Evaluating the Availability of Nutrients for Maintenance and Growth in Ruminants

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Summary

Two experiments were performed with mature wether lambs to evaluate availabilty of selected nutrients and volatile fatty acids for maintenance and growth. We used a technique in which known amounts of volatile fatty acids were infused into the rumen and casein into the abomasum. Sampling portal blood allowed measurement of nutrients absorbed across the gastrointestinal tract. Approximately 49, 62, and 21% of the infused acetate, propionate, and butyrate, respectively, were absorbed across the gastrointestinal tract.

Introduction

The microorganisms that inhabit the rumen ferment fiber and other nutrients and produce volatile fatty acids (VFA). The VFA then can be absorbed and used as energy to support maintenance and growth. Because feedstuffs are altered by the microorganisms, research evaluating nutrients available to the animal is very difficult. We have been using a technique in which we can eliminate the effect of microorganisms in the rumen by infusing VFA, and then studyingVFA absorption. The difference between amounts of VFA infused into the rumen and absorbed into the portal blood provides an estimate of gastrointestinal tract tissue utilization of VFA.

Methods

Two experiments were conducted using mature wether lambs (avg. wt. 100 lbs.) whose only nutrient intake was intraruminal infusions of VFA and intraabomasal infusions of casein. Lambs had permanent catheters in the portal vein entering the liver, in a mesenteric vein, and in either the femoral artery (Experiment 1) or mesenteric artery (Experiment 2). Four sets of portal and arterial samples per day were taken at 1.5 hour intervals on 2 consecutive sampling days. Portal nutrient flux measurements were made by multiplying the difference between artery and portal vein nutrient concentration by portal blood flow. Portal flux of nutrients measures nutrients that are absorbed across the gastrointestinal tract, and are thus available for body maintenance and growth.

In Experiment 1, blood samples were taken when lambs were fed pelleted alfalfa calculated to supply 1.95 Mcal metabolizable energy (ME) per day and then started on continuous infusions of VFA (2.0 Mcal gross energy (GE) per day) and casein (13.3 g nitrogen per day). Blood was sampled again after 29 and 37 days of infusion.

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Acetate, propionate, and butyrate were infused into the rumen in molar proportions of 65:25:10, respectively. Ruminal fluid samples for pH and VFA concentration were taken at the same time as blood samples.

In Experiment 2, lambs were sampled and infused by the same protocol used in Experiment 1. Total energy from VFA and casein infusions were 1.64, 1.82, and 2.37 Mcal GE per day and nitrogen infusions were 10.9, 12.3, and 15.0 g per day. Blood was sampled at each level of infusion, and total urine and feces were collected for a 3-day period at each infusion level to determine nitrogen balance.

Results and Discussion

Experiment 1. Ruminal fluid pH and VFA concentrations in lambs maintained on infusions are in shown Table 34.1. Molar proportions of ruminal acetate, propionate, and butyrate were similar to the infusion solution, although ruminal concentrations of branched chain VFA increased for both infusion periods.

Arterial concentration of most nutrients were within normal ranges (Table 34.2) but glucose and ammonia-N were higher ($P<.05$) and alpha-amino-N and urea-N were lower ($P<.05$) in the infused lambs compared to alfalfa-fed lambs. Acetate was the VFA in highest concentration in arterial blood in both alfalfa-fed and infused lambs.

Net portal flux of total VFA, propionate, and butyrate (Table 34.3) was greater in the infused lambs compared to alfalfa-fed lambs. In this experiment, only 51, 58, and 23% of ruminally infused acetate, propionate, and butyrate, respectively, were found in the portal blood, which indicated that significant quantities of all VFA were metabolized by the gastrointestinal tract during absorption.

Experiment 2. Ruminal fluid pH decreased linearly ($P<.10$) as the level of VFA infusion increased (Table 34.4). Molar concentrations of propionate, butyrate, and branched chain VFA increased as level of VFA infusion increased. Arterial concentrations of most nutrients were very similar to those in Experiment 1 for both alfalfa-fed and infused lambs with the exception that arterial ammonia (NH_3) levels averaged .21 mM over all sampling periods and urea-N was 6.8 mM when alfalfa was fed and 2.8 mM during infusion periods.

Net portal flux of glucose, alpha-amino-N, and urea (Table 34.5) were not significantly different for lambs given alfalfa or any level of energy infusion. Net flux of NH_3 decreased linearly as level of infusion increased. Glucose fluxes were negative, indicating that glucose was used by gastrointestinal tissue. Portal oxygen flux values were negative, indicating use of oxygen by gastrointestinal tract tissue for nutrient metabolism. The lambs were in a positive nitrogren (N) balance when fed alfalfa and during 1.82 and 2.37 Mcal GE infusion periods. Lambs were in a negative nitrogen balance when infused with 1.64 Mcal GE and 10.9 g nitrogen per day; these levels are below calculated maintenance requirements. The energy from VFA in the portal blood accounted for 39% of total energy fed or infused. Results, similar to those found in Experiment 1, indicated that 47, 65, and 19% of infused acetate, propionate, and butyrate, respectively, were found in the portal blood and did not differ for any level of VFA infusion.

Table 34.1. Ruminal Fluid pH and VFA Concentration in Lambs Maintained by Infusions of VFA and Casein in Experiment 1

Item	Day of Infusion	
	29	37
Ruminal pH	5.58	5.97
VFA, mM:		
Acetate	112.1	111.7
Propionate	39.5	36.2
Butyrate	12.9	12.2
Branched Chain VFA[a]	.2	.6
Acetate:Propionate:Butyrate	68:24:8	69:22:8

[a]Day 29 different than day 37, P<.001.

Table 34.2. Arterial Concentrations of Nutrients in Lambs Maintained on Pelleted Alfalfa or Infusions of VFA and Casein in Experiment 1

Arterial Concentration, mM	Alfalfa	VFA Infusion	
	day 34	day 29	day 37
Glucose[ab]	3.66	4.15	4.16
L-lactate[ac]	.98	1.55	.96
D-ß-hyroxybutyrate[b]	.31	.30	.27
L-glutamate[ac]	.32	.20	.27
Alpha-amino-N[ab]	3.43	2.21	2.45
Ammonia-N[abc]	.06	1.12	1.42
Urea-N	13.18	5.16	8.67
Acetate	1.30	1.37	1.22
Propionate	.10	.13	.10
Butyrate	.02	.03	.02
Branched Chain VFA	.01	.01	.01

[a]Alfalfa different than day 29, P<.05.
[b]Alfalfa different than day 37, P<.05.
[c]Day 29 different than day 37, P<.001.

Table 34.3. Net Portal Flux of VFA in Lambs Maintained on Pelleted Alfalfa or Infusions of VFA and Casein in Experiment 1

VFA flux, mmol/hr.	Alfalfa	VFA Infusion	
	day 34	day 29	day 37
Acetate	47.5	86.0	83.1
Propionate[ab]	11.2	37.3	43.0
Butyrate[ab]	.1	5.8	6.2
Branched Chain VFA	3.7	.7	2.1
Total VFA[ab]	64.5	129.8	138.3

[a]Alfalfa different than day 29, $P<.05$.
[b]Alfalfa different than day 37, $P<.05$.

Table 34.4. Ruminal Fluid pH and VFA Concentrations in Lambs Fed Pelleted Alfalfa or Infused with Various Levels of VFA and Casein in Experiment 2

Item	Alfalfa-Fed	VFA Infusion, Mcal GE		
	1.95 Mcal ME	1.64	1.82	2.37
Ruminal pH[b]	6.76	6.18	6.00	5.85
VFA, mM:				
Acetate	42.2	60.6	62.2	77.5
Propionate[a]	10.3	19.8	21.1	26.5
Butyrate[b]	6.1	5.9	6.7	8.3
Branched Chain[a]	1.8	.1	.1	.1
Total VFA	60.3	86.3	90.2	112.4

[a]Linear effect, $P<.05$.
[b]Linear effect, $P<.1$.

Table 34.5. Net Portal Flux of Nutrients in Lambs Fed Pelleted Alfalfa or Infused with Various Levels of VFA and Casein in Experiment 2

	Alfalfa-Fed	VFA Infusion, Mcal GE		
Flux mm/hr.	1.95 Mcal ME	1.64	1.82	2.37
Acetate	56.4	72.0	68.4	104.0
Propionate	20.9	35.4	28.2	46.0
Butyrate	3.4	4.5	3.4	6.4
Branched Chain VFA[a]	1.1	.2	.2	.2
Glucose	-4.9	-6.0	-5.3	-8.8
Alpha-amino-N	38.3	28.2	18.2	20.9
NH_3[a]	36.0	21.3	19.2	17.5
Urea	-7.2	-5.9	-5.9	-6.1
Oxygen	-135.3	-85.7	-51.1	-118.4

[a]Linear effect, $P<.05$.