^{ab}	86.0^{c}	94.4^{ab}

^{abc}Means in a row with different superscripts are significantly different ($P<.05$).

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