INFLUENCE OF SOYBEAN MEAL AND SORGHUM GRAIN SUPPLEMENTATION ON INTAKE, DIGESTA KINETICS, RUMINAL FERMENTATION, SITE AND EXTENT OF DIGESTION AND MICROBIAL PROTEIN SYNTHESIS IN BEEF STEERS GRAZING BLUE GRAMA RANGELAND[1,2]

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ABSTRACT

Six beef steers (British × Brahman) cannulated at the rumen, duodenum and ileum (avg wt 334 kg) and three mature steers (British × British) cannulated at the esophagus were used in a replicated 3 × 3 latin square design and fed no supplement (C), .5 kg soybean meal (SBM) or .5 kg steam-flaked sorghum grain (SFS)·head^{-1}·d^{-1} (DM basis) while grazing blue grama rangeland. Periods of the latin square included a minimum of 14 d for adaptation and 11 d for esophageal masticate collection and digesta sampling. In September, October and November, respectively, forage collected by esophageally cannulated steers averaged 74.5, 88.8 and 71.0% grasses; 2.06, 1.53 and 1.77% N and 68.3, 82.6 and 77.1% NDF (OM basis). Forage OM, ADF, NDF and N intakes were not affected ($P > .10$) by treatment, but total N intake was greater ($P < .05$) for SBM vs C and SFS treatments. No differences ($P > .10$) were detected among treatments in OM, NDF, ADF and N digestibilities in the rumen, small intestine or hindgut, but total tract OM digestibility was greater ($P < .10$) for SBM and SFS than for C, and total tract N digestibility was greater ($P < .10$) for SBM than for C or SFS. Duodenal ammonia N flow was greater ($P < .05$) when SBM was fed that when SFS and C were fed, but microbial N and non-ammonia, non-microbial N flows and microbial efficiency were not altered by treatment. Likewise, ileal N flow was not affected ($P > .10$) by treatment. Particulate passage rate, gastrointestinal mean retention time, forage in vitro OM disappearance and in situ rate of forage NDF digestion also were not affected ($P > .10$) by treatments. Ruminal fluid volume was greater ($P < .05$) for SFS vs SBM and C treatments, but no differences were noted in fluid dilution rate. Ruminal fluid ammonia concentration was greater ($P < .05$) when SBM was fed than when SFS and C were fed (13.5, 9.9 and 8.7 mg/dl, respectively), whereas pH and total VFA concentrations were not different ($P > .10$). Proportion of acetate in ruminal fluid was less ($P < .10$) for SBM and SFS than for C. Small amounts of supplemental SBM and SFS had little effect on forage intake, ruminal fermentation and site of digestion but both increased total tract OM digestion in steers grazing blue grama rangeland.

(Key Words: Rangelands, Beef Cattle, Soybean Oilmeal, Sorghum, Rumen Digestion, Microbial Protein.)

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Introduction

Providing protein and energy supplements to range cattle during periods of late summer or early fall, when forages are declining in nutritive value, is a common practice among livestock producers. Live weight gains, intake and digestibility often increase as a result of feeding small amounts of high-protein meals to cattle fed low-quality roughages (Lusby et al., 1982; Lusby and Horn, 1983; Guthrie et al., 1984). Forage intake sometimes is increased as a result of protein supplementation, but results are not conclusive (Rittenhouse et al., 1970). Particulate passage can be altered if intake is influenced by protein supplementation (McCollum and Galyean, 1985). In contrast to supplemental protein meals, supplemental grains generally have no effect or tend to decrease forage intake and digestion (Cook and Harris, 1968; Fick et al., 1973). Economically, supplementing low-quality forage with grain would be preferred to using protein meals (Adams, 1986), but differences in nutrients supplied by grain vs protein supplements also must be considered. The objective of the present study was to evaluate effects of soybean meal (SBM) and steam- flaked sorghum grain (SFS) supplementation on forage intake, digestibility, ruminal fermentation, digesta kinetics and microbial protein synthesis in cattle grazing dormant blue grama rangeland.

Experimental Procedure

Study Area. The experiment was conducted at the Clayton Livestock Research Center in northeastern New Mexico. Vegetation in study pastures was dominated by blue gram (*Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*) and tobosa grass (*Hilaria mutica*). Other important grass species present were bottlebrush squirrletail (*Sitanion hystrix*), sand dropseed (*Sporobolus cryptandrus*), sideoats grama (*Bouteloua curtipendula*), silver bluestem (*Bothriochloa saccharoides*), vine mesquite (*Panicum obtusum*), western wheatgrass (*Agropyron smithii*) and threeawns (*Aristida* spp.). Important forbs were scarlet globemallow (*Sphaeralcea coccinea*), Wright verbena (*Verbena wrightii*), locoweed (*Astragulas* spp.) and kochia (*Kochia scoparia*).

Between September 1 and November 30, 1985, approximately 20 cm of precipitation were recorded; all precipitation occurred in September (114 mm) and October (86 mm). Daily temperature ranged from mean values of 24.4 to 9.4°C in September, 19.4 to 3.9°C in October and 12.2 to −3.9°C in November. A killing frost occurred on September 29, 1985.

Sample Collection Periods. Three periods, each 11 d long, were conducted from September 19 to 29 during early autumn dormancy, October 20 to 30 (mid-autumn dormancy) and November 17 to 27, 1985 (late autumn dormancy). September and October collection periods were conducted in a 16-ha pasture; the November collection was conducted in a 12-ha pasture similar in botanical composition to the 16-ha pasture. Within each sampling period, six steers (British × Brahman cross) cannulated at the rumen, duodenum (T-type cannula) and ileum were used in a replicated 3 × 3 latin square and fed no supplement (C), .5 kg SBM DM daily or .5 kg SFS DM daily. The amount of SBM fed was similar to the amount reported by Lusby and Horn (1983); the amount of SFS provided approximately the same amount of supplemental energy as the SBM. Steers were fed supplements in individual buckets on a daily basis at 1000, and a minimum of 14 d for dietary adaptation was allowed before sample collection began in each period. A similar length of adaptation period to supplementation (18 d) was used by McCollum and Galyean (1985). Water and a 1:1 mix of salt and dicalcium phosphate were available free choice. Steers had been used in a previous experiment (Funk et al., 1987a,b) at the Research Center. After the end of the collection periods, steers were switched to their respective treatments and continued to graze the study pasture. In addition, three esophageally cannulated, mature beef steers were allowed to graze the study pasture throughout the trial but were not fed supplement. Judkins et al. (1985) reported that diet selection by cattle grazing blue grama rangeland was not influenced by protein supplementation.

On d 1 to 3 of each period, forage masticate was collected from esophageally cannulated steers fitted with screenwire-bottomed collection bags at sunrise (approximately 0530) and late afternoon (approximately 1730) of each day. Steers were allowed to graze freely, without penning or fasting beforehand, for 30 to 45 min/collection. Following collection, an aliquot of each masticate sample was frozen

for later analysis. Remaining masticate was composited across steers and collection days. A portion of the composited masticate was freeze-dried and used as substrate for in vitro and in situ forage digestibility measurements during each period. Another portion was rinsed with tap water, followed by distilled water to remove salivary contamination, and labeled with Yb (Teeter et al., 1984) for use as a particulate-phase marker.

Ruminally cannulated steers received 30 g/d of chromic oxide-impregnated paper containing approximately 30% Cr_2O_3 by placing paper in the rumen by equal proportions at 0600 and 1800, beginning 5 d before sampling and extending throughout the sampling period. Samples were collected from the duodenum and ileum at 0600, 1200 and 1800 on d 2 through 5 of each sampling period. Approximately 200 ml of digesta were taken from each site at each collection time. In addition, rectal grab samples were taken at 0600 and 1800 on d 7 to 11 of each period. Duodenal, ileal and fecal samples were composited for each steer and frozen.

On d 4 of each period, at 0600, each ruminally cannulated steer was dosed with 200 ml of Co-EDTA (Uden et al., 1980) as a fluid passage marker. Ruminal samples were collected via cannula at 0, 3, 4, 6, 9, 12, 24, 30 and 36 h after dosing (–3, 0, 1, 3, 6, 9, 21, 27 and 33 h after supplementation). Samples taken at –3 through 9 h after supplementation were analyzed immediately for pH using a combination electrode and subsequently were analyzed for ammonia and VFA concentrations. All samples were strained through four layers of cheesecloth, acidified with 1 ml 7.2 *N* H_2SO_4/100 ml strained fluid and frozen.

At 0600 on d 6 of each sampling period, a measured dose of Yb-labeled esophageal masticate was stratified from the ventral to the dorsal part of the rumen of each steer. Because of differences in the quantity of esophageal masticate collected during each period, 267 g labeled forage DM/steer were dosed in September (4.0 g Yb) and October (4.3 g Yb), and 144 g forage DM/steer were dosed in November (2.7 g Yb). Fecal samples were collected at 0, 4, 8, 12, 16, 20, 24, 28, 32, 36, 42, 48, 54, 60, 72, 84, 96, 108 and 120 h after dosing.

Beginning at 1800 on d 8 of each period, 9- × 16-cm nylon bags (pore size 27 × 47 μm) containing approximately 3 g freeze-dried esophageal masticate were suspended in the rumen of each steer for 72, 48, 36, 30, 24, 12, 8, 4 and 0 h. Empty bags served as blanks for each incubation time. After removal from the rumen, bags were rinsed with tap water until water flowing through the bags was clear, after which bags were dried at 60°C.

On d 11 at 1400, approximately 2 liters of ruminal fluid were removed from each steer. Ruminal contents were strained through four layers of cheesecloth and used as inoculum to determine in vitro OM digestibility (**IVOMD**) of esophageal masticate and supplements (Tilley and Terry, 1963). Ruminal bacteria were isolated from remaining fluid after preservation with formaldehyde (25 ml .9% NaCl in 37% formaldehyde/100 ml ruminal fluid) and differential centrifugation (Merchen and Satter, 1983).

Laboratory Analysis. Esophageal masticate samples were freeze-dried[5] and ground to pass a 2-mm screen in a Wiley Mill. Samples were composited across day within steers and analyzed for DM, ash and Kjeldahl N (AOAC, 1985). Neutral detergent fiber, ADF and ADL were analyzed by nonsequential methods of Goering and Van Soest (1970). Nitrogen content was fractioned into soluble N using the .15 *M* NaCl procedure of Waldo and Goering (1979). Acid detergent insoluble N was determined by Kjeldahl N analysis of ADF residue (Goering and Van Soest, 1970). Residue remaining in nylon bags after in situ digestion was analyzed for DM and NDF.

Botanical composition of esophageal masticate was determined using procedures of Sparks and Malechek (1968). Five slides of composited esophageal sample from each steer were mounted and examined (20 fields/slide) at 100× magnification.

Ruminal samples were thawed at room temperature and centrifuged at 10,000 × *g* for 10 min. The supernatant fluid was analyzed for Co by atomic absorption spectroscopy and for ammonia by the phenol-hypochlorite procedure of Broderick and Kang (1980). After addition of 2-ethylbutyric acid as an internal standard, fluid was recentrifuged for 10 mi at 10,000 × *g* and VFA concentrations were analyzed by gas chromatography (Goetsch and Galyean, 1983).

[5]Labconco Freeze Drier, Model 75040, Labconco Corporation, Kansas City, MO.

Fecal samples collected for passage rate estimates were dried at 50°C, ground to pass a 2-mm screen and analyzed for DM and ash. Ytterbium was extracted from fecal samples with EDTA (Hart and Polan, 1984) and measured by atomic absorption spectroscopy with a nitrous oxide/acetylene flame.

Duodenal, ileal and fecal samples were freeze-dried and ground to pass a 2-mm screen. Samples were analyzed for DM and ash (AOAC, 1985), NDF, ADF and N as described previously. Chromium concentration of duodenal, ileal and fecal samples was determined by atomic absorption spectroscopy with a nitrous oxide/acetylene flame using the procedure of Williams et al. (1962). Duodenal samples were analyzed for ammonia N (AOAC, 1985) and nucleic acids (Zinn and Owens, 1986). Isolated freeze-dried bacterial samples also were analyzed for DM, ash, N and nucleic acids.

Calculations. Fecal OM output was calculated by dividing the amount of Cr dosed daily by Cr concentration in fecal OM. Fecal output was corrected for quantity of feces attributable to supplement by multiplying amount of supplement fed daily by the supplement OM indigestibility coefficients (13.1% and 11.5 for SFS and SBM, respectively). Forage intake was calculated by dividing corrected fecal output by forage IVOMD.

Fluid passage rates were calculated by regressing the natural logarithm of Co concentration on time after dosing. Ruminal fluid volume was calculated by dividing Co dose by ruminal Co concentration extrapolated to 0 h. Particulate passage rates were estimated using the one-compartment model described by Pond et al. (1982). Rate of NDF disappearance was calculated using methods described by Mertens and Loften (1980).

Organic matter flow to each segment of the tract was calculated by dividing daily Cr dose by Cr concentration of duodenal, ileal and fecal samples. Individual feed constituent flows were calculated by multiplying feed constituent concentrations (OM basis) by OM flows. The ratio of nucleic acids to N in isolated bacterial cells was used to calculate flow of bacteria to the small intestine. Passage of forage and(or) supplement N (in supplemented groups) was determined by subtracting microbial N and ammonia N from total N passage to the duodenum.

Statistical Analysis. Because a latin square design assumes absence of period × treatment interactions, data were subjected to a preliminary analysis to evaluate the potential for such interactions. To test period effects, a model combining squares was used that included period, treatment, period × treatment, and steer within period × treatment as residual error. Only IVOMD ruminal pH and ammonia, and total tract OM digestibility showed a significant ($P < .05$) period × treatment interaction. Evaluation of period and treatment data for these variables led to the conclusion that the nature of the interaction (changes in magnitude rather than in direction of treatment response) would not preclude averaging treatment effects across periods. Thus, intake, digesta kinetics, digesta flow, digestibility and microbial protein data were analyzed as a 3 × 3 replicated latin square with treatment, square, period within square and steer within square as effects in the model using the GLM procedure of SAS (1982). Time sequence data (ruminal pH, ammonia and VFA) were analyzed by split-plot analysis with treatment as the main plot and time in the subplot (Gill and Hafs, 1971). The split-plot model included effects for steer within square, period within square, treatment, square, steer × period × treatment within square, time, time × treatment, time within steer within square, time within period within square, time × square and residual. Treatment effects were tested with steer × period × treatment within square, and the time × treatment interaction was tested with residual error. Treatment means were separated by the least significant difference method (Snedecor and Cochran, 1980) protected by a preliminary *F*-test.

Results and Discussion

Latin squares are used infrequently in range studies because of potential period effects. Interactions between treatment and period will inflate the error term and decrease sensitivity of treatment comparisons. Use of non-replicated squares will obviate period contrasts. Nevertheless, treatment comparisons should be conservative using a latin square. Replicating latin squares will enhance sensitivity.

Dietary Botanical and Nutrient Composition. During this trial, forage availability should never have limited forage intake. Masticate samples were approximately 78.1% grass and 21.9% forbs over the three sampling periods (Table 1). Blue grama and western

TABLE 1. BOTANICAL AND CHEMICAL COMPOSITION OF ESOPHAGEAL MASTICATE SAMPLES FOR BEEF STEERS GRAZING BLUE GRAMA RANGELAND[a]

Item	Period		
	September	October	November
Botanical composition			
Grasses, %	74.5	88.8	71.0
Forbs, %	25.5	11.2	29.0
Chemical composition			
OM, %	82.4	80.8	80.3
	% of OM		
Total N	2.1	1.5	1.8
Soluble N	.8	.4	.6
Insoluble N	1.3	1.1	1.2
Acid detergent insoluble N	.2	.3	.3
NDF	68.3	82.6	77.1
ADF	38.1	41.8	40.9
ADL	5.7	5.0	5.5

[a]Composition of supplements (DM basis) as percentage of DM, ash and total N, respectively, were: soybean meal, 93.2, 7.1 and 7.6% and steam-flaked sorghum, 91.7, 2.8 and 2.0%.

wheatgrass were the primary grasses consumed by cattle during all sampling periods. Percentage forbs decreased from September (25.5%) to October (11.2%) but increased during November (29%) to levels similar to those in September. Decreased forb consumption during the late growing season has been reported by Funk et al. (1987b) on the same location as the present study.

Masticate N (Table 1) content decreased from September to November as a result of advancing forage maturity. Decreased soluble N and increased acid detergent insoluble N also were noted. Cook (1972) reported that grasses can lose up to 75% of their N during winter dormancy. Funk et al. (1987b) noted that N content of masticate samples was lower during early and late summer dormancy compared with early and late growing seasons. Similarly, Krysl et al. (1987) reported that N content of esophageal masticate samples declined with advancing season on blue grama rangeland in southern New Mexico. As a percentage of total N, soluble N decreased and acid detergent insoluble N increased from September to November. In contrast, McCollum et al. (1985) observed no differences with advancing forage maturity in esophageal masticate levels of soluble N as a percentage of total N for cattle grazing blue grama rangeland. Contents of NDF and ADF were greater during October than during September and November (Table 1), probably as a result of decreased forb consumption during October. Forbs have less cell wall in their OM than do grasses. Contents of ADL in masticate samples from the three periods also reflect minor changes in the proportions of grasses and forbs.

Intake and Passage Rate. Body weights of steers were not affected by treatment (Table 2). Total OM intake and forage OM, NDF and ADF intakes did not differ statistically; however, total OM intake (g/d or g/kg BW) was increased slightly when steers were supplemented with SBM compared with the SFS and C treatments (Table 2). Intake responses may differ with CP content of the forage. Hennessy et al. (1983) reported that intakes of low-quality grass pasture (3.9% CP) were increased more by a protein supplement than by an energy-rich (sorghum) supplement when both were fed at approximately .4% of BW. In contrast, Minson (1982) reported that protein supplements had no effect on intake or digestibility when CP content of forage was 11%. Likewise, Judkins et al. (1985) found no effect of supplemental cottonseed meal fed at approximately .3% of BW on forage intake of steers grazing blue grama rangeland during late winter and early spring when forage CP levels were greater than 8%. A barley supplement at levels ranging from .4 to 1.1% of BW slightly increased voluntary intake of roughages with less than 1% N but decreased intake of roughage with greater than 1% N (Lamb and Eadie, 1979). Improvements from supplemental protein in performance of steers grazing Oklahoma native ranges (Lusby and Horn, 1983) during late summer and early fall, using

TABLE 2. INFLUENCE OF SOYBEAN MEAL (SBM) AND STEAM-FLAKED SORGHUM GRAIN (SFS) SUPPLEMENTATION ON INTAKE BY BEEF STEERS GRAZING BLUE GRAMA RANGELAND

Item	Treatment			SE[a]
	Control	SBM	SFS	
Steer wt, kg	330	337	336	3
	g/d			
Total OM intake	7,723	8,748	8,206	335
Forage OM intake	7,723	8,284	7,720	335
Forage NDF intake	5,906	6,310	5,840	225
Forage ADF intake	3,116	3,339	3,010	126
Total N intake	137[b]	187[c]	149[b]	7
Forage N intake	137	149	140	7
	g/kg BW			
Total OM intake	23.4	26.0	24.4	.9
Forage OM intake	23.4	24.6	22.9	.9

[a]SE = standard error of treatment means (n = 6).

[b,c]Row means that do not have common superscripts differ ($P < .05$).

SBM at a level similar to that in the present study, may be the result of correction of a protein deficiency, or increased forage intake, because forages in that region typically have much lower CP contents during early dormancy than do those noted in the present study.

Total N intake was greater ($P < .05$) in steers supplemented with SBM than in C and SFS steers. Supplements had no effect ($P > .10$) on forage N intake (Table 2). Similarly, Judkins et al. (1985) supplemented cattle grazing dormant blue grama rangeland with either alfalfa pellets, cottonseed cake or no supplement and reported no difference in forage N intake among treatments.

Effects of supplements on both fluid and particulate passage in forage-fed ruminants probably were related to intake responses. Thus, lack of a change in forage intake with supplementation in the present study led to the limited effects of treatments on particulate and fluid passage rates. Particulate passage rates were not affected ($P > .10$) by treatment (Table 3); however, SBM-supplemented steers had a numerically greater passage rate, presumably reflecting their slightly greater total intake. Numerically, intestinal transit time was less in supplemented steers than in C steers, and gastrointestinal mean retention time was less for SBM- and SFS-fed steers than for C steers, but these differences were not significant

TABLE 3. RUMINAL PARTICULATE AND FLUID DIGESTA KINETICS AS INFLUENCED BY SOYBEAN MEAL (SBM) AND STEAM-FLAKED SORGHUM GRAIN (SFS) SUPPLEMENTATION IN BEEF STEERS GRAZING BLUE GRAMA RANGELAND

Item	Treatment			SE[a]
	Control	SBM	SFS	
Particulate passage rate, %/h	3.1	3.4	3.2	.2
Intestinal transit time, h	16.1	14.6	14.1	1.0
Gastrointestinal mean retention time, h	55.3	50.5	52.3	1.5
Fluid passage rate, %/h	9.7	10.4	9.1	.7
Ruminal fluid volume, liters	47.0[b]	42.5[b]	57.5[c]	2.8
Forage in vitro digestibility, %	53.6	54.2	56.0	.9
NDF digestion				
At 72 h, %	54.2	55.3	54.6	1.7
%/h	3.3	3.0	3.0	.6

[a]SE = standard error of the treatment means (n = 6).

[b,c]Row means that do not have common superscripts differ ($P < .05$).

TABLE 4. INFLUENCE OF SOYBEAN MEAL (SBM) AND STEAM-FLAKED SORGHUM GRAIN (SFS) SUPPLEMENTATION ON pH, RUMINAL AMMONIA CONCENTRATION AND VOLATILE FATTY ACIDS IN BEEF STEERS GRAZING BLUE GRAMA RANGELAND[a]

Item	Treatment			SE[b]
	Control	SBM	SFS	
pH	6.3	6.3	6.3	.04
Ammonia, mg/dl	9.9[c]	13.5[d]	8.7[c]	.43
Total VFA, m*M*	100.8	108.0	100.7	2.3
	mol/100 mol			
Acetate	71.4[d]	70.5[c]	70.5[c]	.26
Propionate	17.2	17.4	17.3	.13
Butyrate	8.4[c]	8.8[cd]	9.2[d]	.22
Isobutyrate	1.19	1.22	1.14	.03
Isovalerate	1.01	1.12	1.01	.05
Valerate	.90[c]	.93[d]	.89[c]	.01

[a]Least-squares means averaged across sampling times of –3, 0, 1, 4, 6 and 9 after supplementation.

[b]SE = standard error of treatment means (n = 36).

[c,d]Row means that do not have common superscripts differ ($P < .05$).

(Table 3). Judkins et al. (1987) concluded that protein supplementation did not affect particulate passage in ruminants grazing the blue grama rangeland with a CP greater than 8%. In contrast, Caton et al. (1988) observed increased particulate passage and reduced gastrointestinal mean retention time in cottonseed meal-supplemented beef steers grazing blue grama rangeland compared with nonsupplemented steers. Branine and Galyean (1985) reported no effect of .5 or 1 kg of supplemental corn grain on particulate passage rate in steers grazing blue grama rangeland of similar protein content to that in the present study. In addition, Aitchison et al. (1986) reported no effect of supplemental starch on particulate passage in sheep fed perennial ryegrass hay at two levels of intake.

Fluid passage rate was not affected by treatment (Table 3); this agrees with results of Branine and Galyean (1985) and Henning et al. (1980). Ruminal fluid volume was greater ($P < .05$) in steers supplemented with SFS than in those supplemented with SBM and C; however, reasons for increased volume with SFS are not clear. Errors associated with marker techniques could be responsible. Protein supplementation did not affect ruminal fluid passage rate in steers grazing blue grama rangeland during late winter and early spring (Judkins et al., 1987), but cottonseed meal supplementation increased ruminal fluid passage rate in beef steers fed prairie hay (McCollum and Galyean, 1985).

Forage IVOMD was not affected ($P > .10$) by treatment. These results agree with those of McCollum and Galyean (1985) and Judkins et al. (1985) with regard to protein supplementation and Branine and Galyean (1985) for grain supplementation. Ernst et al. (1975) reported no effect of supplemental protein or energy on DM or OM digestibility in steers consuming native pasture hay.

In situ NDF disappearance of forage at different incubation times was not altered ($P > .10$) by supplementation. Extent of NDF digestion after 72 h of ruminal incubation for supplemented steers was not different ($P > .10$) from that of C steers. Likewise, supplementation had no effect ($P > .10$) on rate (%/h) of NDF digestion. Miller and Muntifering (1985) concluded that depressions in fiber digestibility by dietary starch levels above 60% are mediated primarily through a decrease in the potential extent of digestion. Mertens and Loften (1980) also reported a depressing effect on the potential extent of fiber digestion by incubating starch at levels of 40% or greater in the total diet with forages in vitro, which could reduce forage intake. However, feeding barley-grain supplements at levels less than 30% of the total diet resulted in no effect on OM digestion of hays and straws (Lamb and Eadie, 1979) or of citrus pulp and soybean meal supplements (Silva and Ørskov, 1988) on potential degradability of barley straw.

Ruminal Fermentation. No significant time × treatment interaction was detected in split-plot analysis of ruminal pH, ammonia and VFA concentrations; therefore, treatment means were pooled across time (Table 4).

Ruminal pH was not affected ($P > .10$) by treatment. Low ruminal pH may be associated with depressed fiber digestion when concentrates are fed with roughages (Ørskov and Fraser, 1975). The level of supplemental SFS used in the present study apparently was not great enough to depress ruminal pH. Similarly, Branine and Galyean (1985) reported no effect on pH of supplementing .5 or 1 kg of corn grain to steers grazing blue grama rangeland.

Ruminal ammonia concentrations in SBM-supplemented steers were greater ($P < .05$) than those in SFS and C steers. Ruminal ammonia concentrations also tended to be decreased (8.7 vs 9.9 mg/dl) in SFS-supplemented steers compared with C steers. Supplemental protein has increased ruminal ammonia concentrations in both pen-fed and grazing steers consuming low-quality roughages (McCollum and Galyean, 1985; Caton et al., 1988). In contrast to results of the present study, Branine and Galyean (1985) found that ruminal ammonia concentrations at 7 h after feeding were lower in steers fed supplemental corn than in nonsupplemented controls. Moreover, feeding sorghum grain with protein to steers consuming low-quality grass hay tended to reduce ruminal ammonia concentrations compared with feeding protein alone (Hennessy et al., 1983).

Total concentration of VFA was not affected ($P > .10$) by treatment (Table 4). Ruminal molar proportions of acetate were decreased ($P < .05$) in SBM- and SFS-supplemented steers compared with C steers, but differences were small. No effect of treatment on the molar proportion was observed. Molar proportions of butyrate were increased ($P < .05$) in steers supplemented with SFS compared with C steers, but butyrate proportions in SBM-supplemented steers did not differ from those in C and SFS steers. Proportions of isobutyrate and isovalerate were not affected by treatment, but steers supplemented with SBM had greater ($P < .05$) proportions of valerate than did those fed no supplement or SFS. Changes in molar proportions of VFA with supplements could reflect fermentation of the soluble components of the supplement itself or could reflect general changes in the activity or nature of the microbial population as a result of supplementation.

Increased ruminal molar proportions of propionate as a result of cottonseed meal supplementation were noted by McCollum and Galyean (1985). Likewise, these authors reported that supplemental cottonseed meal resulted in decreased acetate proportions at –3, 0, 1, 3, 6 and 9 h after supplementation and increased butyrate proportions at –3, 1 and 3 h after supplement feeding. Molasses plus urea or corn-fat supplements had no effect on ruminal total VFA concentrations in steers grazing orchardgrass (Rumsey et al., 1971). No differences in VFA proportions as a result of protein supplementation in cattle grazing dormant rangelands were found by Topps et al. (1965) and Wagner et al. (1983). Branine and Galyean (1985) also reported no effect of .5 or 1 kg of supplemental corn grain on ruminal VFA proportions in beef steers grazing blue grama rangeland of similar quality to that in the present study.

Digestion. Apparent and true ruminal OM digestibilities (Table 5) were not affected ($P > .10$) by treatment. True ruminal digestibilities in the present study (avg 40.5%) were about 10 percentage units less than those reported by Funk et al. (1987a) for steers grazing at the same range site during early and late summer. Treatment had no effect ($P > .10$) on ruminal NDF and ADF digestibilities, but values again were lower than those reported by Funk et al. (1987a). Ruminal fiber digestion was less in diets that contained the greatest percentage of forbs in the study of Funk et al. (1987a). Hence, the fairly high proportion in the present study of maturing forbs could account for low ruminal OM and fiber digestibilities. In addition, although the digesta flow marker was the same in the present experiment and in the experiment of Funk et al. (1987a), marker recovery errors could have caused differences between results of the two experiments.

Petersen et al. (1985) fed a low-protein native hay to steers and reported no difference in ruminal OM digestibility with supplemental corn-urea or soybean meal. A corn-urea supplement did not affect ruminal DM or ADF digestion in sheep fed low-quality hay (Ortigues et al., 1988). Jones et al. (1988) reported that supplemental corn (.3% of BW) had no effect on OM and NDF digestion of bermudagrass hay, but increased ruminal digestion of these components in supplemented cows that were fed orchardgrass hay. Soybean meal at .12 or .24% of BW increased ruminal OM and NDF digestion in cows fed prairie hay (Stokes et al., 1988). Similar to results of our study,

TABLE 5. INFLUENCE OF SOYBEAN MEAL (SBM) AND STEAM-FLAKED SORGHUM (SFS) SUPPLEMENTATION ON RUMINAL, SMALL INTESTINAL AND LARGE INTESTINAL OM, NDF AND ADF DIGESTIBILITIES IN BEEF STEERS GRAZING BLUE GRAMA RANGELAND

Item	Treatment			SE[a]
	Control	SBM	SFS	
	Digestibility, % of intake			
Ruminal				
Apparent OM	30.6	32.3	37.7	3.1
True OM[b]	37.8	38.9	44.9	2.7
NDF	58.1	56.4	61.0	3.4
ADF	57.9	57.1	59.9	3.1
Small intestinal				
OM	20.4	22.6	18.0	2.2
NDF	5.1	8.5	5.8	2.1
ADF	2.9	5.3	3.2	2.2
Large intestinal				
OM	2.6	1.5	2.4	2.5
NDF	.6	−.8	.1	1.8
ADF	−.9	−1.5	−.1	1.9
Total tract				
OM	53.6[c]	56.3[d]	58.1[d]	.8
NDF	63.7	64.1	66.9	1.2
ADF	60.0	60.9	63.0	1.1

[a]SE = standard error of the treatment means (n = 6).

[b]Corrected for microbial OM systems in the rumen.

[c,d]Row means that do not have common superscripts differ ($P < .10$).

supplementation of alkali-treated oat straw with rolled barley (700 g/d) had no effect on ruminal OM digestibility; however, supplemental cottonseed meal at 700 g/d reduced ruminal OM digestion slightly (Spragg et al., 1986).

Small and large intestinal OM digestibility (% of intake; Table 5) did not differ ($P > .10$) among treatments. Small and large intestinal digestibilities of NDF and ADF were low or negative across diets, and CV were large. Funk et al. (1987a) evaluated site and extent of digestion in steers grazing the same range site during the summer and also reported that quantitative importance of fiber digestion postruminally was low compared with ruminal fiber digestion. Supplemental grain (Jones et al., 1988) or soybean meal (Stokes et al., 1988) had little effect on small and large intestinal digestion in cattle fed low-quality roughages.

Total tract OM digestibility (Table 5) was greater ($P < .10$) for steers supplemented with SBM and SFS than for control steers. Compared with the control steers, substantially greater quantities of OM were digested in the total tract for steers fed either SBM (785 g/d) or SFS (628 g/d). Because only 500 g DM from each supplement was fed daily, this indicates the presence of positive associative effects of supplements either on forage intake or on forage digestion. Digestion of NDF and ADF likewise tended to be increased. As a result of the techniques used to estimate forage intake, total tract OM digestion coefficients were a function of forage and supplement IVOMD estimates. In contrast to present results, Ernst et al. (1975) reported no effects of supplemental protein or energy on DM or OM digestibilities of low-quality hay. Likewise, Rittenhouse et al. (1970) reported little effect of protein, and no effect of energy supplementation, on forage DM digestibility.

Nitrogen Flow and Microbial Protein Synthesis. Total N flow to the duodenum tended to be greater in SBM-supplemented than in SFS and C steers (Table 6). Likewise, no treatment effects ($P > .10$) were noted for duodenal microbial N flow. Ammonia N flow was greater ($P < .05$) in SBM-supplemented steers than in SFS and C steers, but non-ammonia, non-microbial N flow was not affected ($P > .10$) by supplementation. Ammonia N flows were about twice those reported by Funk et al. (1987a). Microbial efficiency (g microbial N/kg truly OM fermented) was decreased slightly in supplemented steers compared with C

TABLE 6. INFLUENCE OF SOYBEAN MEAL (SBM) AND STEAM-FLAKED SORGHUM GRAIN (SFS) SUPPLEMENTATION ON DUODENAL AND ILEAL N FLOW AND MICROBIAL EFFICIENCY IN BEEF STEERS GRAZING BLUE GRAMA RANGELAND

Item	Treatment			SE[a]
	Control	SBM	SFS	
	g/d			
Duodenal				
N flow	191.6	208.3	176.9	14.6
Microbial N flow	58.1	59.6	58.7	4.2
Ammonia N flow	9.1[b]	11.5[c]	8.0[b]	.6
Non-ammonia, non-microbial N flow	124.4	137.2	110.1	13.8
Ileal N flow	86.7	82.6	80.9	5.2
Microbial efficiency, g microbial N/kg OM truly fermented	19.7	18.5	16.8	1.9
	Digestibility, % of intake			
Ruminal N digestibility				
Apparent	-38.4	-11.1	-21.0	9.8
True	9.5	27.2	26.8	10.1
Small intestinal N	75.7	66.7	64.2	8.0
Large intestinal N	5.9	.8	5.1	3.5
Total tract N	43.3[d]	56.4[e]	48.2[d]	2.8

[a]SE = standard error of the treatment means (n = 6).

[b,c]Row means that do not have common superscripts differ ($P < .05$).

[d,e]Row means that do not have common superscripts differ ($P < .10$).

steers, but differences were not significant ($P > .10$). Mean percentages of OM (80.2, 83.1 and 81.4; SE = 1.6), N on an OM basis (10.1, 10.4 and 10.0; SE = .2) and nucleic acids on an OM basis (12.8, 14.7 and 12.3; SE = 10) in isolated microbial cells for C, SBM and SFS, respectively, did not differ among treatments.

In previous studies, supplemental soybean meal at .12 and .24% of BW has linearly increased microbial, feed N and ammonia N flow in cows fed prairie hay containing .77% N (Stokes et al., 1988). Similar increases in total and microbial N flows were reported in heifers supplemented with cottonseed meal while consuming a basal diet of alkali-treated oat straw (Spragg et al., 1986). Rolled barley at 700 g/d also increased microbial, but not total N flow in the study of Spragg et al. (1986). Jones et al. (1988) reported increased total and feed N flow to the duodenum in steers receiving ground corn at .3% of BW fed either bermudagrass or orchardgrass hay; however, corn supplementation had no effect on microbial efficiency. Results of the present study suggest little effect of either .5 kg of SBM or SFS on microbial protein synthesis. Difference between results of the present study and those of Spragg et al. (1986), Jones et al. (1988) and Stokes et al. (1988) may be a function of forage N content, forage intake and potential degradability of forage OM. Nitrogen flow to the ileum was not changed ($P > .10$) by treatment, although numerically, values for supplemented steers were less than those for C steers.

No differences were noted among treatments in apparent ruminal N digestibility; all values were negative. Funk et al. (1987b) reported negative apparent ruminal N digestibilities during periods of summer dormancy when forage N content was low. Correction of the present data for bacterial N synthesis, however, results in estimates of true ruminal N digestion that were positive for all treatments and similar to estimates reported by Funk et al. (1987a) for steers grazing the same range site during a period of summer dormancy induced by drought. Digestion of N entering the small intestine (expressed as a percentage of N intake) was not affected by treatment. Similarly, large intestinal N digestibility was not affected by treatment, but estimates were quite variable, as indicated by the large CV. Total tract N digestibility was greater ($P < .10$) for steers fed SBM than for those fed SFS or C steers, presumably reflecting digestion of N from added SBM or simply dilution of metabolic fecal N.

The relatively low ruminal degradation of N across treatments could reflect marker recovery errors and overestimation of N flow to the duodenum, as discussed earlier for OM and fiber digestion. Analysis of the N content of esophageal masticate samples indicates that about two-thirds of the forage N was insoluble, with a fairly high proportion in the bound fraction (acid detergent insoluble N). Results of the present experiment, taken with those of Funk et al. (1987a,b), suggest that, although the CP content of blue grama rangeland forage appears to be adequate for most classes of cattle, the ruminal degradation of N from such forage is quite low. Additional research to evaluate the in situ degradation of N should prove useful to define further the value of N in blue grama rangeland forage.

Present data indicate that supplementation of .5 kg of SBM or SFS did not affect forage intake and ruminal digestion in steers grazing blue grama rangeland during early dormancy. Total tract OM digestion was increased by both SBM and SFS supplementation, reflecting increased forage and supplement digestion. Had forage N content been less than 1%, alterations in intake and ruminal digestion of OM and fiber as a result of supplementation might have occurred. Despite the failure of treatments to elicit major changes in forage intake, both SBM and SFS might provide a means by which livestock producers could enhance animal performance under conditions similar to those in this study. Because forage intake and microbial protein synthesis were not changed by supplementation, greater total tract digestion with SBM and SFS should increase intake of digestible OM and animal performance.

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