PROTEIN AND FIBER DIGESTION BY STEERS GRAZING WINTER ANNUALS AND SUPPLEMENTED WITH RUMINAL ESCAPE PROTEIN[1,2]

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ABSTRACT

Six abomasally cannulated Hereford steers (12 mo of age, 300 ± 10 kg) grazing annual ryegrass (*Lolium multiflorum* Lam.) paddocks were used in a replicated 3 × 3 Latin square design to determine effects of ruminal escape protein (EP) supplementation on forage intake, fiber digestion, and protein flow to the intestine. Steers were fed one of three isoenergetic supplements: high ruminal escape protein (HEP), low ruminal escape protein (LEP), or corn, which supplied an estimated .25, .125, or 0 kg of EP/d in addition to EP supplied by corn. Fish meal (FM) and distiller's dried grains with solubles (DDGS) were sources of EP; FM provided 66.7% and DDGS provided 33.3% of estimated EP. Steers were adjusted to each supplement for 7 d before a 4-d collection period. Both total and forage DMI responded quadratically ($P < .03$ and $P < .07$, respectively) to EP supplementation. Total tract DM digestion tended ($P < .13$) to increase linearly with EP supplementation. Abomasal total CP flow increased linearly ($P < .10$) as supplemental EP increased. Crude protein flow in steers receiving HEP, LEP, and corn was 1,137, 1,027, and 844 g/d, respectively. Likewise, abomasal nonammonia N (NAN) tended to be greater ($P < .15$, linear) for steers receiving HEP. Nonammonia N flows were 1,044, 955, and 771 g/d for steers receiving HEP, LEP, and corn, respectively. Abomasal ammonia flow did not differ ($P < .20$) among treatments, nor did reticuloruminal fiber digestion ($P < .20$). These data indicate that EP can increase postruminal protein flow and will not negatively affect fiber digestion in steers grazing annual ryegrass pastures.

Key Words: Steers, Abomasum, Rumen Digestion, Proteins

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Introduction

Protein nutrition of growing cattle is of utmost importance, because a deficiency of 1 g of protein/d can reduce gain by 10 g/d (NRC, 1984). Winter annual pastures containing up to 33% CP (Beever, 1984) are often considered to provide all the CP required by young, growing ruminants; however, much of this CP never reaches the small intestine (Ulyatt et al., 1975; Vogel et al., 1987). Hence, postruminal protein supply could be deficient for young ruminants, resulting in less than maximal performance.

Increased weight gains have been reported for steers supplemented with ruminal escape protein (EP) while grazing perennial grass pastures (Stock et al., 1981; Craig, 1983). Similar improvements with steers grazing winter annuals were noted by Donaldson et al. (1989). Supplements fed to such steers usually contain a feedstuff or a combination of feedstuffs high in EP, such as fish meal (FM), meat meal, corn gluten meal, or distiller's dried grains with solubles (DDGS); relatively low ruminal CP degradability allows a high percentage of supplemental CP to flow to the abomasum (NRC, 1985; Satter, 1986). If much of the CP from winter annual pasture fails to reach the small intestine, CP supplied to the abomasum by EP supplements might give

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steers the gain advantage noted in other experiments. Nonetheless, data are limited concerning effects of EP supplements on performance and intraruminal protein metabolism of steers grazing winter annuals.

Objectives of our study were 1) to determine effects of EP supplementation on abomasal CP flow in steers grazing winter annuals, 2) to estimate DMI of steers grazing annual ryegrass, and 3) to determine effects of EP supplementation on ruminal DM and fiber digestion.

Materials and Methods

Six abomasally cannulated Hereford steers (12 mo of age, 300 ± 10 kg) were blocked into two groups of three each and used in a replicated 3 × 3 Latin square design. Steers grazed six volunteer annual ryegrass (*Lolium multiflorum* Lam.) paddocks (230 m^2) for 24 h/d beginning in late March, and they were supplemented with one of three isoenergetic supplements: high ruminal escape protein (HEP), low ruminal escape protein (LEP), or corn (Table 1). Supplements provided .25, .125, or 0 kg of estimated EP daily from FM and DDGS. Ruminal escape protein was supplied by FM and DDGS (Satter, 1986) in a 2:1 ratio, respectively, in both the HEP and LEP supplements.

Steers were given 15 g of Cr_2O_3 and 10 g of crystalline Co-EDTA in the supplement once daily as particulate and fluid digesta markers. Each period lasted 11 d, divided into a 7-d adjustment period and a 4-d collection period. Steers were individually fed supplements at 0730 daily. Occasional intake problems were noted with the HEP supplement. On d 6 of each period, forage quality was estimated from samples (20 per paddock) pulled by hand at a height similar to the level in the forage canopy that the steers were grazing. Abomasal and fecal samples (80 g minimum) were collected at 0230 and 1430, 0530 and 1730, 0830 and 2030, and 1130 and 2330 on d 1 to 4 of the collection period, respectively.

Forage and fecal samples were dried in a forced-air oven at 55°C and ground to pass a 1-mm screen. After drying, 50 g of each fecal sample was composited by steer across days within period. Abomasal samples (60 ml from each sample) were composited (by steer across days within period) and centrifuged at 1,500 × *g* for 15 min to separate particulate and fluid digesta components. Abomasal particulate digesta were lyophilized, ground to pass a 1-mm screen, and stored.

TABLE 1. RUMINAL ESCAPE PROTEIN (EP) SUPPLEMENTS FED TO STEERS GRAZING RYEGRASS PASTURE

	Supplements[a]		
Ingredient, %	HEP	LEP	Corn
Cracked corn	60.0	79.5	100
Distiller's dried grains with solubles	23.5	12.0	—
Menhaden fish meal	16.5	8.5	—
Daily supply/steer			
Total feed, kg	1.52	1.50	1.48
CP, kg	.34	.24	.14
Estimated EP, kg[b]	.25	.13	0

[a]HEP = high ruminal escape protein; LEP = low ruminal escape protein.

[b]Estimated from Satter (1986).

All samples were analyzed for CP (AOAC, 1980). Total abomasal CP was calculated by summing CP in fluid and particulate digesta. Ammonia in fluid digesta was measured with an ammonia electrode[5]. Forage, supplements, abomasal particulate, and fecal samples were analyzed sequentially for NDF, ADF, and ADL (Robertson and Van Soest, 1981). Cell solubles were calculated as DM minus NDF, hemicellulose as NDF minus ADF, and cellulose as ADF minus ADL. All fiber components were calculated on an ash-free basis. These samples and oat samples were wet-ashed (Hill and Anderson, 1958) and analyzed for Cr concentration using a spectrophotometer set at a wavelength of 430 nm. Abomasal fluid was filtered through four layers of cheesecloth and centrifuged at 20,000 × *g*. Cobalt concentration of the supernatant fluid was determined using an atomic absorption spectrophotometer[6]. Total fluid digesta flowing to the abomasum was calculated from dilution of Co-EDTA fed daily.

Abomasal, fecal, supplement, and forage samples were digested in vitro (Tilley and Terry, 1963) for 144 h as described by Henderson et al. (1985) but were not subjected to pepsin digestion. The inoculum source was a steer consuming wheat silage. After the in

[5]Orion Research 95-10, Cambridge, MA.
[6]Perkin-Elmer 5000, Norwich, CT.

vitro digestion, samples were poured through ADF crucibles and boiled in ADF detergent (Goering and Van Soest, 1970) to determine indigestible ADF (IADF) percentage. Indigestible ADF served as an internal marker to measure apparent digestibility coefficients for DM and fiber. Concentration of chromic oxide in the feces was used to estimate DMI, where DMI = (Cr_2O_3 intake/Cr_2O_3 fecal concentration)/fraction of undigested fecal DM (undigested fecal DM = IADF diet/IADF feces) (Pond et al., 1987). Dry matter flow to the abomasum was calculated as intake × undigested DM. Apparent digestibilities of specific components (fiber, CP) were calculated as described by Galyean (1985).

Analysis of variance (SAS, 1985) was used to analyze data. Main effects used in the model were treatment, period, square, and steer within square. Dependent variables were analyzed for linear and quadratic effects using orthogonal contrasts.

Results and Discussion

Forage composition remained relatively constant throughout the trial (Table 2). These data indicate that forage quality is higher than that reported by Donaldson et al. (1989), and, based on cell solubles, NDF, ADF, and ADL contents, the forage should be highly digested. Cell solubles accounted for approximately half the forage DM content. In addition, ADL content of the forage was low, indicating that forage cellulose and hemicellulose digestibility should be high.

Total DMI and forage DMI (Table 3) increased quadratically ($P < .03$ and $P < .07$, respectively) as EP increased. Increased DMI confirms other reports indicating that EP increased intake by calves fed perennial ryegrass (*Lolium perenne* L.) silage (England and Gill, 1985). Likewise, cattle grazing wheat (*Triticum aestivum* L.) pasture and supplemented with meat meal had a 39% increase in DMI (Anderson et al., 1988) compared with controls; this compares favorably with the 36% increase observed in this study. Anderson et al. (1988) suggested the increased intake was a result of an improved balance of amino acids flowing to the small intestine.

Winter annuals are readily fermented in the rumen (Beever, 1984; Ulyatt et al., 1975). Ruminal and total tract mean apparent DM digestibilities were 62.5 and 74.9%, respectively (Table 3). Ruminal DM digestion was not influenced by supplement ($P > .10$); however, there was a trend for increased total tract DM digestion ($P < .13$) with EP supplementation. In addition, fiber digestion was not different between corn and EP supplements (Table 4).

I ncreases in forage DMI are normally accompanied by decreases in DM digestibility. In the current study, DMI increased in steers receiving EP supplements (Table 3), but reticuloruminal DM digestion was not affected by supplements. However, total tract DM digestion was increased ($P < .13$) by EP supplementation. These data may indicate that neither gut fill nor digestibility was a factor controlling intake, but the steers receiving EP

TABLE 2. ESTIMATED COMPOSITION (DM BASIS) OF FORAGE GRAZED BY STEERS RECEIVING RUMINAL ESCAPE PROTEIN SUPPLEMENTS

Item	Period 1	2	3
	%		
DM	17.2	18.2	17.6
CP	29.7	28.5	27.4
NDS[a]	47.8	45.2	43.7
NDF	52.2	54.8	56.3
ADF	21.5	22.1	23.0
ADL	2.4	2.5	2.9

[a]Neutral detergent solubles.

TABLE 3. DRY MATTER INTAKE AND DRY MATTER DIGESTIBILITY BY STEERS SUPPLEMENTED WITH RUMINAL ESCAPE PROTEIN AND GRAZING ANNUAL RYEGRASS PASTURES

Item	Supplement[a] Corn	LEP	HEP	SE
DMI, kg/d[b]	8.8	12.0	11.8	.80
Forage DMI, kg/d[c]	7.3	10.5	10.3	.86
Supplement intake, kg/d	1.5	1.5	1.5	–
Apparent DM digestibility, %				
Reticulorumen	62.0	62.3	63.3	2.7
Total tract[d]	73.3	75.6	75.7	1.0

[a]LEP = low ruminal escape protein; HEP = high ruminal escape protein.

[b]Quadratic ($P < .03$).

[c]Quadratic ($P < .07$).

[d]Linear ($P < .13$).

TABLE 4. FIBER DIGESTION BY STEERS SUPPLEMENTED WITH RUMINAL ESCAPE PROTEIN AND GRAZING ANNUAL RYEGRASS

Item	Supplement[a]			SE
	Corn	LEP	HEP	
	%			
NDF digestion				
Reticulorumen	70.6	75.9	73.2	2.3
Total tract	73.2	72.6	72.9	1.9
ADF digestion				
Reticulorumen	58.0	59.2	53.6	4.4
Total tract	59.5	61.7	61.0	1.9
Hemicellulose digestion				
Reticulorumen	79.2	81.8	81.4	1.5
Total tract	82.6	85.7	86.1	2.3
Cellulose digestion				
Reticulorumen	78.3	76.0	67.1	4.4
Total tract	79.1	78.7	80.9	1.6

[a]LEP = low ruminal escape protein; HEP = high ruminal escape protein.

supplements responded to some other physiological mechanism (e.g., amino acid balance) associated with intake control.

In cattle consuming high-forage diets, intake can be very dependent on digestibility because intestinal fill can limit intake. Therefore, a more digestible diet favors greater intake (Waldo, 1986). Because the forage in our trial was very digestible, DMI could have been directly dependent on forage DM digestibility. In addition, a more complete supply (quantitatively and qualitatively) of amino acids to the small intestine could increase intake if particular amino acids had limited growth. Because these amino acids would no longer be limiting, cattle could consume enough energy and other nutrients to maximize growth.

Crude protein intake increased linearly ($P < .07$) as EP supplementation increased (Table 5). The majority of the increased CP intake was a result of increased forage intake. A small percentage of the increased CP intake resulted from more CP provided by the LEP and HEP supplements. Protein flow to the abomasum increased linearly ($P < .10$) with EP supplementation. Likewise, nonammonia N (NAN) flow tended ($P < .15$, linear) to be greater in calves supplemented with EP. Increased CP and NAN flows agree with the results of Santos et al. (1984), who reported increased flow of NAN in steers supplemented with EP and fed corn silage. Gill and Ulyatt (1977) reported that supplementation with FM increased NAN flow more than supplementation with sucrose in lambs receiving a diet of high-quality grass silage. There was no difference ($P > .20$) in abomasal ammonia content among treatments.

Increased protein flow postruminally may increase steer performance if protein is a limiting nutrient. Daily gain by steers consuming the same EP supplements and grazing wheat-annual ryegrass pastures responded linearly ($P < .08$) to EP supplementation (Donaldson et al., 1989). In our study, percentage of protein degraded in the rumen was greatest ($P < .09$) for EP supplementation and least for steers supplemented with corn. However, these results may be confounded because of the increased forage intake by steers supplemented with EP over those supplemented with corn. Crude protein degradation in the rumen was greatest for treatments in which steers consumed the most forage because much of the dietary protein was composed of forage protein that was readily degraded in the rumen. Total tract CP digestion increased linearly ($P < .05$) with increasing EP levels. Furthermore, percentage of total undegraded CP decreased

TABLE 5. INTAKE, ABOMASAL, AND FECAL CRUDE PROTEIN FLOWS OF STEERS SUPPLEMENTED WITH RUMINAL ESCAPE PROTEIN AND GRAZING RYEGRASS PASTURES

Item	Supplement[a]			SE
	Corn	LEP	HEP	
CP				
Intake, kg/d[b]	2,240	3,370	3,480	240
Total abomasal, g/d[c]	844	1,027	1,137	99
Abomasal NAN, g/d[d]	771	955	1,044	104
Ammonia N, g/d[e]	73	72	93	17
Fecal, g/d	672	782	770	55
CP disappearance				
Ruminal, %[f]	62.3	69.5	67.3	3.2
Hind gut, %	7.7	7.3	10.5	1.8
Total tract, %[g]	70.0	76.8	77.9	1.8
Undigested CP, %[g]	30.0	23.8	22.3	1.8

[a]LEP = low ruminal escape protein; HEP = high ruminal escape protein.

[b]Linear ($P < .07$).

[c]Linear ($P < .10$).

[d]Nonammonia nitrogen CP equivalent, linear ($P < .15$).

[e]Crude protein equivalent recovered as NH_3 N; calculated as grams of NH_3 N × .8235 × 6.25.

[f]Linear ($P < .09$).

[g]Linear ($P < .05$).

linearly ($P < .05$) as EP supplementation increased. More total CP was available for utilization, and more CP flowed through the gastrointestinal tract of steers receiving EP supplements. These results indicate that EP supplementation is a viable and effective alternative to increase total usable protein in high-performing ruminants.

Our data indicate that EP is superior to corn supplementation for improving forage intake and abomasal protein flow of growing steers on winter annual pastures. Ruminal escape protein increased protein flow to the hindgut and more of the protein was digestible. Although a true control was not used, EP increased total and forage DMI over corn supplementation without having detrimental effects on DM or fiber digestion. Therefore, it seems that EP is one method to increase protein flow and increase nutrient intake without negatively affecting fiber digestion in growing ruminants consuming high-quality forages.

Implications

Our data suggest that supplementation of cattle grazing winter annual pasture with a ruminal escape protein supplement increases the supply of protein postruminally. This result may be of particular importance because ruminal microbes cannot produce enough protein to meet the needs of high-producing ruminants. Supplementation of growing cattle grazing high-quality winter annuals with escape protein will provide more protein postruminally and reduce the possibility of protein deficiency. Therefore, escape protein supplementation offers the opportunity to improve cattle performance in certain production situations.

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