RUMINAL WATER EVASION AND STEADY STATE

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Story in Brief

Three experiments were conducted to compare the behavior of water soluble markers in the rumen. A total of 17 cannulated mature cattle were fed an 80% concentrate diet or a prairie hay diet. Water was offered free choice and individual water intake was monitored at 2 hour intervals. Markers were dosed either in the drinking water or infused directly into the rumen. Animals tended to drink more water during the late afternoon in all experiments. Evasion of drinking water estimated by the inflow-outflow method was 79 and 44% for polyethylene glycol or 66 and 51% for chromium for the concentrate and hay-fed animals, respectively. Water evasion for the concentrate-fed animals was 41% with the marker ratio method. Markers added to the water behaved similarly in the rumen, but they never reached steady state concentrations in the rumen. Estimates of liquid passage rate were similar for chromium and cobalt, but showed diurnal patterns. Although water evasion estimated by the ratio approach was lower, values indicate that a sizable percentage of imbibed water evades the rumen. Nutritional effects of ruminal evasion of drinking water deserve study.

(Key Words: Drinking Water, Evasion, Markers.)

Introduction

Ruminal passage rate of liquids and solids can influence digestibility, feed intake and efficiency of microbial growth (Owens and Isaacson, 1977). In general, as dilution rate of liquids in the rumen increases, efficiency of bacterial growth increases. Consequently changes in rate of flow from the rumen may have a direct effect on animal performance. The rate at which water flows through the gastrointestinal tract of the ruminant is influenced partially by the amount of liquid ingested, however the quantity of ingested water that enters the rumen has not been clearly defined. Woodford et al.

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(1984) reported that a small amount of drinking water (18%) evaded the rumen of lactating cows. Our experience (Garza and Owens, 1989) with beef heifers fed high concentrate diets indicated that drinking water evasion from the rumen was as high as 80%. The objectives of this research were to compare the behavior of chromium-EDTA (Cr-EDTA) and polyethylene glycol (PEG) in the rumen to verify previous water evasion results which were all based on PEG, to evaluate an alternative approach to calculate water evasion, and to estimate the passage rate of fluids and rumen liquid volume during a 48-h period with water soluble markers.

Materials and Methods

Experiment 1

Four rumen cannulated Hereford heifers (1,300 lb) housed in individual pens were fed a prairie hay or an 80% concentrate diet (Table 1) at 1.8% of body weight twice daily (0830 and 1600) in a crossover experiment with 2-week periods. All heifers were adapted to their diets during the initial 11 days of each period. Water was offered free choice and water intake was recorded daily. On days 12 through 15 of the trial, a solution of Cr-EDTA (68 mg Cr/gallon) was added to the drinking water. Polyethylene glycol (MW 3350) in solution also was included in the drinking water at a rate of 10.0 g per gallon of water offered. Water disappearance from the trough was measured at 3-h intervals. Water samples were collected to determine

Table 1. Composition of concentrate (dry matter basis).

Ingredient	Percent
Dry rolled corn	63.10
Dehydrated alfalfa pellets	6.00
Cottonseed hulls	14.10
Soybean meal	10.05
Cane molasses	5.00
Salt	.50
Ground limestone	.50
Dicalcium phosphate	.50
Aurofac-10	.15
Urea, 42% N	.10

concentration of Cr and PEG. On day 14 of the study, one pulse dose of 250 ml of a Co-EDTA solution (1.2 g Co) were administered intraruminally after the afternoon feeding and approximately 18 h prior to the ruminal evacuation. Samples from the rumen (250 ml) were obtained at 4-h intervals during the final three days of the trial starting immediately after the water soluble marker (WSM) solutions were included in the drinking water.

Chromium and cobalt concentrations in ruminal fluid were analyzed by atomic absorption spectroscopy and PEG concentration was analyzed turbidimetrically. Values from ruminal evacuation were used to calculate percentage of water evading the rumen (Garza and Owens, 1989). Mean water intake, rumen volume, marker concentration in ruminal fluid and dilution rate data were used to simulate ruminal steady state conditions and compare this condition with the observed behavior of markers in the rumen.

Experiment 2

Five mature beef steers (990 lb) were used to investigate ruminal evasion of drinking water. Calculations were based on comparison of concentration of markers dosed by two routes, either in the rumen or in the drinking water. Experimental procedures and management were similar to those described previously for Experiment 1.

In contrast to Experiment 1, animals were dosed intraruminally a solution of Co-EDTA (60 ml containing 150 mg CO) every 8 h during an 80-h period. Meanwhile, 25 ml of Cr-EDTA (12.1 g/gallon) were mixed per gallon of offered water. Water and ruminal samples were collected immediately after dosing began for three consecutive days at 8 a.m., noon, 2 p.m., 4 p.m., 8 p.m. and midnight. Data from marker concentration in the drinking water and ruminal liquid were used to calculate water evasion from the rumen, based on the following ratio:

$$\frac{\text{[Cr-EDTA] in ruminal fluid/drinking water dosed Cr-EDTA}}{\text{[Co-EDTA] in ruminal fluid/ruminally dosed Co-EDTA}}$$

This ratio will represent directly the proportion of drinking water mixing with rumen liquid; consequently 1 minus this value equals the proportion of water that evaded the rumen. No attempt was made to correct for marker absorption from the rumen.

Experiment 3

Eight Angus x Hereford cattle (1,230 lb) fitted with rumen cannulas were used in a 48-h trial. Animals were fed as outlined for Experiments 1 and 2. All animals were dosed in the rumen at 4 a.m. and noon of day 1 or 4 a.m. of day 2 with 120 ml of Co-EDTA (8.0 g Co/gallon) and Cr-EDTA (5.1 g Cr/gallon) solutions according to the schedule presented in Table 2. Ruminal samples (250 ml) were collected at approximately 2-h intervals for 40 h after dosing. Water intake was recorded for the intervals between times of rumen sampling. Ruminal samples were used to determine Cr and Co concentrations. Liquid rate of passage was estimated for both markers within and between infusion times by regressing the natural logarithm of marker concentration against time (Grovum and Williams, 1973). Rumen volume was calculated by dividing marker dose by the antilogarithm of the intercept of the slope line (marker concentration at time zero).

Statistics

Data generated from Experiment 1 were analyzed for a crossover experimental design. Classes in the statistical model were represented by animal, period and treatment. In Experiment 2, the statistical model included animal, marker, day and hour as classes. In Experiment 3, the slopes (liquid dilution rate) were compared between markers for the same infusion time; in addition, the overall slopes also were compared between the three different infusion periods. For the three experiments, means were separated using least significant differences when significant effects were detected.

Table 2. Sequence of markers used for intraruminal dosing.

	Infusions[a]		
Animal	1	2	3
1	Cr,Co		Cr,Co
2	Co	Cr	Co
3	Cr,Co		Cr,Co
4	Cr	Co	Cr
5	Cr	Co	Cr
6	Co	Cr	Co
7	Cr	Co	Cr
8	Co	Cr	Co

[a] Infusion 1 markers were dosed at 4 a.m. on day 1.
Infusion 2 markers were dosed at noon on day 1.
Infusion 3 markers were dosed at 4 a.m. on day 2.

Results and Discussion

Consumption of drinking water and frequency (number of animals drinking) across the three experiments were higher during the evening following the late afternoon meal (Figure 1). Compared to the hay diet, estimates of drinking water evasion from the rumen were higher for the concentrate diet (79 vs 49% for PEG; $P<.02$ and 66 vs 51% for Cr; $P<.08$). Marker comparison within diets showed a higher estimate of drinking water evasion for PEG as compared to Cr (79 vs 66%; $P<.02$) for the concentrate diet (Table 3, Experiment 1). The marker ratio method gave a lower evasion estimate (41%, Experiment 2; Table 3). Ruminal concentration of two markers, PEG and Cr-EDTA, placed in the drinking water, expressed as a ratio yielded similar marker behavior in the rumen (Figure 2), indicating that either PEG or Cr-EDTA could be used for water evasion estimates; however, marker concentrations even after three days of continuous ingestion, never reached steady state conditions (Figure 2). This suggests that rumen liquid volume or outflow were not constant; changes might occur from day to day as feed or water intakes change. Diurnal and nycterohemeral shifts also may cause erroneous interpretations when steady

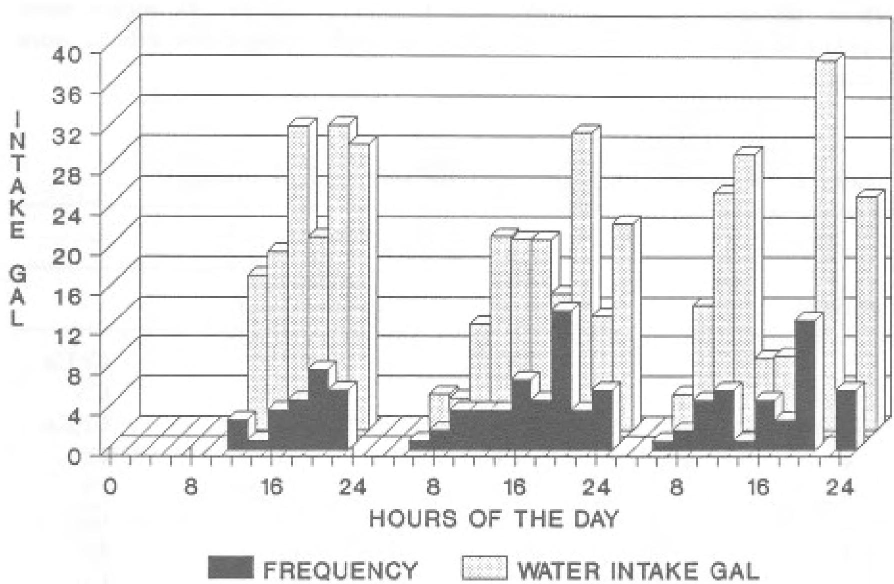

Figure 1. Water intake across the three experiments and number of animals (frequency) drinking water during three consecutive days.

Table 3. Water evasion estimates using two different methods.

Method	Evasion, % water intake		
	Concentrate	Hay	SE[a]
Experiment 1			
Inflow/outflow, PEG	79[b f]	44[c]	3.6
Inflow/outflow, Cr-EDTA	66[dg]	51[e]	3.2
Experiment 2			
Marker ratio[h]	41		9.9

[a] Standard error.
[b,c] Means in the same row with different superscripts differ (P<.05).
[d,e] Means in the same row with different superscripts differ (P<.10).
[f,g] Means in the same column with different superscripts differ (P<.02).
[h] Cr-EDTA in rumen/drinking water dosed Cr / Co-EDTA in rumen/intraruminally dosed Co

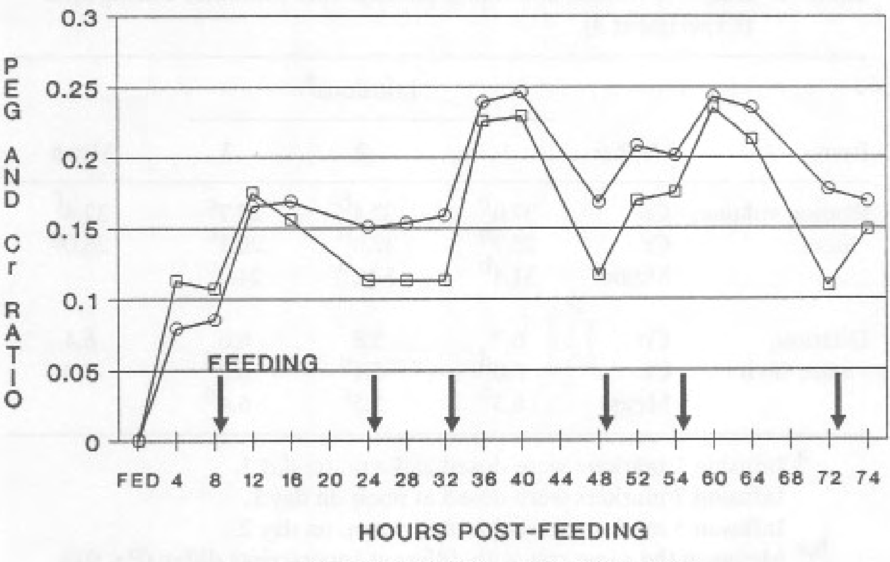

Figure 2. Marker (PEG and Cr) concentration ratios in ruminal fluid of beef heifers fed hay or concentrate diets (Experiment 1).

state is assumed. Consequently, in Experiment 3, short term ruminal liquid dilution rate and ruminal volumes were estimated on two consecutive days at different hours of the feeding cycle (Table 4). Mean liquid dilution rate were similar between Co-EDTA (6.4 %/h) and Cr-EDTA (5.8 %/h). Changes in dilution rate also were observed ($P<.01$) at various times of the day (Table 4) being lower at noon than at 4 a.m. In addition, ruminal volume was smaller ($P<.01$) when estimated form the 4 a.m. infusion on the second day of the trial, suggesting that volumes may change from day to day. Calculated volumes also were different ($P<.01$) between markers (32.4 liters for Co vs 26.0 liters for Cr). Results from these trials indicate that the rumen is a very dynamic pool. Estimates of drinking water evasion using different diets and different approaches remain high (41 to 80%). Even though PEG and Cr-EDTA behaved similarly in the rumen when included in the drinking water (Experiment 1) liquid dilution rate differences among times (Experiment 3) suggest nycterohemeral flow patterns in liquid digesta.

Table 4. Ruminal volume and liquid passage rate estimates during 48 h (Experiment 3).

Item	Marker	Infusions[a]			Mean
		1	2	3	
Rumen volume, liters	Co	37.0[b]	32.4[b]	27.7[c]	32.4[f]
	Cr	25.7[b]	32.0[b]	20.1[c]	26.0[g]
	Mean	31.4[b]	32.2[b]	24.0[c]	
Dilution, rate, %/h	Co	6.7	5.8	6.6	6.4
	Cr	6.0[d]	5.1[e]	6.2[d]	5.8
	Mean	6.3[b]	5.5[c]	6.4[b]	

[a] Infusion 1 markers were dosed at 4 a.m. on day 1.
Infusion 2 markers were dosed at noon on day 1.
Infusion 3 markers were dosed at 4 a.m. on day 2.
[b,c] Means in the same row with different superscripts differ ($P<.01$).
[d,e] Means in the same row with different superscripts differ ($P<.05$).
[f,g] Means in the same column with different superscripts differ ($P<.01$).

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