EFFECTS OF SAMPLING SITE ON FLUID AND PARTICULATE PASSAGE RATE ESTIMATES

A. L. Goetsch[1] and F. N. Owens[2]

Story in Brief

Four beef heifers were fed diets of chopped alfalfa hay (ALF) or 80 percent concentrate (80C) twice daily at 2.0 percent of body weight. Animals were pulse dosed with a fluid (CoEDTA) and a particulate (Yb labeled feed) marker and samples were obtained from the rumen, duodenum, ileum and rectum at time intervals to investigate the influence of sampling site on the estimated values for rates of passage of fluid and particulate matter from the rumen. Rate of particulate passage was evaluated with both a 1) time dependent-time independent and a 2) time independent two compartmental model. Fluid passage rate estimated from rumen samples was higher ($P<.05$) than calculated from other sites. Ruminal and fluid passage rates estimated from ruminal and fecal samples were closely related with the ALF diet ($r=.98$; $P<.03$). Particulate dilution rate, k_2, by model 2, thought to represent rate of ruminal exit, was higher when calculated from duodenal than from ileal or fecal samples with the ALF diet. However, for the 80C diet, k_2 values were similar for all postruminal sampling sites. In general, rate of particulate passage from the rumen as calculated from samples obtained at the duodenum, ileum and rectum differed and were not correlated. Mixing at the passage front and secondary mixing pools for solids in the abomasum and large intestine are probably responsible for these effects.

Introduction

Extent of ruminal digestion can be limited by the time which feed spends in the rumen. For measurement of ruminal residence time, feed or fluids can be tagged with markers and the rate of ruminal exit can be monitored by the change in marker concentration in digesta at some point later in the digestive tract. The rare earth ytterbium (Yb) is often attached to feed, serving as a particulate marker, and cobalt EDTA (CoEDTA) is water soluble, serving to label fluids. Changes in concentrations of these markers in fecal samples at various times after the markers are dosed can be fitted to curves devised by Ellis et al. (1979) and Grovum and Williams (1973) to calculate rate of passage from the rumen. A dilution rate of 5.8 percent/hr indicates that about half of the marker leaves the rumen in 12 hours. Ruminal passage rates were calculated by these two models based on concentrations of markers in samples obtained from several locations in the digestive tract to see if site of sampling would influence the estimates.

Experimental Procedure

Four cannulated beef heifers (315 lb) were used in two 18-day experiments. Chopped (3.8 mm screen) alfalfa hay, fed in the first trial, and an 80 percent concentrate diet (rolled corn based), used in the second trial, were offered at 2.0 percent of body weight per day. Heifers were fed at 12-hour intervals. On day 15 of each trial, a fluid

[1]Research Associate [2]Professor, Animal Science

phase marker (CoEDTA) was administered into the rumen and chopped alfalfa or rolled corn labeled with a rare earth (ytterbium) was mixed with the morning meal. Samples were simultaneously taken from the rumen, duodenum, ileum and rectum at various times after dosing. Samples from the rumen were taken at 0, 4, 8, 12 and 24 hr after dosing. Samples were analyzed for dry matter and marker concentrations. Fluid dilution rates were calculated by regressing the natural log of marker concentration in centrifuged fluid versus time for the decreasing portion of the marker passage curve. Particulate passage rates were calculated using the two compartment models of Ellis et al. (1979), a time dependent-time independent model (1) and of Grovum and Williams (1973), a time independent model (2), both of which should partially adjust for delays in marker mixing or an additional mixing pool.

Results and Discussion

Rate of Fluid Passage

Ruminal fluid dilution rate for both diets was greater ($P<.05$) when calculated from ruminal samples than from samples obtained later in the tract (Table 1) with differences being as high as 40 percent. The difference between ruminal dilution rate estimated from ruminal and duodenal samples must be attributed either to rumen sampling problems or to mixing the omasum and abomasum. Mixing of fluid in these organs may be more extensive and flow to, from and between these organs may be less constant with meal fed than with frequently fed animals. Ruminal dilution rates with both diets tended to be lower when calculated from rectal samples, possibly due to an additional mixing pool in the cecum plus large intestine. However, ruminal passage rate as calculated from rumen and fecal samples were well correlated for both the ALF ($r=.98$; $P<.03$) and the 80C diet ($r=.80$; $P<.21$). Consequently, rectal samples might be used to calculate relative rates of fluid exit from the rumen though absolute values differed by 44 percent.

Among postruminal sampling sites, ruminal dilution rate estimated from ileal samples was greatest. In contrast, sampling from the duodenum with the ALF diet resulted in the greatest ($P>.05$) estimate for ruminal liquid passage rate. With the 80C diet, more unimbibed or free liquid may be present in the cecum and colon and large intestine to dilute and delay passage of the fluid marker.

Total digesta from postruminal sites was analyzed for marker content and would represent the combined passage estimates of free and imbibed fluid providing markers equilibrated prior to exit from the rumen. The differences between the fluid passage estimate calculated from various sites and ruminal measures were greater for the ALF diet than for the 80C diet, possibly because of the greater amount of imbibed fluid in ALF heifers. Depending upon rapidity of marker equilibration between free and imbibed fluid and proportional pool sizes, fluid dilution rates as commonly measured probably relate to the combination of both free fluid capable of immediate exit and imbibed fluid. Hence, liquid dilution rate has a different physiological meaning if the degree of entrained fluid differs.

Rate of Particulate Passage

Differences in particulate passage rates between models 1 and 2 were not large (Table 1). However, a slightly greater k_2 for model 1 than model 2 with duodenal samples with the ALF diet and for ileal and rectal sampling with the 80C diet were noted. A higher ($P<.05$) k_2 was

Table 1. Effect of sampling site and model on marker passage rate estimation.

Diet	Ruminal phase	Item	Model	Sampling site			
				Rumen	Duodenum	Ileum	Rectum
Alfalfa hay	Fluid	k_2	Log	10.6[c]	6.3[d]	5.6[d]	5.6[d]
	Particles	k_2	1[a]		6.9[c]	3.9[d]	4.3[d]
	Particles	k_2	2[b]		5.1	3.7	4.2
	Particles	k_1	1		28.7	30.0	22.1
	Particles	k_1	2		14.4	14.8	13.3
80% concentrate							
	Fluid	k_2	Log	10.3[c]	6.8[d]	7.2[d]	6.1[d]
	Particles	k_2	1		5.1	7.1	6.7
	Particles	k_2	2		4.5	4.6	4.5
	Particles	k_1	1		25.6[c]	18.1[d]	11.4[d]
	Particles	k_1	2		22.0[c]	12.3[d]	10.3[d]

[a]Model 1, Ellis et al. (1979).
[b]Model 2, Grovum and Williams (1973).
[c,d]Means in a row with different superscripts differ ($P<.05$).

estimated for duodenal than ileal and rectal samples by model 1.

Slightly greater k_2 values from rectal than ileal samples (Table 1) indicates that mixing with the cecal and large intestinal pool is minimal, in agreement with fluid passage rate trends. With the 80C diet, the k_2 from model 2 was the same at each sampling site. However, with model 1, values tended to be greater for ileal and rectal versus duodenal sampling. In contrast, with the ALF diet, ileal particulate k_2 from model 2 tended to be greater than the ruminal k_2 estimated from other sites, and rectal k_2 was slightly less than the ileal estimate. Greater starch fermentation in the cecum plus large intestine may have increased backflow and slowed rate of passage. In addition, peristalsis and large intestinal passage rate should be less with the grain than with the roughage diet.

Particulate k_1 did not markedly vary between sampling sites with the ALF diet (Table 1). Hence, k_1 would appear to be a function of ruminal action. If k_1 compensated for an additional mixing pool function late in the digestive tract, its function should be absent just preceding the additional pool. With the 80C diet, duodenal k_1 for model 2 was greater than k_1 estimated from ileal and fecal samples. In contrast, duodenal k_1 for model 1 was about 7 units greater than the ileal k_1 which was also about 7 units greater than the fecal k_1. This may reflect mixing along the passage front as the marker proceeds through the small and large intestine. The change was more drastic with the 80C than the ALF diet, possibly due to greater digestion in the small intestines, more fermentation in the cecum and proximal colon and less gut peristalsis with the 80C diet.

In summary, ruminal dilution rates estimated from marker concentrations in feces of meal fed animals appears inaccurate. How much of the marker problems above are due to detachment and reattachment of markers under the acidic conditions of the abomasum remains to be determined though if solid and liquid markers flow together through the small intestine, detachment should cause no problem. However, migration and subsequent reattachment of markers could explain some of the problems with particulate markers but not for fluid markers. Secondary mixing pools in the abomasum and cecum plus large intestine and at the passage front may be involved.

Literature Cited

Ellis, W. C., et al. 1979. Fed. Proc. 38:2702.
Grovum, W. L. and V. J. Williams. 1973. Br. J. Nutr. 30:313.