EFFECTS OF DIET ON RUMINAL LIQUID AND ON BLOOD SERUM OSMOLALITY AND HEMATOCRIT IN FEEDLOT HEIFERS

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Story in Brief

Eight ruminally cannulated beef heifers were used in a crossover experiment to examine osmolality changes in ruminal liquid and blood serum. Blood hematocrit and ruminal pH also were examined. Heifers were adapted for 20 days to ad libitum intake of either a concentrate or a hay diet. After the adaptation period, ruminal and blood samples were obtained for three consecutive days at -2, 1, 2, 4 and 6 hours after feeding. Ruminal pH varied with diet and post-prandial time, being higher prefeeding than post-feeding. Ruminal osmolality peaked 1 and 2 hours post-feeding for the hay and concentrate diet at 265 and 296 mOsm/kg, respectively. Serum osmolality was consistently higher than ruminal osmolality. Hematocrit was higher for heifers fed hay than for heifers fed concentrate but post-prandial changes were minor. Ruminal liquid and serum osmolality ranged within normal physiological values indicating that drastic changes in these parameters may occur only under special dietary conditions, and that peak values can be expected between 2 to 4 hours post-feeding.

(Key Words: Ruminal Osmolality, Serum Osmolality, Hematocrit, Beef Cattle.)

Introduction

Dietary constituents and metabolites markedly influence the ruminal environment. Ruminal pH has been studied extensively because of its special importance to ruminal fermentation and volatile fatty acid utilization. Other important variables within the rumen, which might influence rumen fermentations, such as osmotic pressure have received less attention. Previous experiments have demonstrated that osmotic pressure in the rumen is important. (Warner and Stacy, 1965; Ternouth and Beattie, 1971; Bergen,

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1972; Warner and Stacy, 1977; Phillip et al., 1981). Although most of these studies have been conducted with sheep, they generally agree that ruminal fluid hypertonicity limits feed intake and causes an influx of water from blood into the rumen. After feeding, ruminal liquid normally is thought to be hypotonic to blood, but it rises (350-380 mOsmol/l) soon after feeding. According to Phillip et al. (1981), high ruminal osmolalities (525 mOsm/kg) depressed feed intake of ruminally cannulated lambs within 30 min after feeding. Based on these findings the authors concluded that ruminal osmolality inhibited short term feed intake. The purpose of this experiment was to measure changes in osmolality in ruminal liquid and blood serum with time after feeding in cattle fed two different types of diets. Packed red cell volume (hematocrit) and ruminal pH also were monitored.

Materials and Methods

Eight crossbred beef heifers averaging 1210 lb body weight, each fitted with a rumen cannula (10 cm ID), were used in two 23-day experimental periods. Animals were randomly assigned to individual pens and received a concentrate diet (Table 1) or chopped Prairie hay plus 1.5 kg daily of a 50% protein concentrate in a crossover experiment. During the first 20 days of each period, animals were adapted to ad libitum intake of the experimental diets. Feed intake was recorded daily. Fresh feed was provided twice daily at 8:30 a.m. and 4:30 p.m. during the entire trial at 120% of the previous days intake. After day 20, intake was restricted to 90% of the mean intake of days 14 to 19. Water and mineral premix were available ad libitum. Ruminal and blood samples were collected sequentially during the last 3 days of each experimental period, at -2, 1 , 2, 4 and 6 hours after the 8:30 a.m. feeding. A

Table 1. Diet composition (dry matter basis).

Ingredients	Concentrate %
Dry rolled corn	63.06
Dehydrated alfalfa pellets	6.03
Cottonseed hulls	14.07
Soybean meal (44%)	10.05
Cane molasses	5.03
Salt (trace mineralized)	.50
Ground limestone	.50
Dicalcium phosphate	.50
Aurofac-10	.15
Urea (42% N)	.10
total	100.00

30 ml blood sample was withdrawn at each time via jugular venipuncture. Blood was placed in siliconized tubes to harvest serum. Immediately after collection, 10 ml of blood were transferred into heparinized tubes for microhematocrit determination. Blood plasma samples were frozen at -20°C until osmolality was analyzed. Aliquots from heparinized blood samples were transferred to microhematocrit capillary tubes. Hematocrit was determined in triplicate soon after blood sampling.

Ruminal liquid samples were taken prior to each blood sample. Approximately 250 ml of fluid were withdrawn from the ventral ruminal sac with a suction flask and a manual pump. This ruminal fluid was filtered through two layers of cheesecloth and pH was determined immediately with a glass electrode. Thereafter, the samples were centrifuged at 10,000 g for 15 min; aliquots of the supernatant fluid were frozen and stored at -70°C until analyzed. At the time of analysis the serum and the ruminal samples were thawed and osmolalities were determined in duplicate in an osmometer using the freezing point depression procedure. Data were analyzed using the general linear model procedure.

Results and Discussion

Ruminal pH was altered ($P<.05$) by diet (Table 2). Heifers fed the high concentrate diet had lower ruminal pH. Ruminal pH at -2 hours was higher ($P<.0001$) than the mean pH post-feeding (Figure 1). Post-feeding, linear quadratic, cubic terms revealed quadratic ($P<.04$) effects of time on pH. Mean values for ruminal pH were in the range expected for concentrate (5.5 and 6.5), and roughage (6.2 and 7.0) diets suggested by Owens and Goetsch (1988). These authors indicated that pH usually is lowest between 1/2 and 4

Table 2. Effect of diet on ruminal pH, hematocrit, ruminal liquid and serum osmolalities of heifers fed hay or concentrate diets.

Parameter	Diets		SE
	Concentrate	Hay	
Ruminal pH	6.2[b]	6.7[a]	.09
Hematocrit %	34.4[b]	37.0[a]	.43
	-------- osmolality (mOsmol/kg)--------		
Ruminal liquid	284.0	250.4	13.60
Serum	303.0	296.0	4.61

[a,b]Mean values in a row with different superscripts are significantly different ($P<.05$).
SE=Standard error of the mean.

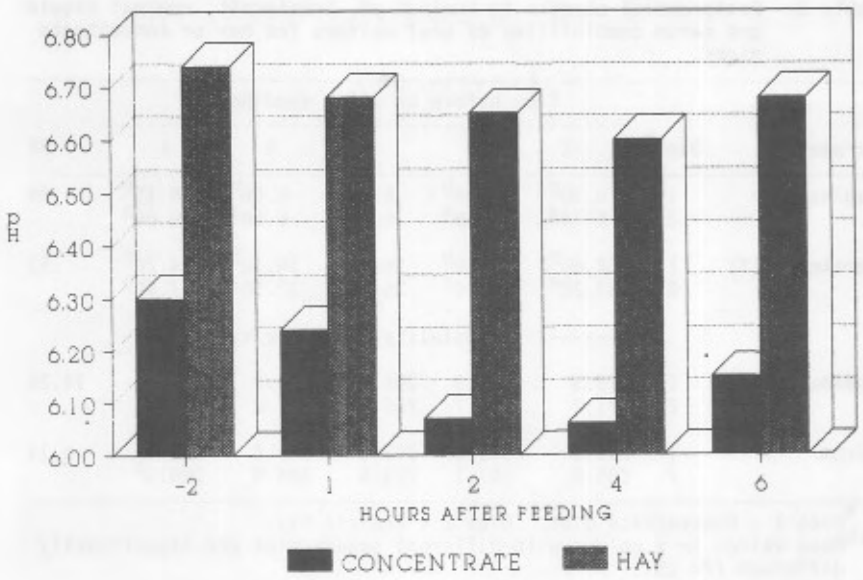

Figure 1. Ruminal pH versus time in beef heifers fed concentrate and hay diets.

hours after a meal, which agrees with our concentrate diets. In this study pH was lowest two hours after feeding for the concentrate diet versus 4 hour post-feeding for the hay diet (Figure 1).

Osmolalities for ruminal liquid and serum are presented in Tables 2 and 3. Post-prandial values for both materials were higher ($P<.05$) than before feeding. Peak values never reached those reported by other authors (Phillip et al., 1981; Engelhardt, 1975; Ternouth, 1967; Warner and Stacy, 1965). One explanation for these differences in our results may be attributed to the type of animal and diet composition. Most of the above studies measured osmolality in sheep which had been deprived of food or water for a certain period of time and in some studies salt loads were infused into the rumen. Such experimental procedures would dramatically alter ruminal liquid osmolality. Presumably, the preprandial osmolality values in the range of 200 to 280 mOsmol/kg as we observed, are more physiological. Postprandial ruminal osmolality values, however, can vary considerably depending on the concentration of either the dissolved substances in the feed or the products of microbial activity. Lower ruminal osmolality values for the roughage diet presumably are due to lower production of solutes and greater dilution of these solutes (VFA and mineral salts) by saliva. Intraruminal

Table 3. Postprandial changes in ruminal pH, hematocrit, ruminal liquid and serum osmolalities of beef heifers fed hay or concentrate diets.

Parameter	Diet*	Time before or after feeding (h) -2	1	2	4	6	SE
Ruminal pH	1	6.30^b	6.24^b	6.07^b	6.06^b	6.15^b	.09
	2	6.74^a	6.68^a	6.65^a	6.60^a	6.68^a	
Hematocrit(%)	1	34.80^b	34.80^b	34.00^b	34.10^b	34.20^b	.53
	2	37.20^a	36.70^a	36.80^a	37.50^a	37.00^a	
		osmolality (mOsmoles/kg)					
Ruminal Liq	1	278.5	288.9	296.0	280.2	277.8	14.26
	2	241.2	264.7	256.9	247.2	241.9	
Serum	1	296.5	302.5	303.9	304.4	308.7^a	6.11
	2	285.6	301.1	299.5	304.9	288.9^b	

*Diet 1 = Concentrate diet. Diet 2 = Prairie hay.
a,bMean values in a column with different superscript are significantly different (P<.05).
SE=Standard error of the mean.

infusions of water or hypertonic solutions altered the osmotic pressure of the rumen liquid and blood (Warner and Stacy, 1977). If the rumen becomes hyperosmolar as a result of feeding, direct addition of water to the rumen will lower the ruminal osmolality (Ternouth, 1967). Yet Engelhardt (1969) stated that hypotonicity of the rumen contents cannot be explained either by the inflow of saliva or by influx of water into the rumen. He concluded that a major cause of ruminal liquid hypotonicity was due to absorption of VFA through the ruminal epithelium. Similarly Ternouth (1967) indicated that 2 hours after feeding, VFA concentration and osmolality dropped simultaneously, and that ruminal osmolality always remained higher than normal serum levels. Serum osmolality (Figure 2) increased after feeding and remained elevated for up to 4 hours. Thereafter osmolality decreased slightly to return to their preprandial level. Serum osmolality values never were lower than the ruminal fluid osmolalities as suggested by Ternouth (1967). Thus, VFA uptake or influx of water across the rumen wall cannot explain the difference between rumen and serum values.

Whether changes in salivary flow were associated with the low osmolality of rumen contents of heifers fed the hay diet is not known. Further studies should consider both how saliva production alters osmotic status of the rumen and the converse, how osmolality of serum alters salivary flow. Packed red cell volume (hematocrit) was higher (P<.004) for heifers

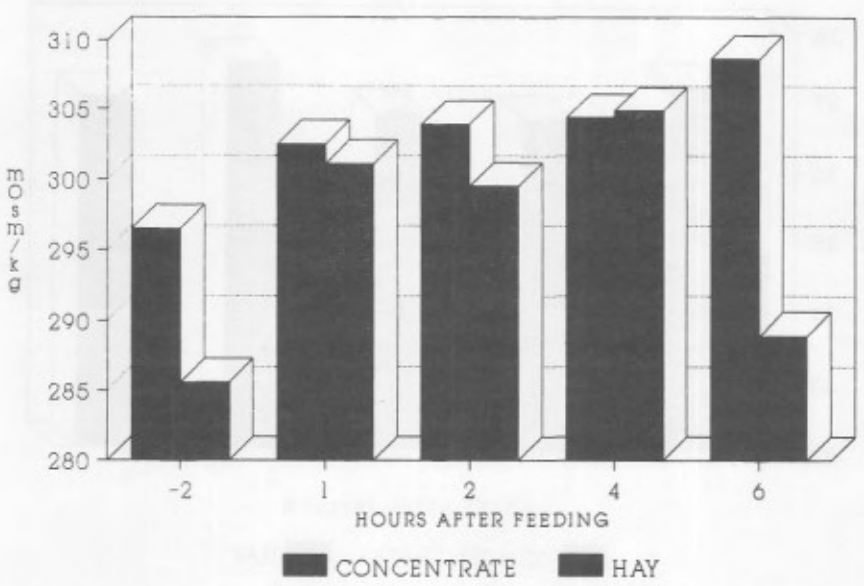

Figure 2. Serum osmolality versus time in beef heifers fed concentrate and hay diets.

fed hay than for heifers fed concentrate (Figure 3). No difference between preprandial and postprandial times or between postprandial times proved significant. Hematocrits were close to the normal physiological values (32 to 35) reported in the literature (Swenson, 1984). Published information on the effects of different types of diets on hematocrit is limited. Warner and Stacy (1965) indicated that high ruminal osmolalities (near 400 mOsmol/kg) were accompanied by hemoconcentration in sheep. They attributed these changes to transfer of body water from the blood into the rumen. Similarly, Ternouth (1967) with Merino ewes observed that packed cell volume and serum proteins in blood increased during the first hour post-feeding. Unfortunately neither of these reports presented absolute hematocrit changes to compare with the values obtained in our study. As ruminal osmolality averaged about 240 mOsm/kg with the roughage diet, water should be absorbed from, not diffuse into the rumen. This would decrease hematocrit, not increase it as we observed.

Ruminal liquid osmolalities in our study never attained the high values reported by Warner and Stacy (1965). One interesting finding was the higher ($P<.05$) (Table 2 and Figure 4) hematocrit and the lower ruminal osmolality (250.4 mOsm/kg) of the heifers fed the hay diet. Serum osmolality remained constant for both diets. Hence, hematocrit changes may

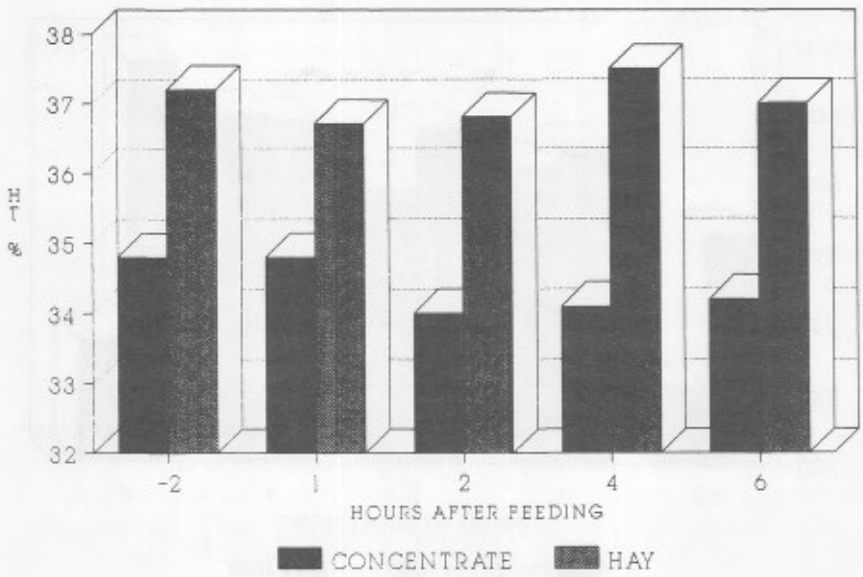

Figure 3. Hematocrit versus time in beef heifers fed concentrate and hay diets.

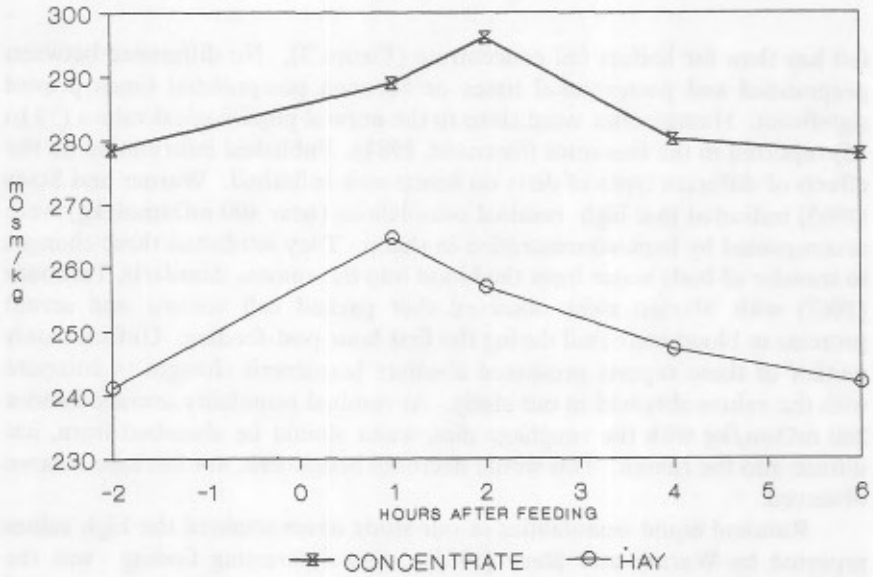

Figure 4. Rumen osmolality versus time in beef heifers fed concentrate and hay diets.

be due to differences in saliva production. Warner and Stacy (1977) indicated that salivary flow was affected by the osmotic status of the animal. When water was infused into the rumen of sheep, rate of saliva flow decreased. When rumen contents were hypotonic due to the addition of water to the rumen, a clear decrease in salivary flow was observed. These findings would be opposite to our results, because the animals consuming hay had lower ruminal osmolality and presumably had greater saliva flow.

As indicated previously, little water moves across the rumen wall when rumen osmotic pressure is isotonic (260 to 340 mOsmol/kg). If true, one cannot attribute our higher hematocrits to net transfer of water from blood into the rumen. Red blood cell size variation also alters hematocrit. Increased serum osmolality would shrink red blood cells (RBC) and decrease hematocrit. As diet did not alter serum osmolality, altered size of RBC would be unlikely as an explanation for the change in hematocrit. Nevertheless this assumption deserves study.

In conclusion, our results suggest that osmolality values of rumen contents are maximum between 1 to 2 hours after feeding, and are higher with grain than low quality forage. Serum osmolality peaked later (4 to 6 hours after feeding). Increased hematocrits with the low quality forage diet were not expected and have not been reported previously. Differences between diets and post feeding changes in osmolality of the blood serum and ruminal fluid do not support the idea that flux of water across the rumen wall is extensive under normal feeding conditions. Flux may be more evident with restriction of water or salt feeding or infusion into the rumen. High hematocrit and low ruminal osmolality may reduce salivary flow; whether such changes depress forage intake deserves study.

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