Passage Rates, Rumen Fermentation, and Weight Change in Protein Supplemented Grazing Cattle

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Abstract

Protein supplementation is widely used to enhance the nutritional status of cattle on rangeland. The effects of protein supplementation on particulate and fluid passage rates, rumen fermentation, and weight gain were evaluated on cattle grazing dormant blue grama rangeland. Twelve rumen-cannulated steers were randomly allotted to 3 equal supplement groups (4/treatment): cottonseed cake (CSC), pelleted alfalfa (ALF), or no supplement (CON). Supplements were individually fed every other day at isonitrogenous levels (1.7 kg/hd CSC vs 3.6 kg/hd ALF). Particulate passage rate was measured during 2 collection periods. Concurrently, 102 yearling heifers were allotted to the same treatment groups for measurement of average daily gain. Cattle were fed these treatments from January through April 1983. In a second trial, 9 rumen-cannulated steers were randomly allotted to the same treatment groups as trial 1. An intraruminal dose of Co-EDTA was used to estimate fluid passage rates. Rumen ammonia, volatile fatty acids, and pH were also measured. In trial 1, average daily gain did not differ between ALF and CSC supplemented heifers; however, both ALF and CSC gained more than CON heifers. Passage rate estimates were not different among treatment groups. In trial 2, rumen fluid dilution rate, volume, and outflow rate were not different among treatments. Rumen ammonia-N was different at 11 h postsupplementation when the CSC steers had higher levels than steers in other treatment groups. Rumen pH was not influenced by supplementation. Molar proportions of acetate and propionate at 8 and 11 h after supplementation differed among treatment groups. Acetate was lowest in ALF, intermediate in CSC, and highest in CON supplemented steers. Propionate followed the reverse trend. Overall, protein supplementation improved livestock performance but the mechanism involved was not elicited. The current data suggest shifts in fermentation patterns and meeting dietary demands for gain are the factors involved in improving performance.

Key Words: nitrogen supplementation, rumen fermentation, passage rates, volatile fatty acids, ammonia nitrogen

Improving nutritional status of livestock on rangelands often requires supplemental feeding. Declines in crude protein and available nitrogen content of mature and senescent vegetation result in a need for supplemental protein (Allden 1981, McCollum and Galyean 1985). Although protein supplementation has improved performance of beef cows grazing dormant range (Speth et al. 1962, Parker et al. 1974, Bellido et al. 1981, Clanton 1982), these improvements may not result from increased intake (Rittenhouse et al. 1970, Forero et al. 1980).

Increased voluntary intake of low-quality forages with supplementation is believed to result from increased rate of digestion and(or) passage (Ellis 1978). Gut fill is considered the most limiting factor for intake of forage diets (Campling 1970, Freer 1981). Alteration of rate of passage and(or) digestion may alleviate or potentiate fill effects. Moreover, ruminal escape of supplemental protein may enhance voluntary intake of dormant forage through metabolic effects (Egan 1965, Kempton et al. 1977).

The influence of protein supplementation on fermentation patterns of grazing cattle has not been extensively investigated. Topps

et al. (1965) and Wagner et al. (1983) found no differences in VFA proportions as a result of protein supplementation in cattle grazing dormant rangelands. However, McCollum and Galyean (1985) noted a shift toward higher propionate with protein supplementation of low-quality prairie hay. The overall objective of this study was to evaluate the effects of protein supplementation and type of supplement (roughage vs concentrate) on livestock performance, passage rates and fermentation patterns. Specifically, this study evaluated the effects of cottonseed meal cake and ground, pelleted alfalfa hay or long-stem alfalfa hay supplements on average daily gain of heifers, digesta and fluid passage rates, and rumen pH, ammonia and volatile fatty acid concentrations in steers grazing dormant blue grama rangeland.

Study Area

Experiments were conducted at the Fort Stanton Experimental Ranch, a mountain-foothill region in south-central New Mexico. The study area consisted of blue grama (*Bouteloua gracilis*) rangeland typical of the Southwest. Climate is mild, with cool winters and warm summers. The 78-yr average annual precipitation is 348 mm, of which approximately 55% occurs from July to September. Mean precipitation for January through May is 83.9 mm. Pasture size, topography, and vegetative composition have been previously described (Judkins et al. 1985).

Methods

Trial 1

In January 1983, 9 esophageal- and 12 rumen-cannulated steers (average weight of 230 kg) were randomly allotted to 1 of 3 treatments (3 esophageal- and 4 rumen-cannulated steers/treatment): control (no supplemental feed [CON]), mechanically extracted cottonseed meal cake (1.7 kg/hd [CSC]) and ground, pelleted alfalfa hay (3.6 kg/hd [ALF]) (Table 1). Supplements were individually fed at specified amounts (isonitrogenous) every other day from January to May, 1983. Chemical analyses and composition of the diet selected did not differ between treatments (Judkins et al. 1985). All steers were herded to a central location on supplementation days at 0800 h. Control steers were withheld from grazing while supplemented steers were tethered and fed. Following supplement feeding, steers were released to resume grazing. A salt-mineral mix (50% dicalcium phosphate, 45% salt and 5% cottonseed meal) was provided free choice in the pasture.

Esophageal collections were conducted for 3 consecutive days in 2 periods (mid-February and late March). Esophageal extrusa, composited across steers in a treatment, was used for rate of passage determination.

Particulate rate of passage was measured with rumen-cannulated steers. On day 1, at supplement feeding, ytterbium (Yb)-labeled forage was placed in the rumen (mid-dorsal to mid-ventral region) of each steer via the rumen cannula. Forage had been labeled with Yb by the immersion and washing procedure described by Teeter et al. (1984). Steers received 95.0, 117.1, and 107.8 g (CON, ALF and CSC, respectively) in February and 90.5, 101.5, and 100.6 g (CON, ALF, and CSC, respectively) in March of Yb-labeled esophageal forage (dry matter basis). Dose sizes differed due to inevitable dry matter loses during the labeling procedure. Ytterbium content of the labeled forage was 20.7, 19.0, and 21.1 mg Yb/g dry matter (CON, CSC, and ALF, respectively) in February and 23.9, 26.0, and 22.6 mg Yb/g dry matter (CON, CSC, and ALF, respectively)

Table 1. Organic matter, nitrogen and fiber components of esophageal fistula samples, cottonseed cake (CSC) and pelleted alfalfa hay (ALF) supplements for steers grazing blue grama rangeland.

Item	Forage diets[a]			Supplements		
	Feb. 1983	March 1983	Jan. 1984	Trial 1 and 2 CSC	Trial 1 ALF	Trial 2 ALF
Organic matter	--%--					
Organic matter	82.6	79.3	87.1	91.5	89.0	88.6
Crude protein[b]	10.4	12.6	7.7	47.7	23.0	16.4
Soluble nitrogen[b]	.42	.50	.30	.85	1.40	.91
Insoluble available nitrogen[b]	.86	.79	.50	6.50	2.20	1.59
Insoluble unavailable nitrogen[b]	.40	.73	.45	.31	.15	.12
Neutral detergent fiber[b]	80.7	78.0	87.4	21.9	42.1	44.3
Acid detergent fiber[b]	62.3	65.4	52.7	16.2	30.1	34.2
Acid detergent lignin[b]	9.3	10.7	10.9	6.5	6.7	7.2

[a]Judkins et al. (1985).
[b]Percentage of organic matter.

in March.

Rectal grab samples were taken at 0, 4, 8, 12, 20, 24, 28, 32, 36, 42, 48, 56, 60, 72, 80, 96, 104, and 120 h postdosing. Actual times were recorded and used in compartmental modeling analysis. However, 1 deviation from the above sampling schedule occurred. In March, a snow storm (50.0 cm of snow) prevented sampling after 96 h postdosing.

Fecal samples were prepared for Yb analysis by drying at 50° C for 24 h. Samples were ground through a 2-mm screen and approximately 2-g subsamples were ashed at 550° C. Ash was solubilized by boiling in 3.1 N HCl, filtered through ashless (Whatman #541) filter paper and brought to 50 ml volume with deionized water. Standards for Yb analysis were made in solubilized ash from 0 h collections. All samples and standards contained 2,000 μg/ml of K as an ionization buffer. Ytterbium content was determined by atomic absorption spectroscopy using a nitrous oxide/air-acetylene flame.

Fecal Yb excretion curves were evaluated with a one-compartment model when the data sets failed to fit a two-compartment model (Pond et al. 1982). Curve fitting was accomplished using the nonlinear regression option (Marquardt method) of the Statistical Analysis System (SAS 1982). The equation for the one-compartment model is:

$$Y = k_o \bullet (t-tau) \bullet (k_1)^2 \bullet e^{-k_1(t-tau)}$$

Y = marker concentration in feces
k_o = initial marker concentration
t = time postdosing
k_1 = time dependent rate constant
tau = time from dose until first appearance of marker in feces

Computation of passage rate, gut fill, intestinal transit time and total mean retention time are:

Flow, %/hr = $(k_1 \times .59635) \times 100$
Undigested dry matter fill = dose/$k_o \times k_1 \times .59635$
Total mean retention time in the gastrointestinal tract, hr = $2/k_1 + tau$
Intestinal transit time = tau

Rate of passage data were analyzed as a split-plot design. Supplementation (mainplot) was tested against steer within treatment as an error term. Sampling period and interaction of supplementation $\times$ sampling period were tested against residual error.

Intake was determined on rumen-cannulated steers concurrently with passage rate measures and has been previously described and reported by Judkins et al. (1984). Briefly, total fecal collections were conducted for 5 consecutive days. Bags were replaced every 12 hours and combined into 24-hour collections for each steer. Feces were weighed, mixed, and a subsample of 500 g obtained. Organic matter intake was estimated using fecal organic matter output and diet in vitro organic matter indigestibility from two-stage in vitro digestion. Statistical analysis followed the same procedure as rate of passage parameters.

Animal performance was evaluated using 102 yearling, crossbred Angus $\times$ Hereford heifers (average initial weight of 242 kg). Heifers were randomly allotted to the same treatment groups as the cannulated steers, except long-stem alfalfa hay was fed rather than pelleted alfalfa. Supplements were fed every other day from 12 January 1983 to 29 April 1983 (107 d on feed). Heifers were weighed at the beginning and end of the trial and average daily gain during this time period was analyzed as a completely randomized design using initial weight as a covariate in the analysis of variance. Supplementation was the only independent variable in the analysis of variance. The least significant difference procedure was used to compare means when a significant F test was observed (Steel and Torrie 1980).

Trial 2

In January 1984, rumen-cannulated steers (average weight of 340 kg) were randomly allotted to the same treatments as in Trial 1. The alfalfa supplement differed slightly in composition from that used in Trial 1, such that the ALF group received 4.3 kg/hd of ground, pelleted alfalfa. Cottonseed cake was the same as fed in Trial 1. Supplements were fed individually every other day for a 5-d adjustment period. All steers had been grazing the pasture for 2 weeks before supplementation. Chemical composition of supplements and the diet selected by esophageal-fistulated steers is shown in Table 1. Esophageal samples were collected from 3 unsupplemented steers on 3 consecutive days. Esophageal-fistulated steers were unsupplemented because previous work indicated no difference in diet selected (Judkins et al. 1985) between supplemented and unsupplemented steers. On supplementation days at 0800 h, steers were tethered where they grazed and fed, while control steers were restricted from grazing.

On the third supplementation day, an intraruminal dose of 200 ml Co-EDTA containing 499.4 mg Co was administered immediately after feeding to estimate fluid dilution rates (Uden et al. 1980). Rumen samples (250 ml) were collected prior to dosing (0 h) and at 4, 8, 11, and 24 h thereafter. For each rumen sample, pH was determined with a combination electrode immediately after removal. Samples were strained through 4 layers of cheesecloth, acidified with 1 ml of 7.2 N H_2SO_4/100 ml of strained fluid and frozen in plastic bags.

In the laboratory, rumen samples were thawed at room temperature and centrifuged at 10,000 $\times$ g for 10 min. The supernatant fraction was analyzed for ammonia by the phenol-hypochlorite procedure of Broderick and Kang (1980) and for Co by atomic absorption spectroscopy with an air/acetylene flame. After an additional centrifugation at 10,000 $\times$ g with addition of an internal standard, volatile fatty acid concentrations were analyzed by gas chromatography as described by Goetsch and Galyean (1983).

Rumen fluid dilution rate was calculated by regressing the natural logarithm of Co concentration on time postdosing (0-h sample not included). Fluid volume was estimated by dividing the dose by the extrapolated concentration at 0 h. Turnover rate was calcu-

lated by multiplying rumen volume by the fractional equivalent of dilution rate.

Data for Trial 2 were analyzed within time of sampling as a completely randomized design with the main effect of treatment. The least significance difference procedure was used to compare means when a significant F value was obtained from the analysis of variance (Steele and Torrie 1980).

Results and Discussion

Trial 1

Initial weight of heifers (Table 2) did not differ ($P > .10$) among treatments; however, supplementation increased ($P < .001$) average

Table 2. Least square means and standard errors for initial weight, final weight, and average daily gain of heifers supplemented with long-stem alfalfa hay (ALF), cottonseed cake (CSC) or no supplement (CON) while grazing blue grama rangeland.

| Item | Treatment | | | SE[a] |
	ALF	CSC	CON	
Initial weight, kg	239.9	242.9	242.8	5.7
Final weight, kg	264.5[b]	268.8[b]	240.0[c]	6.0
Average daily gain, kg/d	.23[b]	.24[b]	−.03[c]	.02
Animals/treatment	34	34	34	

[a]Standard error of least squares means.
[b,c]Row means with different superscripts differ ($P < .001$).

daily gains (ADG) and final weights. Although both supplemented groups gained weight, heifers receiving no supplemental feed lost weight (ADG = −.03 kg/d). Daily gain did not differ ($P > .10$) between supplemented heifers (ALF = .23 kg/d vs CSC = .24 kg/d). These results agree with work of others at Fort Stanton Experimental Ranch using cottonseed cake (Parker et al. 1974), as well as work by others comparing oilseed meal cakes and alfalfa supplements (Clanton 1982, Smith 1981).

The interaction of supplementation $\times$ sampling date was not significant for intake, passage rate, and fill estimates (Table 3). Forage intake of rumen-cannulated steers based on total fecal collections was not influenced by supplementation (Judkins et al. 1985). Total intake was higher ($P < .05$) in ALF steers than in CSC steers, which were higher than CON steers. Because forage intake did not differ among treatments, increases in total intake reflect addition of supplements rather than associative effects.

Passage rate estimates were not influenced ($P > .10$) by supplementation. However, passage rate tended to be faster in steers fed ALF (greater total intake), than in steers fed CSC or CON. Moreover, total mean retention time was shorter ($P < .10$) for ALF than for CSC or CON steers. The significant positive association between voluntary intake and particulate passage rate reported by others (Campling et al. 1962, Minson 1966, and McCollum and

Galyean 1985) was not noted in this study, but the current data resembled previous reports on supplementation effects. The absence of a significant supplementation effect on passage rate and forage intake may have resulted from a small number of steers and(or) experimental error. Previous work using identical experimental numbers detected significant treatment effects (McCollum and Galyean 1985).

Between sampling dates, however, passage rate and voluntary intake were not positively related. Passage rates were more rapid and total mean retention times shorter ($P > .05$) in March (3.91 %/h, 49.4 h) than February (3.43 %/h, 53.3 h), while total intake tended to be lower in April than in February. Other factors such as gut fill (Ellis 1978) and particle size (Troelsen and Campbell 1968) can influence the relationship between passage rate and intake, which may be the case in sampling period results from the present study.

Previously reported data on diet composition (Judkins et al. 1985) showed increases in dietary forb content (68.2% to 78.8% forbs, February to March, respectively) caused a rise in dietary crude protein, soluble nitrogen and digestibility. Legume-type forages (i.e., forbs) tend to fragment easily during comminution and to pack more densely in the digestive tract, thereby increasing gut fill (Troelsen and Campbell 1968). Additionally, forbs have a more rapid rate of digestion and increased passage compared with grasses (Kothmann 1980, Poppi et al. 1980). The increases noted in particulate passage rate and gut fill between February and March may reflect dietary shifts in grasses and forbs.

The reason for the discrepancies between increasing particulate passage and slightly lower intake is not apparent. Many factors may have been involved. However, the occurrence of a snow storm (50.0 cm snow) at approximately 60 h postdosing and early termination of fecal sampling (96 h) may have led to overestimation of particulate passage compared with actual values. Conversely, behavioral changes, including increases in time spent grazing, have been associated with approaching weather fronts (Smith and Malechek 1974). Both of these situations will result in conditions which cause fluctuations in passage rate. Marker-based estimates of particulate movement may be erroneous under changing intake conditions (Morgan et al. 1976), thus, rate of passage results may be environmentally related.

Trial 2

Rumen ammonia was not different ($P > .10$) except at 11 h post-supplementation when the CSC ammonia levels were higher ($P < .05$) than ALF or CON levels (Table 4). At supplementation (0 h), rumen ammonia levels were similar for all 3 groups; however, at 4 h post-supplementation, a slight increase was noted in the 2 supplemented groups. Rumen ammonia during all time periods except at 4 h for CSC steers was below the 5 mg/100 ml requirement suggested by Satter and Slyter (1974) as optimum for microbial protein synthesis. Forage available crude protein level [4.9%,

Table 3. Total and forage intake, particulate passage rate, rumen retention time and intestinal transit time of steers supplemented with ground pelleted alfalfa (ALF) cottonseed cake (CSC) or no supplement (CON) while grazing blue grama rangeland.

| Item | Treatment | | | | Sampling period | | |
	ALF	CSC	CON	SE[a]	February	March	SE[a]
Steer weight, kg	274	246	249	—	251	263	—
Forage intake, g/kg body weight[b]	7.7	9.6	10.8	1.1	9.8	8.9	.44
Total intake, g/kg body weight[b]	14.1[c]	12.9[d]	10.8[e]	.60	13.1	12.1	.46
Particulate passage rate, %/h	4.29	3.35	3.36	.32	3.43[c]	3.91[d]	.13
Gastroinestinal dry matter fill, g/kg body weight	11.2	12.8	12.7	1.4	11.9	12.5	.4
Total mean retention time, h	45.8	54.8	53.4	2.75	53.3[c]	49.4[d]	1.2
Intestinal transit time, h	17.2	18.0	16.8	1.64	17.3	17.4	.6

[a]Standard error of the mean, n = 4.
[b]Organic matter basis (previously reported, Judkins et al. 1985).
[cde]Row means with different superscripts differ ($P < .05$).

Table 4. Rumen ammonia and pH of steers grazing blue grama rangeland and receiving either alfalfa pellets (ALF), cottonseed cake (CSC) or no supplemental feed (CON), Trial 2.

Time post-supplementation	Ammonia (mg/100ml)				pH			
	ALF	CSC	CON	SE[a]	ALF	CSC	CON	SE[a]
0	2.9	2.0	1.5	.78	6.7	6.4	6.3	.19
4	3.7	6.1	1.3	3.33	5.8	6.0	6.0	.21
8	1.4	4.1	1.4	1.27	5.9	6.2	6.2	.20
11	0.9[b]	2.9[c]	1.3[b]	.43	5.8	6.1	6.1	.18
24	2.8	3.6	1.6	.95	6.4	6.2	6.2	.20

[a]Standard error of the mean, n = 3.
[bc]Row means with different superscripts differ (P<.05).

(total N - sinoluble unavailable N) $\times$ 6.25] supports the low rumen ammonia concentrations observed in this study. Kellaway and Leibholz (1983) attributed low rumen ammonia concentrations to low rates of production or high rates of utilization. As a result, studies evaluating ammonia concentration and in situ fiber digestion have had mixed results (Mehrez et al. 1977, Grummer et al. 1984).

The absence of a consistent ammonia-N response due to supplementation contrasts sharply with results of others. Wagner et al. (1983) and McCollum and Galyean (1985) noted higher rumen ammonia-N levels in protein-supplemented steers. McCollum and Galyean (1985) noted peak concentrations 1 h after supplementation. In the current study a slight trend was noted for CSC and ALF rumen ammonia levels to increase between 0 and 4 h after supplementation. Therefore, it is likely that peak ammonia levels were not detected by the sampling scheme utilized in our study.

Rumen pH was not influenced (P>.10) by supplementation (Table 4), but tended to decline after supplementation in all treatment groups. Wagner et al. (1983) and McCollum and Galyean (1985) also found no differences in rumen pH as a result of protein supplementation. Addition of finely ground roughages and(or) concentrate feeds has been noted to reduce ruminal pH (Van Soest 1982). The current data and data by others (Wagner et al. 1983, McCollum and Galyean 1985) indicate no decrease in pH from addition of cottonseed meal or ground alfalfa. Values in this study ranged from a low of 5.8 to a high of 6.7. Mertens (1977) suggested that fiber digestion is inhibited at a pH lower than 6.7. If this supposition is correct, the effects of pH on fiber digestion and subsequent utilization needs to be further evaluated.

Rumen fluid dilution rate, volume, and turnover rate were not different (P>.10) between treatment groups (Table 5). Dilution

Table 5. Rumen fluid, dilution rate, volume and outflow in steers grazing blue grama rangeland receiving either alfalfa pellets (ALF), cottonseed cake (CSC) or no supplemental feed (CON).

Item	Treatment			
	ALF	CSC	CON	SE[a]
Dilution rate, %/h	6.93	7.13	7.29	1.91
Rumen volume, liters	60.0	64.2	56.0	6.43
Turnover rate, liters/h	4.1	4.3	3.8	.4
Steer weight, kg	333	338	350	

[a]Standard error of the mean, n = 3.

rate values are typical of forage diets and similar to the 7.7 %/h reported by McCollum and Galyean (1984) during January 1983 at Ft. Stanton. Other studies have shown that fluid turnover and total fluid volume increase as total intake increases (Grovum and Hecker 1973). Increasing fluid dilution rate may also increase the relative proportions of acetate and butyrate while decreasing propionate (Owens and Isaacson 1977); however, this relationship may not hold over a wide variety of diets (Estell and Galyean 1985). Dilution rate in this study was unaffected by supplementation,

which generally corresponds with responses observed in total VFA and individual acids, although there was an increase in total VFA and proportion of propionate at 8 h post-supplementation for both supplemented groups.

Table 6. Molar proportions of acetate, propionate, butyrate and total volatile fatty acids in the rumen of steers grazing blue grama rangeland receiving alfalfa pellets (ALF), cottonseed cake (CSC) or no supplemental feed (CON).

Item	Time after supplementation (h)				
	0	4	8	11	24
Acetate	------------mol/100 mol------------				
ALF	76.2	73.1	71.3[b]	70.3[b]	73.3
CSC	77.6	75.1	73.5[c]	73.4[c]	74.8
CON	76.4	76.3	75.9[d]	76.2[d]	75.5
SE[a]	.7	1.5	.6	.7	.8
Propionate					
ALF	17.1	19.1[b]	20.5[b]	21.1[b]	17.8
CSC	16.2	15.8[c]	17.3[c]	17.3[c]	18.0
CON	16.5	16.2[c]	15.4[d]	15.6[d]	16.8
SE[a]	.5	.7	.6	.3	.5
Butyrate					
ALF	6.8	7.7	8.2	8.6	9.0
CSC	6.2	9.1	9.2	9.3	7.2
CON	7.1	7.5	8.7	8.2	7.6
SE[a]	.3	1.1	.7	.6	.8
Total	------------mM$_b$------------				
ALF	93.3	116.6	113.4[b]	121.3	109.4
CSC	105.8	73.3	109.8[b]	123.3	111.6
CON	99.6	94.4	75.9[c]	103.6	113.9
SE[a]	10.9	16.8	7.8	8.9	7.3

[a]Standard error of the mean, n = 3.
[bcd]Means with different superscripts differ (P<.05).

Molar proportions of acetate and propionate (Table 6) differed (P<.05) among supplementation groups at 8 and 11 h after supplementation. At 8 h, acetate was lowest (P<.05) in ALF steers (71.3 mol/100 mol), intermediate in CSC steers (73.5 mol/100 mol) and highest (P<.05) in CON steers (75.9 mol/100 mol). Propionate was highest (P<.05) in ALF steers (20.5 mol/100 mol), intermediate in CSC steers (17.3 mol/100 mol) and lowest (P<.05) in CON steers (15.4 mol/100 mol). Butyrate proportions were not altered by supplementation. Total volatile fatty acid concentrations differed (P<.05) only at 8 h after supplementation, at which time steers supplemented with ALF (113.4 mM) and CSC (109.8 mM) had similar total volatile fatty acid concentrations while CON steers (75.9 mM) had lower (P<.05) values.

The shift in acetate: propionate observed as a result of ALF and CSC supplementation may have an impact on energy metabolism of the grazing ruminant. Specific information on rates of production and absorption of VFA would be needed to determine the extent to which energy metabolism was influenced. Research by other workers concerning VFA concentrations as influenced by

supplementation is not conclusive. Wagner et al. (1983) and Topps et al. (1965), working with cattle grazing dormant rangeland, reported no differences in molar proportions of acetate and propionate due to protein supplementation. McCollum and Galyean (1985), working with cottonseed meal-supplemented steers fed prairie hay, noted a shift from acetate to propionate but no difference in total VFA concentration.

The extent to which protein supplementation stimulates livestock performance and digestive processes remains uncertain in light of the current results. Ruminal escape of supplemental protein and subsequent metabolic stimulation of intake may be a factor involved in responses to protein supplementation. The current data would suggest that supplemental protein did not increase heifer weight gains through associative effects that caused increased passage rates and forage intake. Fermentation measurements indicate some stimulatory effects of protein supplements. Low rumen ammonia concentrations not consistently stimulated by supplementation coupled with low available forage protein imply that rate of ammonia production is low or that utilization and incorporation of additional ammonia into microbial protein and(or) absorption across the rumen wall is rapid. It should be noted, however, that the sampling scheme employed in this study was most likely inadequate to detect peak ammonia concentrations following supplementation, and further study is warranted. The slight shift toward propionate production may improve metabolic energy efficiency, but the exact role of shifts in VFA proportions needs clarification. It is clear, however, that further study of rumen fermentation patterns is needed to evaluate the effects of such fermentation shifts on animal metabolism and resulting performance.

Overall, it appears that protein supplementation of cattle on dormant blue grama rangeland can improve livestock performance. Fermentation shifts may, in part, be responsible for improved performance. Associative effects, while noted in other studies, were not an apparent factor with the current data. The data suggest that improved livestock performance with protein supplementation may be a result of meeting dietary requirements and not enhanced forage intake.

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