Protein Versus Energy Supplementation of High Alfalfa Silage Diets for Early Lactation Cows[1]

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ABSTRACT

An experiment was conducted to test the hypothesis that cows in early lactation are more likely to be limited by protein than by energy when fed diets containing high proportions of alfalfa silage. After a 2-wk covariate period, 26 multiparous cows were assigned to one of four treatments from wk 3 to 14 of lactation. Treatments were a positive control diet with equal amounts of forage and grain (DM basis), an all forage diet serving as negative control, and two test diets with 75% forage and 25% of either high moisture ear corn or expeller soybean meal. The latter two diets were equal in energy content but differed in the amount of protein made available for absorption in the small intestine. Alfalfa silage was the only forage in all diets. Milk yield with the four diets averaged 36.3, 25.5, 32.1, and 35.5 kg/d, and milk protein content was 2.93, 2.63, 2.77, and 2.75%. The negative control diet severely depressed milk protein content, which was not restored totally by either test diet. We concluded that absorbable protein supply to the intestine is first-limiting when high alfalfa silage diets are fed to cows in early lactation.

(**Key words**: alfalfa silage, energy, expeller soybean meal, protein)

Abbreviation key: **BHBA** = β-hydroxybutyrate, **ESBM** = expeller soybean meal, **HMEC** = high moisture ear corn, **NC** = negative control, **PC** = positive control.

INTRODUCTION

High forage, low grain diets fed to dairy cows are advantageous under certain economic conditions. These diets normally result in reduced milk yield from the constraints that forage is thought to impose on DMI, digestibility, and passage. The poorer performance of early lactation cows fed high forage diets usually has been attributed to low NE_L intake. However, high forage diets also are likely to reduce flow of protein to the small intestine. The addition of dietary grain or readily fermentable carbohydrate can increase the total NE_L available to the cow and the flow of microbial protein to the duodenum with a subsequent increase in milk yield and milk protein content (13).

Utilization of dietary N usually is poor for diets based on alfalfa silage or grass silage, in part because of the lack of synchrony between N and energy availability to the rumen microbes. Inclusion of readily fermentable carbohydrate sources in the grain mix can increase synthesis of microbial protein with subsequent improvement in cow performance (8, 13). Another approach is to increase the amount of rumen-resistant protein in the diet. Dietary protein escaping rumen degradation can compensate for the deficiency in microbial protein. This strategy has been used with diets based on grass silage (14, 18). Crude protein content in alfalfa silage is usually higher than CP in

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grass silage; however, when alfalfa silage constitutes a large proportion of the total DMI, milk yield and milk protein content are usually reduced (5). Some of this reduction in milk yield might be averted if rumen-resistant protein supplements are fed.

The objective of the experiment reported herein was to test whether milk yield from early lactation cows fed alfalfa silage-based diets was primarily limited by energy or by protein supply and to evaluate the cow's response to supplementation with a rumen-resistant protein source.

MATERIALS AND METHODS

Twenty-six multiparous Holstein cows were assigned randomly to one of four groups on d 15 of lactation after an 11-d covariate period. Calving dates ranged from November 3 to January 11. Cows were moved from maternity pens to a tie-stall barn on d 3 of lactation. No health problems were encountered. Treatment diets (Table 1) were applied from 15 to 98 DIM. Alfalfa silage, the sole forage in all diets, was from different cuttings and was fed from five different silos throughout the experiment. Average NDF, ADF, lignin, and CP contents were 44.2, 38.8, 7.8, and 20.3%, respectively. A conventional diet, with a 48.2:51.8 forage to supplement ratio, was fed to all cows during the covariate period between d 4 and 14 DIM and served as the positive control (**PC**) during the experimental period. An all forage diet served as the negative control (**NC**). Two diets, high moisture ear corn (**HMEC**) and expeller soybean meal (**ESBM**, produced by West Central, Ralston, IA), both with 75:25 forage to supplement ratio, were formulated to provide the same NE_L but a different amount of absorbable protein (Table 2). Diets were fed for ad libitum consumption as TMR once daily at 1100 h, allowing 5 to 10% orts. Dry matter intake was recorded daily. Daily samples of the TMR, orts, and individual feed ingredients were composited weekly and analyzed for DM, CP (2), and NDF (7) contents. The amount of rumen-undegraded protein in ESBM was estimated by an inhibitor in vitro method (1). In vitro protein degradation rate of ESBM was 3.6%/h. The rate of passage for ESBM was assumed to be 6%/h, and the amount of undegraded protein was estimated at 60% (1). The NE_L content of silage was estimated from

TABLE 1. Diet ingredients and composition.[1]

	Treatment			
	PC	HMEC	ESBM	NC
	(% of DM)			
Ingredient				
Alfalfa silage	48.2	75.0	75.0	98.2
High moisture ear corn	40.0	23.2	...	...
Solvent soybean meal	10.0	...	...	...
Expeller soybean meal[2]	...	...	23.2	...
Dicalcium phosphate	1.1	1.1	1.1	1.1
Trace-mineralized salt[3]	.7	.7	.7	.7
Vitamin A, D, and E supplement[4]	trace	trace	trace	trace
Diet composition				
DM, %	60.7	52.2	56.6	46.6
NE_L, Mcal/kg	1.61	1.47	1.48	1.35
CP, % dry basis	18.3	17.4	25.6	19.9
Rumen-undegraded protein, % of CP	32.4	26.8	37.9	23.0

[1]PC = Positive control diet, HMEC = diet supplemented with high moisture ear corn (energy), ESBM = diet supplemented with expeller soybean meal (protein), and NC = negative control diet.

[2]Soy PLUS® (West Central, Ralston, IA).

[3]Composition (g/100 g): NaCl, 95 to 99; Mn > .2; ferrous Fe > .16; ferric Fe > .14; Cu > .033; Zn > .01; I > .007; Co > .003.

[4]Vitamin supplement: vitamin A, 52,000 IU/d; vitamin D, 17,000 IU/d; and vitamin E, 17 IU/d per cow.

TABLE 2. Daily intake of DM, forage, CP, rumen-undegraded protein, and NE_L.

	Treatment[1]			
Item	PC	HMEC	ESBM	NC
DMI, kg/d	23.3[a]	20.9[b]	22.5[ab]	18.8[c]
DMI, % of BW	3.90[a]	3.65[bc]	3.78[ab]	3.43[c]
Forage intake, kg/d	11.2[c]	15.7[b]	16.9[ab]	18.5[a]
CP, kg/d	4.11[e]	3.79[e]	5.82[d]	3.76[e]
Rumen-undegraded protein,[2] kg/d	1.33[e]	1.02[f]	2.21[d]	.87[f]
NE_L, Mcal/d	36.4[a]	32.0[b]	33.7[ab]	25.3[c]

[a,b,c]Means in the same row with different superscripts differ ($P < .05$).

[d,e,f]Means in the same row with different superscripts differ ($P < .01$).

[1]PC = Positive control diet, HMEC = diet supplemented with high moisture ear corn (energy), ESBM = diet supplemented with expeller soybean meal (protein), and NC = negative control diet.

[2]Rumen undegraded protein in ESBM was determined using inhibitor in vitro method (1). For other ingredients, means from NRC (12) were used.

its NDF content (9), and NE_L and rumen-undegraded protein means from NRC (12) were used for all other ingredients. Milk net energy content for energy balance calculations was estimated according to the method of Tyrrell and Reid (19).

Daily milk yield was recorded. Weekly milk samples collected from four consecutive milkings (a.m. and p.m.) were combined according to milk yield into two composites and analyzed for protein and fat contents (11).

Body weight was recorded after parturition and every Monday thereafter. Body condition score (20) was assessed weekly by four different scorers. Every Monday, from wk 1 to 10, blood samples were withdrawn from the coccygeal vein or artery in heparinized vacutainers. Blood samples were centrifuged at 2000 × *g* for 15 min, and plasma was stored at –20°C for subsequent analysis of β-hydroxybutyrate [**BHBA**, (6)].

Treatment effects on all variables were analyzed using Fisher's least significant differences test in the general linear models procedure of SAS (17). The model was

$$Y_{ij} = \mu + D_i + BX_{ij} + E_{ij},$$

where

Y_{ij} = dependent variable for cow j on treatment i during the treatment period,
μ = population mean,
D_i = effect of diet i,
B = linear adjustment factor for the covariate period,
X_{ij} = measure of the dependent trait during wk 2 of lactation for cow j on diet i, and
E_{ij} = error.

RESULTS AND DISCUSSION

Least squares means for DM, CP, NE_L intakes, and rumen-undegraded protein are given in Table 2. Dry matter intake for the ESBM treatment was intermediate between PC and HMEC. Under the assumption that forage contents of the orts and TMR were similar, cows fed HMEC consumed less forage than those fed NC (15.7 vs. 18.5 kg/d; $P < .05$), but forage consumption was not significantly different between treatments ESBM and NC. This result agrees with those from other studies (3, 4, 15) in which the supplementation of silage-based diets with high protein concentrates resulted in lower substitution rates than when corn or barley concentrates were used. The increase in forage DMI could be related presumably to enhanced silage digestibility as a result of higher CP intake (10).

Lactation curves (Figure 1) showed similar yields for all diets at the end of the 2-wk covariate period; yield was slightly higher for the ESBM group. After they were switched to the treatment diets, cows on the ESBM diet maintained yield equal to the PC cows and reached peak yield at wk 6 postpartum. Cows

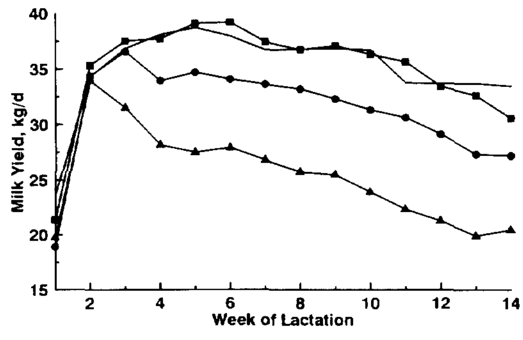

Figure 1. Milk yield of early lactation cows fed alfalfa silage diets supplemented with corn-soybean meal concentrate (—), high moisture ear corn (●), expeller soybean meal (■), or no supplement (▲).

supplemented with HMEC reached their maximum yield by wk 3 of lactation. An average difference of 4.4 kg/d of milk was maintained between the ESBM and the HMEC diets from wk 4 through 14. When milk yields were adjusted for performance during the covariate period (Table 3), an .8-kg/d advantage for the PC over ESBM diets resulted. The difference between ESBM and HMEC diets was narrowed to 3.4 kg/d, which was still a 10.6% ($P < .07$) advantage for the high protein diet. The response was comparable with that usually obtained with postruminal infusion of protein in cows fed high forage diets (5, 16) or with fish meal and soybean meal supplementation (15). Milk yield of NC cows declined sharply after the dietary switch. Their covariate-adjusted yield was > 10 kg/d lower than with the PC cows.

Only CP content of milk from cows fed the all forage diet (NC) was lower ($P < .05$) than for cows fed the PC diet (Table 3). Milk protein content with ESBM and HMEC diets was midway between that of the control diets. Protein yields were higher for the ESBM and the HMEC diets than for the all forage diet; the 9% larger yield for the ESBM diet than for the HMEC diet in cows was nonsignificant. When compared with the all forage diet, only 16 and 25% of the extra intakes of CP and rumen-undegraded protein in the ESBM diet were recovered as milk protein.

The ESBM diet provided significantly more rumen-undegraded protein than any of the other diets. The generous amount of rumen-undegraded protein failed to overcome fully the milk protein depression characteristic of high forage diets, which supports the view that protein availability is not the only factor responsible for the drop in protein content. Fat content was not affected by treatment, despite the substantial differences in dietary composition. Daily fat yields were not different among ESBM, HMEC, and PC treatments.

Average BW gain was lower for NC than for PC control cows. Figure 2 shows BW as a percentage of wk-2 BW. Cows in both ESBM and HMEC groups lost BW to a similar extent over a comparable period; however, recovery of initial BW was faster for the cows fed the high protein diet. These differences were not reflected in body condition score (Figure 3), which was similar for both ESBM and HMEC diets. The PC and NC cows had very different body condition curves, which agreed with the differences in BW change.

Concentrations of BHBA in blood plasma (Figure 4) suggest that reliance on body fat mobilization was minor for the PC cows compared with that of the others. However, concentrations of BHBA were not significantly different between diets except for wk 3 and 10. Efficiency of NE_L utilization (Table 3), calculated as the ratio of milk energy to NE_L available for yield, after maintenance expenditures were subtracted and BW changes corrected for, was not different among diets. Still, efficiencies tended to be higher with the ESBM and NC diets. A 101% efficiency of energy utiliza-

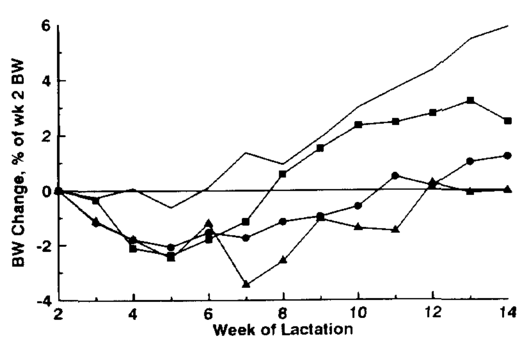

Figure 2. The BW change as a percentage of BW at wk 2 of lactation in cows fed alfalfa silage diets supplemented with corn-soybean meal concentrate (—), high moisture ear corn (●), expeller soybean meal (■), or no supplement (▲).

TABLE 3. Lactation performance, BW gain, efficiency of NE_L utilization, and average body condition score.

	Treatment[1]			
	PC	HMEC	ESBM	NC
Cows, no.	8	6	6	6
Yield,[2] kg/d				
Milk	36.3[d]	32.1[f]	35.5[e]	25.5[g]
3.5% FCM[3]	36.0[a]	32.4[b]	35.0[ab]	26.2[c]
Protein	1.05[a]	.90[b]	.98[ab]	.64[c]
Fat	1.26[a]	1.14[ab]	1.21[ab]	.93[b]
Milk composition, %				
Protein	2.93[a]	2.77[ab]	2.75[ab]	2.63[b]
Fat	3.54	3.58	3.42	3.57
BW at wk 2 of lactation, kg	588	588	604	542
BW Gain, kg/d	.48[a]	.19[ab]	.25[ab]	−.09[b]
Body condition score	2.97[a]	2.76[bc]	2.85[ab]	2.59[c]
Efficiency of NE_L utilization,[4] %	101.1	103.0	108.0	113.1

[a,b,c]Means in the same row with different superscripts differ ($P < .05$).

[d,e,f,g]Means in the same row with different superscripts differ ($P < .10$).

[1]PC = Positive control diet, HMEC = diet supplemented with high moisture ear corn (energy), ESBM = diet supplemented with expeller soybean meal (protein), and NC = negative control diet.

[2]Yield data are adjusted by covariance.

[3]3.5% FCM = .432 (kg of milk) + 16.2 (kg of fat).

[4]Efficiency of NE_L utilization = milk energy ÷ (NE_L consumed − maintenance NE_L ± net energy of BW change).

tion for cows on the PC diet indicates that the NRC (12) is accurate in predicting energy utilization by the lactating cow consuming conventional diets. The prediction was less accurate for diets deviating from the common standards. The increase in milk yield with the ESBM diet compared with the HMEC diet was concomitant with a nonsignificant increase in DMI and NE_L intake. The 1.7-Mcal difference in NE_L intake does not seem to be enough to sustain the extra 2.6 kg/d of FCM on the ESBM diet.

The amount of ESBM used in this experiment is more than is practical. Nonetheless, our results show that, for dairy feeding systems based on high intakes of alfalfa silage, sup-

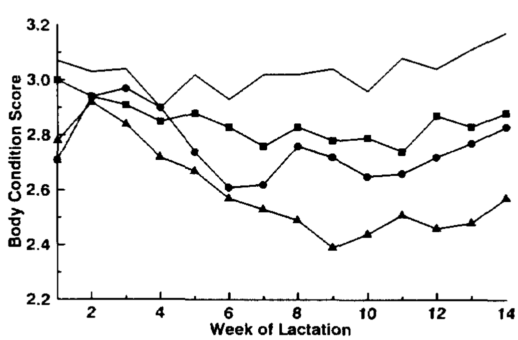

Figure 3. Body condition score (20) during early lactation in cows fed alfalfa silage diets supplemented with corn-soybean meal concentrate (—), high moisture ear corn (●), expeller soybean meal (■), or no supplement (▲).

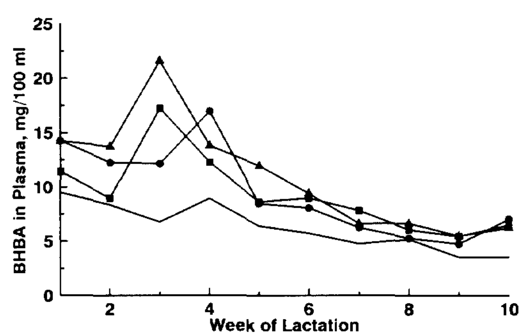

Figure 4. Blood plasma concentrations of β-hydroxybutyrate (BHBA) during early lactation in cows fed alfalfa silage diets supplemented with corn-soybean meal concentrate (—), high moisture ear corn (●), expeller soybean meal (■), or no supplement (▲).

plementation of rumen-undegraded protein supports more milk yield than when only energy is supplemented. The high forage diet supplemented with rumen-undegraded protein supported a milk yield comparable with that obtained with a considerably larger grain input.

CONCLUSIONS

Results from this experiment suggest that dairy diets containing a large proportion of alfalfa silage are likely to be more limiting in rumen-undegraded protein than in NE_L content.

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