

Forb and shrub effects on ruminal fermentation in cattle

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Abstract

One experiment involving steers fed low-quality grass diets singly and mixed with native forbs, native shrubs, or alfalfa (*Medicago sativa* L.) was conducted to compare the influence of these diets on ruminal fermentation. Native forbs used in our study were a 50:50 mixture of scarlet globemallow (*Sphaeralcea coccinea* Nutt.) and leatherleaf croton (*Croton pottsii* Lam.); native shrubs were a 50:50 mixture of fourwing saltbush (*Atriplex canescens* [Pursh.] and mountain mahogany (*Cercocarpus montanus* Raf.). Neither passage rate of indigestible neutral detergent fiber nor fluid passage rate differed ($P > .10$) among the 4 diets. Ruminal pH did not differ ($P > .10$) among diets, and ruminal ammonia concentrations differed ($P < .10$) inconsistently among diets, depending on time after feeding. Likewise, total ruminal volatile fatty acid (VFA) concentrations did not differ ($P > .10$) among diets. Except for butyrate [less ($P < .05$) with alfalfa], proportions of individual VFA showed little difference among diets. Based on these data, adding forbs or shrubs with low-quality forage diets appears to elicit few changes in ruminal digesta kinetics and fermentation patterns compared to including alfalfa hay.

Key Words: rangelands, ruminants, nutrition, forages, native shrubs

There is considerable evidence that including forbs and shrubs in cattle diets improves cattle performance during periods when grasses are dormant and low in quality (Holechek et al. 1989a). Several studies reviewed by Holechek et al. (1989a) show that leaves from forbs and shrubs contain more protein, phosphorus, and cell solubles than do grasses at comparable stages of maturity. In recent digestion trials with cattle (Arthun et al. 1992), goats (Hunez-Hernandez et al. 1989), and sheep (Rafique et al. 1992), forage intake and nitrogen retention did not differ between palatable range shrubs and alfalfa (*Medicago sativa* L.) hay fed mixed into low-quality grass diets. However, these studies did not evaluate comparative ruminal fermentation characteristics of the shrub and alfalfa diets.

Our objectives were to determine passage rate of indigestible, fiber, fluid passage rate, ruminal pH, ruminal ammonia (NH_3) concentrations, and ruminal volatile fatty acid (VFA) proportions in beef steers fed a low-quality grass diet singly and in combination with forbs, shrubs, and alfalfa hay. Forbs and shrubs used in our study are common range components in New Mexico, and their use by cattle is well documented. Results from our study should provide a better understanding of how native range forbs and shrubs influence range cattle nutritional status.

Materials and Methods

Four Angus \times Hereford steers (average body weight 315 kg), fitted with 10.2-cm ruminal cannulas, were used in a 4×4 Latin square experiment to evaluate ruminal fermentation and digesta kinetics when native forbs, native shrubs, and alfalfa were added to a basal diet of blue grama (*Bouteloua gracilis* [H.B.K.] hay (blue grama; 1.21% N) and barley straw (*Hordeum vulgare* L.; .56% N). The basal diet was ground to pass a 2.5-cm screen and to provide a N content of 1.04% on a dry matter basis (70% blue grama, 30% straw). Forbs were a 50:50 mixture of actively growing scarlet globemallow (*Sphaeralcea coccinea* Nutt.) and leatherleaf croton (*Croton pottsii* [Klotzsch] Mudl. Arg.); shrubs were a 50:50 mixture of current year growth of fourwing saltbush (*Atriplex canescens* [Pursh.] and mountain mahogany (*Cercocarpus montanus* Raf.). Mixtures (ground to pass a 2.5-cm screen) were used because of poor acceptance by cattle of diets comprised entirely of forbs and shrubs. Forbs, shrubs, or alfalfa (ALF) were mixed with components of the basal diet so that all 4 diets were isonitrogenous. Ingredient and chemical composition of diets used are shown in Table 1. Periods were 15 days, with collections occurring the last 5

Table 1. Ingredient and chemical composition of blue grama-barley straw diets with added alfalfa (ALF), forbs, or shrubs fed to beef steers.

Item	Diets ^a			
	Basal	Basal + ALF	Basal + forbs	Basal + shrubs
Ingredient ^b	----- (%) -----			
Blue grama hay	70.0	29.0	26.0	26.0
Barley straw	30.0	58.0	54.0	54.0
Alfalfa hay	—	13.0	—	—
Forbs	—	—	20.0	—
Shrubs	—	—	—	20.0
Analysis ^c				
DM	92.4	92.4	92.5	92.4
OM ^d	90.0	90.0	90.0	90.0
CP ^d	6.5	6.5	6.5	6.5
NDF ^d	72.9	69.1	67.7	68.9
ADF ^d	47.0	44.8	43.9	43.8
Acid detergent insoluble nitrogen ^d	0.22	0.20	0.22	0.22

days. Steers were housed individually in an uninsulated barn (0.69 \times 1.98 m pens) with free access to water, but no salt was provided. Intake was limited to 1.5% (OM basis) of body weight. Krysl et al. (1987) reported that OM intake by steers grazing dormant blue grama range averaged 1.49% of body weight.

Steers were individually fed their appropriate diet once daily (0700). Fecal bags were used to collect total fecal output, and bags

were changed twice daily. Feces from each steer were mixed thoroughly each day, and a 10% subsample was dried at 50° C in a forced-air oven, ground to pass a 2-mm screen, and composited by steer within period.

On day 1 of the collection period, 200 ml of Co-EDTA (Uden et al. 1980) were dosed into the rumen just before the morning feeding. Pond et al. (1981) reported a dose × meal interaction; therefore, all animals were dosed at the same time relative to feeding for each period. Ruminal samples (250 ml) were taken at 4, 8, 12, 24, 32, and 36 hours after dosing. The pH of digesta samples was measured (combination electrode), and samples were strained through 8 layers of cheesecloth. Strained ruminal fluid was acidified with 7.2N H₂SO₄ (1 ml/100 ml), frozen, and later analyzed for Co, NH₃, and VFA. On day 5, at 4 hours after-feeding, the rumen of each steer was hand-evacuated, contents were weighed, mixed thoroughly, and a subsample taken, dried at 50° C, ground to pass a 2-mm screen, and retained for later analyses.

Duplicate 8-cm × 16-cm nylon bags (pore width 26 ± 6 μm, length 42 ± 5 μm) were suspended in the rumen on day 2 of the collection period to estimate in situ digestion. Nylon bags were filled with a 3-g sample (ground to pass a 2-mm screen) of the basal diet. Nylon bags devoid of forage served as blanks. All steers received 3 bags per incubation time (duplicate sample of basal diet plus 1 blank). Bags were retrieved after 0, 6, 12, 24, 48, 72, and 96 hours, then rinsed with tap water until rinse water was clear. Samples were dried at 50° C for 48 hours, weighed, and later assayed for residual neutral detergent fiber (NDF), (Goering and Van Soest, 1975).

Laboratory Analyses

Ruminal fluid samples were thawed at room temperature and centrifuged at 10,000 × G for 10 min. Supernatant fluid was analyzed for Co by atomic absorption spectroscopy with an air-plus-acetylene flame (McCollum and Galyean 1985) and for ammonia by the procedure of Broderick and Kang (1980). After adding 2-ethyl-butyric acid as an internal standard, fluid was recentrifuged at 10,000 × G for 10 min, and VFA concentrations were analyzed by gas chromatography (Goetsch and Galyean 1983).

Fluid dilution rates were calculated by regressing the natural logarithm of Co concentrations against time. Ruminal fluid volume was calculated by dividing marker dose by marker concentration in the rumen at 0 hour.

Ruminal fill (collected 4 hours after feeding) and feed indigestible NDF (INDF) contents were determined using procedures described by Krysl et al. (1988). Ruminal fluid inoculum was from 2 steers fed ALF hay. Passage (Kp) of INDF was estimated by dividing INDF intake by INDF ruminal fill; division by 24 yields an estimate of passage per hour.

Statistical Analyses

Analysis of variance was conducted using GLM procedures of SAS (1984). Digesta flow and ruminal fill data were analyzed with a model that included treatment (diets), period, and animal as sources of variation. Preplanned orthogonal contrasts were made between forbs and shrubs. If forbs and shrubs were different ($P < .10$), means were separated by the least significance difference method. If forbs and shrubs did not differ ($P > .10$), they were contrasted with ALF. If no differences ($P > .10$) were observed, forbs, shrubs, and ALF were contrasted with the basal diet. If ALF differed ($P < .10$) from forbs and shrubs, ALF was contrasted with the basal diet. Nonlinear regression analysis was used to analyze in situ nylon bag rate of disappearance data (Mertens and Loften 1980). Percentage NDF remaining at each incubation time and disappearance rate were analyzed with the same model as digesta flow and fill data. Ruminal fermentation measurements (pH, NH₃, and VFA) were analyzed as a split-plot design, with a Latin square

arrangement as the main plot, and time and associated interactions with main-plot factors as the subplot. The Latin square error was used to test main-plot effects, and the residual was used to test sub-plot effects.

Results and Discussion

Passage Rate

Estimates of ruminal INDF passage rate did not differ ($P > .10$) among diets (Table 2). Our values were considerably less than

Table 2. Ruminal indigestible neutral detergent fiber passage and fluid dilution rate in steers fed a low-quality basal forage diet with or without forbs, shrubs, or alfalfa.

Item	Basal diet	Basal + ALF diet	Basal + forbs diet	Basal + shrubs diet	SE ^a
INDF passage, %/hour	1.1	0.9	1.0	1.0	0.10
Particulate turnover time, hour	90.9	111.1	100.0	100.0	2.60
Fluid dilution rate, %/hour	7.0	6.1	6.6	8.1	0.88
Fluid volume, liters	39.1	45.4	38.2	32.3	8.4

^an = 4.

those reported by Krysl et al. (1987), who summarized the results of 20 trials with cattle grazing blue grama rangelands in southcentral New Mexico. In their study, cattle grazing dormant and actively growing rangelands had an average Kp of 3.1%/hour and 3.8%/hour, respectively. The lower passage values reported in our study may reflect forage differences, but more likely are a function of different techniques.

Rare-earth labeling techniques used to estimate particulate passage typically yield faster passage rates than techniques like ours that rely on measurement of indigestible forage components. For example, Del Curto et al. (1990) reported indigestible ADF-based passage estimates of approximately 2%/hour in steers fed tallgrass-prairie forage plus supplement (1.5% of body weight); these values are intermediate between our INDF-based estimate and those of Krysl et al. (1987). Rare earth-labeling techniques like those used by Krysl et al. (1987) are subject to migration of the marker from originally labeled particles to small feed particles and bacteria (Combs et al. 1992). Hence, faster passage rate estimates might be expected with rare-earth-labeled forage than with a technique based on fill of an indigestible forage component. In addition, our technique assumes steady-state conditions (constant ruminal fill), which is not likely the case in limit-fed ruminants fed once daily.

Fluid dilution and volume did not differ ($P > .10$) among treatments (Table 3). Fluid dilution rate (%/h) was similar to values reported by McCollum and Galyean (1985) in steers fed prairie hay (1.69% of body weight), but less than in other studies where steers consumed similar diets, but at higher intakes (Funk et al. 1987).

Ruminal Ammonia and pH

Treatment means for NH₃ concentration were analyzed within sampling times because of a treatment by sampling time interaction ($P < .10$). Differences among treatments were noted at 4 hours after feeding, with less ($P < .05$) NH₃ with the ALF diet than for the basal diet (Table 3). At 8 hours after feeding, the shrub diet had a lower ($P < .10$) NH₃ concentration than the other 3 diets. Ruminal NH₃ concentrations peaked 24 hours after feeding for the basal diet, 8 hours for basal plus forbs and 12 hours for the ALF and shrub diets. Ruminal NH₃ concentrations ranged from 2.3 to 6.2 (mg/100 ml), which agrees with reported values for cattle consuming similar diets (Funk et al. 1987, Krysl et al. 1987).

Table 3. Ruminal ammonia concentration (mg/100 ml) in steers fed a low-quality basal forage with or without alfalfa, forbs, or shrubs.

Sampling time (Hour)	Diet ^a				SE ^f
	Basal	Basal + ALF	Basal + forbs	Basal + shrubs	
	----- (mg/100 ml) -----				
0	4.6	5.0	3.1	3.2	.7
4	5.2 ^d	2.9 ^e	4.2 ^{de}	4.2 ^{de}	.8
8	5.1 ^b	6.1 ^b	5.4 ^b	2.3 ^c	.7
12	4.8	6.2	5.2	5.2	.8

^aBasal = 70% blue grama hay, 30% barley straw, ALF = alfalfa, forbs = 50:50 mixture of scarlet globemallow and leatherleaf croton, shrubs = 50:50 mixture of fourwing saltbush and mountain mahogany.

^{b,c}Row means that do not have common superscripts differ ($P < .05$).

^{d,e}Row means that do not have common superscripts ($P < .10$).

^fn = 4.

Slyter et al. (1979) suggested a minimum of 2.2 mg/100 ml of NH₃ for optimum microbial protein synthesis. Maximum microbial growth, however, required 3 to 5 mg/100 ml (Satter and Slyter 1974). Ruminal NH₃ concentrations in the present experiment appear to be within the range for optimum microbial growth. Because of experimental constraints (e.g., fixed intake and isonitrogenous diets), large fluctuations in NH₃ concentrations were not anticipated.

Ruminal pH did not differ ($P > .10$) among diets. Because no treatment by sampling time interaction was detected ($P > .10$), means were pooled across sampling time. Ruminal pH had an overall mean of 6.6, which agrees closely with previous research for cattle consuming similar diets (McCullum et al. 1985, Krysl 1986, Funk et al. 1987, Caton 1987, Freeman 1987). Hoover et al. (1984) reported a pH of 6.5 was optimal for fiber and OM digestion. A generally accepted range of 6.2 to 7.0 for grazing ruminants has been suggested by Ørskov (1982), with pH values below 6.2 resulting in inhibited cellulolytic bacterial growth. Hence, the pH values in our study fall within the optimum range for OM digestion and microbial growth.

Ruminal VFA

Total ruminal VFA concentrations did not differ ($P > .10$) among treatments averaged over all sampling times (Table 4). A

Table 4. Ruminal total VFA concentration and molar proportions of acetate, propionate, butyrate, valerate, isovalerate, and isobutyrate in steers fed a low-quality basal forage with or without alfalfa, forbs, or shrubs.

Item	Diet ^a				SE ^f
	Basal	Basal + ALF	Basal + forbs	Basal + shrubs	
Total, mM ^e	67.0	67.0	64.9	64.5	4.6
	----- mol/100 mol -----				
Acetate ^e	72.4	73.4	72.4	72.7	.5
Propionate ^e	17.9	18.3	18.3	18.0	.4
Butyrate ^e	8.0 ^d	6.7 ^c	7.6 ^d	7.7 ^d	.2
Valerate ^e	.41	.45	.43	.43	.03
Isovalerate ^e	.65	.58	.60	.64	.08
Isobutyrate ^e	.58	.58	.56	.54	.06

^aBasal = 70% blue grama hay, 30% barley straw, ALF = alfalfa, forbs = 50:50 mixture of scarlet globemallow and leatherleaf croton, shrubs = 50:50 mixture of fourwing saltbush and mountain mahogany.

^{b,c,d}Row means that do not have common superscripts differ ($P < .05$).

^eValues are means averaged over 7 times (0, 4, 8, 12, 24, 32, and 36 hours) after feeding ($P > .10$); no treatment × sampling time interaction.

^fn = 28.

treatment × sampling time interaction was not detected ($P > .10$). Rafique (1988) also found no treatment effects on total VFA when sheep were fed the same diets as in our study. Freeman (1987), who fed steers a diet similar to the one in the present study [prairie hay (*Agropyron* spp.); 5.9% CP], reported no treatment effects on total VFA when prairie hay was supplemented with 20 or 40% CP supplements. Pordomingo (1989) reported that total VFA concentrations were not altered when steers grazing summer blue grama rangeland were supplemented with whole-shelled corn. Holechek et al. (1989b) observed no differences in in vitro total VFA concentrations between grasses, forbs, and shrubs (collected from rangeland in eastern New Mexico) when incubated with inoculum from steers consuming a diet of prairie-grass hay.

Ruminal proportions of acetate did not differ ($P > .10$) among treatments. Greater proportions of acetate are often associated with decreased forage quality because acetate is an end-product of cell wall fermentation (Van Soest 1982). Similarly, Rafique (1988) reported no differences in acetate proportions with sheep fed the same diets used in our experiment. Ruminal propionate molar proportions also did not differ ($P > .10$) among treatments. Propionate tends to increase relative to acetate as forage quality increases because propionate is an end-product of cell soluble fermentation. Legumes and forbs typically contain more cell soluble than do grasses; however, in our study, the slightly greater cell wall content of the basal forage than of mixtures was evidently not enough to alter molar proportions of acetate or propionate.

Basal plus ALF had the least ($P < .01$) butyrate molar proportions, with no differences among the other 3 diets. Butyrate, like propionate, is associated with higher forage quality, (primarily greater CP; Topps et al. 1965, McCollum et al. 1985, Krysl 1986, Pordomingo 1989). Decreased molar proportions of butyrate in the ALF diet are perplexing. Rafique (1988) found butyrate levels to be equal among the same diets when fed to sheep. Minor acids (valerate, isovalerate, isobutyrate; Table 4) did not differ among treatments. Caton (1987) reported no differences in minor VFA in protein supplemented and nonsupplemented steers grazing dormant blue grama range.

Digestibility

In situ rate of NDF disappearance from nylon bags did not differ ($P > .10$) among treatments (Table 5). These results agree with

Table 5. In situ NDF disappearance and rates of disappearance of basal forage at various incubation times in steers fed a low-quality basal forage with or without alfalfa, forbs, or shrubs.

Incubation time (Hour)	Diet ^a				SE ^f
	Basal	Basal + ALF	Basal + forbs	Basal + shrubs	
	----- (units) -----				
6	90.7	90.3	92.6	81.4	4.9
12	91.6 ^b	87.8 ^{bc}	87.0 ^{bc}	78.3 ^c	3.4
24	78.4	73.7	75.8	76.6	5.0
48	63.0	47.8	60.1	54.5	6.7
72	54.6	51.0	47.1	41.9	6.5
Disappearance rate, %/hour	3.7	3.1	3.0	2.8	.57

^aBasal = 70% blue grama hay, 30% barley straw, ALF = alfalfa, forbs = 50:50 mixture of scarlet globemallow and leatherleaf croton, shrubs = 50:50 mixture of fourwing saltbush and mountain mahogany.

^{b,c}Means in the same row with different letters in their superscripts differ ($P < .05$).

^dn = 4.

McCullum and Galyean (1985), who observed no overall differences among in vitro rates of DM disappearance with change in percentage of dietary forbs with beef steers grazing blue grama

range. These workers did note, however, that diets that had more forbs (17 vs 77%) were digested to a greater extent at 4 hours incubation. In our data, in situ NDF remaining at 12 hours was greater ($P < .05$) for the basal diet (91.6%) than for basal-plus-shrub diet (78.3%); ALF and forb diets were intermediate.

No differences in NDF remaining were observed at other incubation times. No differences ($P > .10$) were observed for in vivo DM or OM digestibilities among diets (Arthun et al. 1992). In vivo OM digestibility values were 63.8, 56.8, 63.2, and 63.5 for basal, ALF, basal-plus-forbs and basal-plus shrubs diets, respectively.

Conclusions

Scarlet globemallow, leatherleaf croton, fourwing saltbush, and mountain mahogany are important botanical components on many ranges in New Mexico and other western states. Consumption by cattle of these plants, particularly when grasses are dormant, is well documented. A recent study (Arthun et al. 1992) showed that these plants are excellent sources of N for cattle consuming low-quality grass diets. In our study, including these forbs and shrubs in low-quality grass diets had a similar effect on ruminal fermentation as did inclusion of alfalfa. No toxicity problems were observed in any of our trials. Passage rate of indigestible NDF, fluid passage rate, ruminal ammonia concentration, ruminal pH, NDF digestion rate, and total VFA concentration (also molar proportions) were used as measures of ruminal fermentation in our study.

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