INFLUENCE OF RUMINAL BUTYRATE SUPPLY ON NET NUTRIENT PRODUCTION AND ABSORPTION IN STEERS

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Summary

Six Holstein steers were used to evaluate the effects of increasing ruminal butyrate on net nutrient production and absorption by the gastrointestinal tract and liver. Ruminal and arterial concentrations and net hepatic flux of butyrate increased with increasing butyrate infusion. Concentrations of glucose and α-amino-N in arterial blood decreased as butyrate infusion increased. Of the ruminal butyrate infused, 24.5% appeared in portal blood as butyrate. Acetoacetate, D-β-hydroxybutyrate, and α-amino-N were the nutrients most altered by increasing ruminal butyrate.

(Key Words: Butyrate, Volatile Fatty Acids, Bloodflow, Nutrients, Rumen.)

Introduction

Acetate, propionate, and butyrate are major end products of microbial digestion of dietary carbohydrates in ruminants. These volatile fatty acids (VFA) appearing in portal blood draining the rumen make substantial contributions to the animal's energy supply. Of the three major VFA, butyrate is normally found in the lowest concentration (5 to 15% of the total VFA) in the rumen and is extensively metabolized (70 to 80%) during its absorption into portal circulation by the rumen epithelium. We conducted this experiment to determine if increasing amounts of butyrate in the rumen would alter extraruminal nutrient supplies.

Experimental Procedures

Six Holstein steers (720 to 869 lb) were fitted with permanent catheters in the portal vein entering the liver, in a hepatic vein exiting the liver, in two mesenteric veins, and a mesenteric artery and with a ruminal cannula. The steers were fed a diet consisting of 40% brome hay, 30% corn, and 30% milo in 12 portions daily at 1.25 times their maintenance energy requirements. Approximately 15 to 20 hr prior to sampling, butyrate was infused continuously via the ruminal cannula at 50, 100, 150, 200, and 250 mmol/hr. One steer served as the control. Five sets of hepatic, portal and arterial blood samples were taken at 1 hr intervals on the day of sampling. Portal and hepatic blood flow was determined by a primed continuous infusion of para-aminohippuric acid (PAH) into a small mesenteric vein. Portal and hepatic nutrient flux was calculated as venous-arterial concentration difference multiplied by blood flow. Portal and

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hepatic flux measures the quantities of nutrients that are transferred across the gastrointestinal tract (GIT) and liver, respectively, and are thus available for body maintenance and growth.

Results and Discussion

Ruminal fluid pH tended to decrease ($P<.06$) as the butyrate infusion increased (Table 7.1). Molar concentrations of butyrate increased ($P<.01$) while valerate decreased ($P<.05$) with increasing butyrate. Arterial concentrations of acetate, glucose, and α-amino-N decreased linearly ($P<.05$) as butyrate infusion increased. Acetoacetate, D-β-hydroxybutyrate, and butyrate arterial concentrations increased with increased butyrate infusion.

The effect of ruminal butyrate infusions on net portal and hepatic nutrient flux is reported in Table 7.2. A positive number means that the release or production of a specified nutrient by the GIT (portal flux) or by the liver (hepatic flux) has taken place. On the other hand, a negative number implies that an uptake or utilization has occurred. Increased butyrate produced an increased net portal flux of acetoacetate and butyrate ($P<.01$) and an increased

Table 7.1. Effect of Ruminal Butyrate Infusions on Ruminal Fluid pH, Ruminal VFA Concentration and Arterial Nutrient Concentration in Steers

Item	Control	Butyrate infusion rate, mmol/h					SE
		50	100	150	200	250	
Ruminal pH	6.65	6.51	6.57	6.58	6.53	6.43	.06
Ruminal VFA, mM							
Acetate	57.78	57.04	59.80	50.72	48.92	54.72	3.23
Propionate	14.94	14.20	15.39	13.49	13.43	14.59	.71
Isobutyrate	.65	.67	.74	.64	.66	.66	.05
Butyrate[a]	7.36	10.21	15.25	16.17	21.83	28.31	1.13
Isovalerate	1.34	1.31	1.28	1.03	1.37	1.31	.12
Valerate[b]	.68	.69	.69	.59	.58	.57	.04
Arterial conc., mM							
Glucose[b]	3.78	3.87	3.63	3.76	3.73	3.50	.09
Insulin(mU/h)	32.28	30.52	30.33	33.14	39.02	39.16	3.77
α-amino-N[b]	2.08	1.94	1.93	1.98	1.90	1.85	.06
Ammonia-N[c]	.076	.109	.094	.095	.101	.082	.008
Urea-N	2.93	3.13	3.10	2.82	2.89	3.01	.20
L-lactate	.62	.62	.56	.60	.52	.61	.05
D-β-hydroxybutyrate[a]	.29	.39	.46	.53	.67	.70	.04
Acetoacetate[b]	.023	.032	.014	.050	.050	.039	.008
Free fatty acids	.069	.066	.063	.053	.050	.055	.008
Acetate[b]	.95	1.01	.92	.88	.88	.86	.04
Propionate	.026	.031	.029	.038	.032	.034	.003
Butyrate[a]	.011	.021	.019	.034	.036	.048	.004

[a]Linear effect, $P<.01$ [b]Linear effect, $P<.05$ [c]Quadratic effect, $P<.05$

Table 7.2. Effect of Ruminal Butyrate Infusions on Net Portal and Hepatic Flux of Nutrients and Insulin in Steers

Item	Control	Butyrate infusion rate, mmol/h 50	100	150	200	250	SE
Bloodflow, l/hr							
Portal	543	501	600	568	566	597	35.0
Hepatic	644	599	722	674	663	720	44.0
Portal flux, mmol/hr							
Glucose	25.7	3.1	-25.8	1.5	7.0	9.3	17.62
Insulin (mU/hr)	2820	2986	2284	2641	4435	902	1747.9
α-amino-N	103.6	82.1	93.6	88.8	80.0	72.3	12.85
Ammonia-N	71.0	73.7	100.6	61.7	75.1	82.5	13.43
Urea-N	-61.7	-39.9	-27.2	-40.6	-49.5	-89.7	23.69
L-Lactate	147.2	12.4	101.0	91.2	119.6	139.1	51.16
D-β-hydroxybutyrate	59.5	42.0	61.1	63.7	63.5	62.4	12.10
Acetoacetate[a]	15.0	15.9	30.7	25.8	24.6	33.5	3.16
Free fatty acids	7.2	9.0	11.2	11.5	8.3	10.9	1.57
Acetate	387.4	290.8	412.0	345.9	292.1	298.7	41.91
Propionate	134.2	111.7	148.6	129.3	122.9	116.4	10.41
Butyrate[a]	29.5	36.5	55.3	68.6	76.5	88.7	5.57
Hepatic flux, mmol/hr							
Glucose	118.1	120.2	184.7	104.1	120.5	105.8	22.81
Insulin (mU/hr)	-3250	-1838	417	1615	-707	-2879	2119.1
α-amino-N[b]	-63.9	-43.1	-58.8	-35.0	-25.9	-28.1	14.05
Ammonia-N	-77.1	-83.5	-117.6	-71.7	-83.3	-88.9	13.09
Urea-N	126.1	97.1	144.0	94.4	94.3	151.3	19.36
L-Lactate	-102.0	-44.6	-84.2	-144.4	-92.8	-139.5	40.06
D-β-hydroxybutyrate[a]	55.9	65.3	105.9	114.0	139.4	156.9	11.96
Acetoacetate[b]	-11.9	-12.0	-22.1	-21.5	-17.0	-24.4	3.43
Free fatty acids	-9.4	-9.5	-7.4	-8.2	-9.4	-9.8	2.51
Acetate	87.8	59.3	103.6	86.9	91.5	102.8	36.23
Propionate	-121.0	-98.7	-131.0	-109.4	-104.1	-97.4	9.50
Butyrate[a]	-23.4	-30.1	-40.8	-46.9	-54.7	-55.1	4.04

[a]Linear effect, P<.01. [b]Linear effect, P<.05.

net hepatic flux of D-β-hydroxybutyrate. Net portal and hepatic fluxes of glucose, ammonia-N, urea-N, lactate, free fatty acids, acetate, and propionate were not affected by ruminal butyrate. Insulin net hepatic flux tended to respond quadratically (P=.08) to increasing butyrate. Acetoacetate and butyrate uptake by the liver increased as butyrate infusion increased. Alpha-amino-N net hepatic flux (uptake) decreased (P<.05) with increasing ruminal butyrate supply. Simple linear regression showed that 24.5% of butyrate appeared in portal blood (r^2=.98) as butyrate, indicating that 75.5% of infused butyrate was metabolized by GIT tissues.