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Grass hay as a supplement for grazing cattle II. Ruminal digesta kinetics

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Abstract

This study evaluated the effects of supplementing a diet of range hay (5.7% crude protein, 68% NDF) with grass hay from subirrigated meadows (16.5% crude protein, 53.5% NDF), or with a 70% soybean meal:30% wheat grain supplement (40% crude protein) on intake and ruminal digesta kinetics. Twelve ruminally fistulated steers were assigned to 3 treatments (4 steers/treatment) at 2 levels of intake. Treatments were: 1) control, range hay; 2) range hay supplemented with meadow hay (meadow hay was 20% of intake); and 3) range hay supplemented with soybean meal:wheat supplement (supplement was 8% of intake). Intake levels were: 1) ad libitum and 2) equal intake (1.5% of body weight). Range hay was Yb-labeled, and meadow hay and soybean meal:wheat supplements were Er-labeled to measure passage. Intake and digestibility of range hay was not affected by supplementation ($P > 0.05$). During ad libitum intake, total intake (range hay + supplement) was greater ($P < 0.05$) for supplement treatments than for the control. No supplement treatment × level of intake interactions were detected ($P > 0.05$). Total digestibility (range hay + supplement) was greater ($P < 0.01$) for the soybean meal:wheat treatment than for the control or meadow hay treatments. Total digestibility was similar ($P > 0.05$) for control and meadow hay treatments. Ruminal passage rate (% hour^{-1}), total tract mean retention time, and intestinal transit time of range hay did not differ among treatments ($P > 0.05$), but ruminal passage rate, total tract mean retention time, and intestinal transit time were greater ($P < 0.01$) with ad libitum than equal intake. We conclude that a meadow hay supplement produced similar effects on ruminal kinetics and intake of range hay as a soybean meal:wheat supplement.

Key Words: subirrigated meadow, intake, digestibility, passage rate

Protein supplementation of cattle grazing dormant rangelands is a common practice that improves body weight gains by growing animals (Clanton 1982) and maintains body weight and body condition of cows on winter range (Villalobos et al. 1997). Forage supplements have been fed as winter protein supplements for gestating beef cows grazing on range (Cochran et al. 1986, Villalobos et al. 1997), and 15% crude protein hay was an effective supplement for maintaining body condition of gestating beef cows grazing winter native range (Villalobos et al. 1997).

Gut fill may limit intake of forage diets (Campling 1970), and increased voluntary intake of low-quality forages with supplementation is believed to result from increased rate of digestion and(or) passage (Ellis 1978). Forage intake and(or) digestibility are sometimes increased as a result of protein supplementation, but results are not conclusive (Rittenhouse et al. 1970, Kartchner 1980, Ward et al. 1990). Greater intake and(or) digestibility of range forage could improve animal performance. However, there is evidence that improved livestock performance with protein supplementation may result from meeting protein requirements without changes in forage intake or digestibility (Judkins et al. 1987, Freeman et al. 1992, Villalobos 1993).

Our objective was to evaluate the effects of supplementing a basal diet of native range hay with high-quality meadow hay or a soybean meal-based supplement on nutrient status. Measurements included forage intake, forage digestibility, and ruminal digesta kinetics.

Materials and Methods

Treatments and feeding. Twelve crossbred steers (avg. body weight = 431 kg) fitted with 10.2-cm ruminal cannulas were used. Steers were fistulated and housed under conditions described in animal use protocols approved by the Institutional Animal Care and Use Committee at the University of Nebraska-Lincoln. Steers were assigned to 3 treatments (4 steers/treatment). Treatments were: 1) control, native range hay only; 2) native range hay supplemented with meadow regrowth grass hay (supplement was 20% of dry matter intake); and 3) native range hay supplemented with a 70% soybean meal:30% wheat grain supplement (supplement was 8% of dry matter intake). There were 2 feeding periods: ad libitum and equal intake. During the ad libitum period, native range hay and supplement intake were adjusted daily to assure continual access to range hay and supplements; whereas, during the equal intake period, total dry matter (e.g.,

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range hay + supplement) intake was maintained at 1.5 kg/100 kg body weight. Range hay and supplements were fed in separate feed containers so that orts could account for hay and supplement. Periods were 15 days with 7 days for adaptation and 8 days for collection. Steers were housed in a 25° C temperature-controlled environment in 1.78 m × 2.13 m individual stalls. Periods were confounded with intake level, but effects were expected to be negligible because of the controlled environment. Forage was chopped and fed twice daily at 0800 and 2000 hours. Steers had free access to water and trace mineral salt blocks. Trace mineral blocks were 93% to 98% salt, 0.35% zinc, 0.28% manganese, 0.175% iron, 0.035% copper, 0.007% iodine, and 0.007% cobalt. Native range hay intake was measured during the first 7 days of collection, and hay refusals were collected daily.

Upland range hay was harvested at the Gudmundsen Sandhills Laboratory near Whitman, Nebraska during mid-October 1990. Major species were blue grama [*Bouteloua gracilis* (H.B.K.)Lag ex Griffiths], little bluestem [*Andropogon scoparius* (Michx.) Nash], prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.], sand bluestem (*Andropogon hallii* Hack.), switchgrass (*Panicum virgatum* L.), sand lovegrass [*Eragrostis trichodes* (Nutt.) Wood], and ragweed (*Ambrosia psilostachya* Dc.).

Grass hay for supplement was subirrigated meadow regrowth harvested during late August 1990 following an initial harvest and fertilization in June. Harvest procedures and species composition of regrowth hay from subirrigated meadows are described in a companion study (Villalobos et al. 1997). Chemical composition of range hay, soybean meal:wheat supplement, and meadow hay supplement is given in Table 1.

Table 1. Chemical composition of native range hay, meadow hay supplement, and soybean meal:wheat supplement fed to steers.

Item	CP[a]	NDF	ADF	IVDMD
	-------- (% of dry matter)-			-------
Native range hay	5.7	79.0	52.5	53.9
Meadow hay supplement	16.5	73.0	40.2	61.8[b]
Soybean meal:wheat supplement	40.0	---	---	85.7

[a]CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber, IVDMD = in vitro dry matter digestibility.
[b]Estimated in vivo.

Particulate passage estimates. To account for physical factors and moistening effects of saliva (Krysl et al. 1987), 3 steers were selected randomly and their rumens were evacuated by hand. After evacuation, steers were allowed to consume native range hay until an adequate amount of forage to be labeled was obtained. Forage boluses were removed from the rumen and dried in a forced-air oven (50° C). The same evacuation and sampling procedure was followed for the subirrigated meadow hay using 3 different steers.

After drying, the masticated native range hay sample was labeled with Yb using modified procedures described by Teeter et al. (1984). Masticate samples were washed to remove salivary contaminants and soaked for 24 hours in a 12.4 mM aqueous solution of Yb acetate. After soaking, excess fluid was poured off and the remaining sample was soaked in 100 mM acetic acid solution for 5 to 6 hours with occasional stirring. The sample was then washed with slowly flowing tap water overnight in a plastic tub covered with several layers of cheese cloth and then squeezed dry. It was then soaked again in 100 mM acetic acid solution for 5 to 6 hours with occasional stirring, squeezed dry, spread on trays, and dried in a forced-air oven at 50° C.

Subirrigated meadow hay supplement and soybean meal:wheat supplement were labeled with Er following the same procedure as described for Yb using 35 mM aqueous solutions of Er acetate. Labeled forages and supplements were divided into equal portions with 1 aliquot/treatment for Yb and Er dose determinations. On day 1 of the collection phase in both the ad libitum and equal intake periods, steers were pulse-dosed with labeled range forage and their assigned supplement administered intraruminally at 0800 before feeding. The dose was placed in the mid dorsal region of the rumen (Krysl et al. 1987). Marker doses were 150 g of range hay containing 0.23 g of Yb, 100 g of meadow hay containing 0.35 g Er, and 100 g of soybean meal:wheat supplement containing 0.42 g Er. Rectal grab samples were collected at 0, 8, 12, 16, 20, 24, 28, 32, 36, 42, 48, 54, 60, 72, 84, 96, 108, 120, 132, and 144 hours after dosing. Fecal samples were stored frozen (-40° C).

Laboratory analyses. Forage, orts, and fecal samples were dried in a forced-air oven (50° C) and ground in a Wiley mill to pass a 1-mm screen. These samples were analyzed for dry matter (AOAC 1984), NDF (Van Soest et al. 1991), and ADF (Van Soest 1963). Dry matter digestibility of the soybean meal:wheat supplement was estimated using the Tilley and Terry (1963) 2-stage technique (48 hour rumen fluid, 48 hour pepsin digestion on 0.5-g samples in duplicate). Dry matter digestibility of meadow hay supplement was estimated by in vivo digestion performed in a companion study (Villalobos et al. 1997). Apparent total dry matter digestibility (forage plus supplement) was calculated (Schneider and Flatt 1975) using the equation:[(dry matter consumption - dry matter fecal output)/(dry matter consumption)] × 100, where dry matter fecal output was estimated from Yb (Pond et al. 1987). Digestibility of range hay by steers fed meadow hay supplement and soybean meal:wheat supplement was calculated by subtracting the contribution of the supplement from the dry matter intake and feces and calculating digestibility from adjusted dry matter intake and fecal output. We assumed no associative effects of range hay on digestibility of supplements.

Labeled forages and supplement aliquots and fecal samples were prepared for analysis (Karimi et al. 1986) adding 15 ml of 0.01 M DTPA (Diethylenetriaminepentaacetic acid) to 0.2 g of sample in a 20 ml screw cap tube. Tubes were rotated 40 min., centrifuged at 500 × g for 15 min.. Supernatant fluid was filtered (Whatman #4 filter paper, Whatman, Maidstone, UK) into vials for analysis by atomic absorption spectroscopy with a nitrous oxide plus acetylene flame.

Calculations and statistical analyses. Fecal Yb and Er excretion curves were analyzed by nonlinear regression procedures (Marquardt method) of the Statistical Analysis System (SAS 1990) using a 1-compartment model (Pond et al. 1987).

Data were analyzed as a split plot with supplement treatment in the whole plot and intake level and supplement treatment × intake level in the subplot. Steer (supplement treatment) was the whole plot error term and steer (supplement treatment × intake level) was the error term for the subplot (Steel and Torrie 1980) using the GLM procedure (SAS 1990).

Results and Discussion

During ad libitum and equal intake feeding periods, dry matter intake of range hay was similar (P > 0.05) for all treatments. The supplement treatment by level of intake interaction effect was significant for total dry matter intake (P < 0.05). During ad libitum intake, dry matter intake of range hay was not different (P > 0.05) among treatments (Table 2). During ad libitum intake, total dry matter intake (range hay + supplement) was greater (P < 0.05) for meadow hay and soybean meal:wheat supplement treatments than for the control. Total dry matter intake was similar (P > 0.05) for meadow hay and soybean meal:wheat supplement treatments. The difference in total dry matter intake between the control and supplement treatments resulted from addition of supplement and not from an associative effect of supplements on intake of range hay. Similar results were noted by Judkins et al. (1987). During equal intake, total intake was similar (P > 0.05) for all treatments.

Table 2. Range hay and total dry matter intake (e.g., forage + supplement) and total dry matter digestibility in steers fed native range hay, range hay supplemented with meadow hay, and range hay supplemented with soybean meal:wheat supplement.

	Range hay	Range hay + meadow hay	Range hay + Soybean meal:wheat	SE[a]
Range hay intake, kg/100 kg of body weight	1.37	1.31	1.46	.06
Total intake, kg/100 kg of body weight[b]				
Ad libitum intake	1.37[c]	1.69[d]	1.59[d]	0.04
Equal intake	1.44	1.51	1.45	0.04
Range hay digestibility, %	53.9[cd]	52.6[d]	56.1[c]	1.3
Total digestibility, %	53.9[e]	54.7[e]	58.5[f]	1.17

[a]SE = Standard error.
[b]Supplement treatment × level of intake interaction was significant (P<0.05).
[c,d]Means in the same row with different superscripts differ (P<0.05).
[e,f]Means in the same row with different superscripts differ (P<0.01).

Arthun et al. (1992) fed blue grama hay (7.6% crude protein) or barley straw (3.5% crude protein) ad libitum to steers with or without alfalfa hay at 23% or 42% of total diet, respectively. They found that when alfalfa hay was mixed with grass hay at 23% of diet, dry matter intake increased from 1.85 kg/100 kg of body weight for grass-only diets to 2.03 kg/100 kg of body weight for grass-plus-alfalfa diet. When alfalfa was mixed with barley straw at 42% of the diet, dry matter intake increased from 1.16 kg/100 kg of body weight for straw only to 1.71 kg/100 kg of body weight for straw plus alfalfa hay. Results of our study are intermediate to these numbers. Total dry matter intakes were lower in a companion study (Villalobos et al. 1997) in which the same supplements were fed to cows grazing winter range.

Results of protein supplementation on voluntary forage intake have been contradictory. Supplements have had only a small influence on intake and(or) digestibility of grazed diets when crude protein content of extrusa samples was 6.3 to 8.5% (Rittenhouse et al. 1970, Kartchner 1980). Effects of supplemental protein on forage digestibility and intake appeared to be greater during periods of harsh winter weather (Kartchner 1980).

Total dry matter digestibility was not affected (P > 0.05) by intake level and no interactions were detected (P > 0.05). Total dry matter digestibility was lower (P < 0.01) for range hay and range hay supplemented with meadow hay than for range hay with the soybean meal:wheat supplement (Table 2). Total dry matter digestibility was similar (P > 0.05) for range hay and range hay with meadow hay. Similar effects have been reported by Egan and Doyle (1985) in sheep fed a basal diet of chopped oaten hay (5.2% crude protein) at 90% of ad libitum intake and supplemented with either no supplement or urea infused into the rumen. Sanson et al. (1990) reported a difference in dry matter digestibility between control and protein-supplemented steers fed low-quality hay (4.3% crude protein).

Feeding a highly digestible supplement directly affects total dry matter digestibility. Digestibility of the range hay was greater when supplemented with the soybean meal:wheat supplement than when supplemented with meadow hay (P < 0.05; Table 2). Digestibility of the unsupplemented range hay was intermediate to the digestibility of range hay when supplemented with meadow hay and range hay supplemented with soybean meal:wheat.

Conrad et al. (1964) showed that at lower ration digestibility, voluntary intake was mostly related to animal ration digestibility and body weight. They proposed that over a range of lower ration digestibilities, voluntary intake was controlled by gut fill. Van Soest (1982) demonstrated a negative relationship between NDF intake or NDF diet content and forage intake. Native range hay and meadow hay supplement used in our study contained 79 and 73% NDF, respectively, values considered to limit intake (Arthun et al. 1992).

Ruminal particulate passage rate of range hay was faster (P < 0.01) for ad libitum than restricted intake. Total tract retention time and intestinal transit time were longer (P < 0.01) for restricted intake than ad libitum intake. All supplement treatment × level of intake interaction effects for ruminal digesta passage rate, total tract retention time, and intestinal transit time were nonsignificant (P > 0.05). Ruminal particulate passage rate, total tract retention time, and intestinal transit time of native range hay were not

Table 3. Digesta kinetics of steers fed range hay, range hay with meadow hay supplement, and range hay with soybean meal:wheat supplement, ad libitum or restricted intake.

Item	Range hay[a]	SE[b]	Supplements[c]		SE
			Meadow hay	Soybean meal:wheat	
Digesta passage rate, %/hour			3.33[c]	4.9[d]	0
Ad libitum intake	3.52	0.12			
Restricted intake	2.94	0.12			
Total tract retention time, hour					
Ad libitum intake	52.4	1.32	53.7[c]	43.6[d]	1.36
Restricted intake	61.7	1.32	60.6[d]	47.0[d]	1.36
Intestinal transit time, hour					
Ad libitum intake	18.1	0.49	19.2	18.6	0.64
Restricted intake	20.4	0.49	22.7	21.8	0.64

[a]For range hay, intake effects (e.g., ad libitum vs. restricted intake) were significant (P < 0.01) for digesta passage rate, total tract retention time, and intestinal transit time; all supplement treatment and supplement treatment × level of intake interactions were nonsignificant (P > 0.05); therefore, the avg range hay intake for the supplement treatments is reported.
[b]SE = Standard error.
[c]For supplements, level of intake effects were significant (P < 0.01) for total tract retention time and intestinal transit time; level of intake effects were nonsignificant (P > 0.05) for digesta passage rate; all supplement treatment × level of intake interactions were nonsignificant (P > 0.05).
[de]Means under supplement with different superscripts differ (P < 0.01); all other mean were nonsignificant (P < 0.05).

affected ($P > 0.05$) by supplementation (Table 3). Freeman et al. (1992) found no effects of protein supplementation on particulate passage rate and ruminal retention time of prairie hay fed at 1.5% of body weight. However, supplements lowered total tract retention time. Krysl et al. (1987) noted no effect of either soybean meal or steam-flaked milo on passage rate estimates in steers grazing mature blue grama compared to controls. Particulate passage rates obtained in this study concur with those of McCollum and Galyean (1985) and Krysl et al. (1987).

Ruminal particulate passage rate of meadow hay and soybean meal:wheat were not affected ($P > 0.05$) by level of intake (Table 3). Total tract retention time and intestinal transit time of meadow hay and soybean meal:wheat were shorter ($P < 0.01$) during ad libitum intake than restricted intake. Ruminal particulate passage rate and total tract retention time of the meadow hay supplement and soybean meal:wheat supplement (Table 3) were different ($P < 0.05$ and $P < 0.01$, respectively), and intake level effect and the treatment × intake level interaction were nonsignificant ($P > 0.05$). Meadow hay supplement had a slower passage rate and longer total tract retention time than soybean meal:wheat supplement. Differences in passage rate and retention time are a result of differences in chemical composition and digestibility (Table 1) between forages and protein concentrate supplements (Van Soest 1982). Freeman et al. (1992) reported no differences in passage rate and ruminal retention time between a cottonseed meal and cottonseed meal-corn protein supplement in steers fed prairie hay.

Intestinal transit time was not different between meadow hay and soybean meal:wheat supplements ($P > 0.05$). Judkins et al. (1987) obtained similar results with steers grazing blue grama rangeland supplemented with either no supplement, ground pelleted alfalfa, or cottonseed cake.

Implications

Protein supplementation had minimal effects on forage intake and ruminal kinetics when the control forage had 5.7% CP. We conclude that steers fed either meadow hay or soybean meal:wheat supplement would have greater total dry matter intake and crude protein intake than steers fed only range hay. Grass regrowth hay also appears to be an effective alternative to traditional soybean meal-based protein supplements for hay harvested from native range.

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