1993

Omasal and Duodenal Nutrient Flow in Steers.

Kelly K. Kreikemeier
U.S. Meat Animal Research Center

Gary P. Rupp
University of Nebraska Great Plains Veterinary Educational Center, grupp1@unl.edu

Louis J. Perino
University of Nebraska Great Plains Veterinary Educational Center

Omasal and Duodenal Nutrient Flow in Steers.

Kelly K. Kreikemeier, Gary P. Rupp, and Louis J. Perino[1]

Introduction

Feedstuffs are degraded in the rumen, providing energy and nutrients for microbial growth. Volatile fatty acids produced during this process are absorbed and used as an energy source by the animal. The bacteria that are produced and unfermented feed residue flow out of the rumen to the small intestine where further digestion and absorption occurs. Of the total protein flowing to the small intestine, 50 to 90% is microbial protein. It is of high quality, well digested and well used by the animal.

Currently, estimates of the amount of microbial protein synthesized in the rumen vary considerably. We do not understand what portion of this variation can be attributed to nutritional factors such as feed intake, forage versus grain, animal differences, etc. Because the amino acid profile of dietary ingredients and ruminal microflora differ, knowing what influences the amount and proportion of each flowing to the lower gut is very important if we are going to extend our understanding of protein utilization in cattle.

The amount of microbial protein flowing to the small intestine in cattle is measured in the following manner: 1) cattle are surgically fitted with a ruminal and duodenal cannula for digesta sampling; 2) After a dietary adjustment period, ruminal bacteria are harvested and duodenal (anterior small intestine) digesta is sampled; 3) Laboratory analyses are conducted and the amount of microbial protein flowing at the duodenum is determined. Dietary protein flow at the small intestine is calculated as the difference between total protein flow and microbial protein flow.

This approach has been used by researchers for several years, but it may have limitations. First, it is unable to account for endogenous nitrogen flowing at the duodenum, due to either sloughed cells or abomasal secretions. Any endogenous nitrogen would overestimate the flow of dietary protein. Secondly, it is assumed that a sample of bacteria obtained from the rumen represents bacteria flowing out of the rumen. If this assumption is not correct, then our estimate on the amount of microbial protein flowing at the duodenum is not correct.

The potential limitations in research techniques might account for the large variation in the amount of microbial protein synthesized. These limitations might be overcome if a different cannulation technique were employed so we could sample digesta flowing out of the rumen. To our knowledge, this approach has been used in sheep by four different investigators with limited success. Building on the reported limitations of these efforts in sheep, we wanted to conduct a similar surgical preparation in cattle. We had two objectives, 1) determine if nitrogen flowing out of the rumen differed from nitrogen flow at the duodenum, and 2) determine if the composition of bacteria in the rumen differed from bacteria flowing out of the rumen.

Procedures

Six steers (649 pounds) were surgically fitted with digesta sampling cannulae in the rumen omaso-abomasal orifice, abomasum, and duodenum. A flexible nylon sleeve, located in the abomasum and attached to the omasal cannula, was exteriorized via the abomasal cannula during digesta collection. The location of cannulas allowed us to collect digesta in the rumen, digesta flowing out of the rumen, and digesta flowing into the small intestine.

Based on general appearance, body temperature, and feed consumption, steers recovered from surgery in three or four days. At this time, they were transported to the metabolism barn and placed in stalls (3.5 ft by 7 ft) containing rubber floor mats. Steers were turned outside in a dirt lot for exercise 2 hr per day at least three days per week. Steers were fed with automatic feeders so that they were offered a portion of feed every 2 hours.

Three experiments were conducted (Table 1): 1) 95% concentrate fed at maintenance (2760 g organic matter (OM)/day), 2) 95% concentrate fed ad libitum (3484 g OM/day), and 3) low quality brome hay based diet fed ad libitum (2927 g OM/day). For each experiment, steers were fed the diet at least 14 days. Omasal and duodenal digesta were then collected (200 ml) three times daily for three consecutive days. Ruminal digesta was also collected. Bacteria were harvested from ruminal and omasal digesta and laboratory analyses were conducted.

Results and Discussion

Organic matter flow (Table 2) at the omasum was similar to organic matter flow at the duodenum in Experiments 1 and 2 and slightly higher in Experiment 3. Statistically these values were not different. Fluid flow was 29 to 40 lb greater at the duodenum than at the omasum. Our duodenal cannula was 4 to 6 inch distal to the pylorus and our sampling technique assured that no digesta backflow nor pancreatic secretions were collected. Therefore, the greater fluid flowing at the duodenum probably originated from abomasal fluid secretions.

Total volatile fatty acid flow (VFA) was much greater at the omasum than at the duodenum, indicating a significant absorption of VFA across the abomasum. The amount absorbed across the abomasum varied from 370 to 570 mmol/day and this represents approximately 5% of ruminal VFA production. Volatile fatty acid concentration was very low (about 5 mM) at the duodenum, which is consistent with reports that almost all (greater than 95%) of the VFA produced ruminally are absorbed before reaching the duodenum.

Purine flow at the duodenum was higher than purine flow at the omasum in Experiments 1 and 3, but lower in Experiment 2. Purines are commonly used as a microbial marker to measure microbial protein flow to the small intestine. If purine flow at the duodenum had been consistently higher than purine flow at the omasum, then microbial protein flow would have been overestimated.

Nitrogen flow at the duodenum was very similar to nitrogen flow at the omasum in Experiments 1 and 2, and only slightly higher in Experiment 3. Some earlier research suggested that the abomasal mucosa secretes nitrogen, which would contribute to duodenal nitrogen flow. If this occurred to any measurable extent, investigators using duodenally cannulated cattle would overestimate dietary protein escaping ruminal fermentation. Alpha-amino, urea, and ammonia nitrogen are soluble nitrogen components. Tallied, they accounted for less than 5% of the total nitrogen, and their flow was similar at the omasum and duodenum.

[1]Kreikemeier is a research animal scientist, Nutrition Research Unit, MARC; Rupp is director, University of Nebraska Great Plains Veterinary Educational Center; Perino is a veterinarian, University of Nebraska Great Plains Veterinary Educational Center.

In order to determine the amount of bacterial protein in duodenal digesta, a representative sample of ruminal bacteria must be obtained. Their marker to nitrogen ration is then used to calculate the proportion of duodenal nitrogen that is of microbial origin. We harvested bacteria from ruminal digesta and from omasal digesta to determine if their marker to nitrogen ratio differed (Table 3). In all three experiments, omasal digesta contained three to five times more purines than ruminal digesta. This was likely due to a greater enrichment of bacteria in omasal digesta. The complete diet contained 0.10% purines; whereas, the bacteria contained 5 to 7% purines.

The amount of bacteria harvested per unit weight of digesta was higher from omasal digesta, and this was likely due to the greater bacterial enrichment of omasal digesta. Bacteria harvested from omasal digesta contained more nitrogen and purines than bacteria harvested from ruminal digesta. Despite their changing composition, the nitrogen to purine ratio was similar between bacteria harvested from ruminal digesta and bacteria from omasal digesta. Because their nitrogen to purine ratio was similar, the calculated proportion of duodenal protein flow attributed to bacterial protein would not be affected.

Lower nitrogen and purine concentration in ruminally harvested bacteria has other implications with research techniques and data interpretation. The difference between the feed organic matter consumed and digesta organic matter flowing at the duodenum is the amount of organic matter that apparently disappeared in the rumen. Because duodenal digesta contains both undigested feed residue and bacteria, correcting for the bacterial component is required to calculate true ruminal organic matter disappearance. In these experiments, calculating "apparent" versus "true" ruminal organic matter disappearance would be affected differently using data from ruminal or omasal bacteria. Calculations for efficiency of microbial protein synthesis would be affected as well.

In conclusion, 1) there was a net appearance of fluid and disappearance of volatile fatty acids across the abomasum in steers, 2) the technique of fitting cattle with ruminal and duodenal cannulas to measure the amount of feed protein and microbial protein flowing at the duodenum is not confounded by abomasal nitrogen or purine secretions, and 3) composition of bacteria flowing out of the rumen differs from bacteria in the rumen.

Table 1—Diet composition[a]

Ingredient	Percentage of diet dry matter	
	Exp. 1 and 2	Exp. 3
Rolled corn	85.69	0
Cane molasses	5.00	5.0
Brome hay	5.00	92.11
Limestone	1.47	.96
Urea	1.39	1.07
Dicalcium phosphate	.40	.11
Salt	.30	.30
Potassium chloride	.21	0
Sulfur	.09	.02
Vitamin ADE premix[b]	.05	.05
Mineral oil	.05	.05
Trace mineral premix[c]	.05	.05
Magnesium oxide	.03	0
Rumensin-60[d]	.02	.02
Cromic oxide	.25	.25

[a] Diet formulated to contain 13% protein, .7% calcium, .2% magnesium, .35% phosphorus, .7% potassium, .21% sulfur. Actual protein in Exp. 3 was 9.5% because the brome hay contained only 7.0% crude protein.
[b] Contains 8,800,000 IU Vitamin A, 880,000 IU Vitamin D, and 880 IU Vitamin E per kg of premix.
[c] Contains 14% calcium, 12% zinc, 8% manganese, 10% iron, 1.5% copper, .2% iodine, and .1% cobalt.
[d] Added so the diet contained 25 ppm monensin.

Table 2—Effect of digesta sampling site on nutrient flow

Item	Exp. 1		Exp. 2		Exp. 3	
	Omasum	Duodenum	Omasum	Duodenum	Omasum	Duodenum
Organic matter flow, lb/d	1.67	1.53	3.33	3.21	2.83	3.42
Fluid flow, lb/d	34.1	65.3	71.5	111.1	84.7	113.9
VFA flow, mmol/d	589	212	932	359	1158	695
Purine flow, lb/d	.038	.050	.073	.068	.032	.037
Nitrogen flow, lb/d	.089	.089	.155	.157	.087	.097
a-amino-nitrogen flow, lb/d	.002	.003	.002	.002	.002	.002
Urea-nitrogen flow, lb/d	.001	.001	.001	0	.001	.001
Ammonia-nitrogen flow,lb/d	.001	.001	.001	.001	.001	.001

Table 3—Effect of sampling site on the composition of harvested bacteria

Item	Exp. 1		Exp. 2		Exp. 3	
	Rumen	Omasum	Rumen	Omasum	Rumen	Omasum
Digesta purine, %	0.82	2.38	1.01	2.62	0.28	1.16
Bacterial OM harvested, %	6.7	14.9	5.4	7.9	1.88	4.38
Bacterial nitrogen, %	7.31	8.56	6.73	8.43	5.76	7.33
Bacterial purine, %	4.93	6.75	4.73	5.64	3.23	4.49
Nitrogen/purine	1.56	1.29	1.58	1.65	1.87	1.66