Corn Gluten Meal or Dried Brewers Grains as Partial Replacement for Soybean Meal in the Diet of Holstein Cows

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ABSTRACT

Holstein cows (n = 24, 9 primiparous) were assigned equally to diets based on corn silage and high moisture corn supplemented with soybean meal alone or with either corn gluten meal or dried brewers grains. In diets with two protein sources, the protein quantity from each source was similar. Dietary CP and ADF averaged 16.3 and 18.8%, and undegraded protein as a percentage of CP was 33.6, 41.1, and 41.8% for the respective diets. After parturition, cows were fed the soybean meal diet for a 3-wk covariant period, an experimental diet for 10 wk, the soybean meal diet for 3 wk, and the experimental diet for another 10 wk. Milk production by cows fed those diets averaged 30.9, 31.7, and 34.9 kg/d; protein averaged .90, .94, and 1.02 kg/d; and DMI averaged 16.8, 18.8, and 18.2 kg/d, respectively, for the two 10-wk periods. No dietary differences occurred for 3.5% FCM, estimated DM digestibility, BW, BW gain, or percentages of milk fat, protein, or SNF. Ruminal isobutyrate and isovalerate differed by diet; isovalerate was highest in the diet containing soybean meal plus corn gluten meal, probably because of the high Leu content of corn gluten meal. Ruminal NH_3 N did not differ. The favorable production response by cows fed dried brewers grains can be explained by a more favorably balanced AA profile in the ruminally undegraded protein than in other diets.

(**Key words**: protein, undegraded intake protein, dried brewers grain, corn gluten meal)

Abbreviation key: **CGM** = corn gluten meal, **DBG** = dried brewers grains, **RDP** = ruminally degradable protein, **RUP** = ruminally undegraded protein, **SBM** = soybean meal.

INTRODUCTION

Protein availability for milk production may be increased by higher feed intake, optimization of ruminal fermentation and microbial growth in the forestomachs, and supplementation of protein that escapes ruminal degradation (8). Ruminal microorganisms can convert available protein sources, NPN, or both to microbial protein, which, according to Chandler (6), is very similar to milk protein AA composition. However, ruminal microbial protein synthesis cannot supply adequate quantities of AA to meet the requirements of high producing dairy cows. Therefore, ruminally undegraded dietary AA must complement the microbial AA reaching the small intestine (6, 22).

In ration formulation, the amount of ruminally degradable protein (**RDP**) and ruminally available carbohydrate should be adequate to maximize the microbial protein synthesis while minimizing fermentation losses (15, 21, 24). Excess RDP in the diet does not contribute to ruminal fermentation and results in N losses. Microbial growth is reduced, and ≥25% of the total protein may be excreted (18). Also, energy may be expended by the cow to synthesize increased urea to facilitate N excretion.

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Regardless of the ruminally available carbohydrate, this energy loss may occur when readily degradable protein sources are fed as the sole protein supplement in the diet (17). Milk production of high producing dairy cows may be limited as a result.

Partial replacement of degradable supplement with protein sources that are more resistant to microbial degradation in the rumen should reduce losses and insufficient N utilization in the rumen and increase flow of ruminally undegradable protein (**RUP**) to the small intestine. The present study was conducted to evaluate lactational response of Holstein cows when corn gluten meal (**CGM**) and dried brewers grain (**DBG**) partially replaced soybean meal (**SBM**) as protein supplement in the diet.

MATERIALS AND METHODS

Twenty-four lactating cows were assigned to receive one of three dietary treatments. The control diet (Table 1) was 50% corn silage (dry basis) and contained corn and SBM in proportions to ensure that the dietary DM contained 16% CP. The treatment diets contained either CGM or DBG substituted for SBM and corn to change the RUP from 34 to 42% (Table 1). High moisture corn (74% DM) was rolled and fed for most of the study. Coarsely ground dry corn replaced high moisture corn for the last 4 wk in the diets fed to the 5 cows that were the last to finish the experiment.

Fifteen multiparous and 9 primiparous cows were used in the study. Assignments of multiparous cows to treatment groups were balanced according to anticipated producing ability. Primiparous cows were assigned according to anticipated date of calving. At parturition, all of the cows were fed the SBM control diet for 3 wk via Calan doors (American Calan Inc., Northwood, NH). Cows then were offered their assigned experimental diet beginning at 22 DIM for 10 wk; wk 1 was used for adjustment. Subsequently, cows were offered the SBM control diet for 3 wk, and, beginning 112 DIM, a second replication of the experiment was conducted in which cows were reassigned equally to a different experimental diet.

Diets were fed as TMR twice daily (0600 and 1500 h) in equal allotments in amounts to achieve ad libitum intakes (about 10% orts). Amounts fed were recorded twice daily; orts were removed once daily for 4 consecutive d weekly for intake estimation. Feed sources were sampled weekly for component analysis and for in situ determination of CP degradability. Major dietary components were analyzed weekly for DM, CP by the Kjeldahl procedure (3) using Tecator Kjeltec (Tecator, Inc., Herndon, VA), and ADF according to the method of Goering and Van Soest (12). Composites of weekly samples were determined for NDF (30). The AA profile of the three protein supplements was measured after acid hydrolysis and subsequent phenylisothiocyanate derivatization followed by reverse-phase chromatography using a Waters HPLC (Millipore Corp., Milford, MA) (4). Digestibility of DM of the diets was estimated using acid detergent insoluble ash as an internal unabsorbable marker (9). Fecal samples were collected during the final week of each period extended over about 3 d to represent every 4-h interval of the day. Samples were frozen (–20°C) on return to the laboratory. Prior to analysis, samples were thawed and composited over time intervals. Degradability of CP of individual feed sources was estimated by the in situ bag technique (19). Spun polyester dacron bags (10 × 20 cm)

TABLE 1. Diet composition and expected nutrients as formulated.

	Diet[1]		
Item	SBM	CGM	DBG
	(% of DM)		
Corn silage	50.0	50.0	41.8
High moisture corn[2]	28.5	30.4	28.0
SBM	18.3	9.4	11.0
CGM		7.0	
DBG			16.0
Mineral vitamin mix[3]	3.2	3.2	3.2
CP	15.8	16.0	15.8
RUP[4]	34.3	42.3	42.5
NDF	30.3	29.4	31.7
ADF	17.8	17.6	18.3
Ca	.66	.64	.65
P	.52	.50	.51
K	1.02	.94	.79

[1] All diets contain soybean meal (SBM), but, in two diets, SBM was partially replaced with corn gluten meal (CGM) or dried brewers grains (DBG).

[2] Dry corn replaced high moisture corn for <3 wk for a few cows near the end of the study.

[3] Mineral-vitamin mix contained 13.5% Ca, 6.25% P, 2.25% Mg, 1.7% S, 25.0% $NaHCO_3$, 88,000 IU/kg of vitamin A, and 25,000 IU/kg of vitamin D.

[4] Ruminally undegraded protein (percentage of dietary protein).

with 57- to 59-μm pore size were filled with 12 ± .5 g of feedstuff. Prior to incubation, frozen samples of corn silage were thawed, composited, frozen, and ground through a Wiley mill (Thomas Scientific, Swedesboro, NJ) with a 5-mm mesh screen using dry ice. The ground sample then was thawed and incubated with its original moisture content. Other feedstuffs were composited similarly and ground through a 2-mm mesh screen. Duplicate bags were suspended via ruminal cannula for 0, 2, 8, 24, and 72 h in each of two lactating Holstein cows receiving corn silage supplemented with concentrate mix containing SBM.

Dried residuals were ground through a 1-mm screen and analyzed for total N using the Kjeldahl procedure. Parameters describing CP degradation were computed using the Marquardt iterative method in the nonlinear regression (PROC NLIN) of SAS (25). The fitting equation was the first-order kinetics model proposed by Ørskov and McDonald (20), and overall CP degradabilities were predicted for the ruminal turnover rates of 5 and 8%/h according to the Agricultural Research Council (1).

Milk production was recorded at each milking. Milk was sampled on two consecutive milkings at 4 and 8 wk for composition analysis. Milk fat, protein, lactose, and SNF contents were determined by a four-channel spectrophotometer (Multispec Mark I®; Foss Food Technology, Eden Plains, MN) in the Blue Ridge DHI Laboratory. Body weights were recorded immediately following the p.m. milking at the beginning, middle, and end of each experimental period.

Cows were bled by jugular puncture (2 to 4 h postfeeding) at 5 and 9 wk of each experimental period, and blood plasma was preserved (−20°C) for urea analysis. On the same days, ruminal fluid, taken by stomach tube 2 to 4 h postfeeding, was measured immediately for pH and then preserved by addition of 25% metaphosphoric acid for later determination of NH_3 and VFA.

Blood urea was measured as described by Coulombe and Favreau (10). Ruminal NH_3 was determined by the method of Chaney and Marbach (7). The VFA were measured on a Varian Vista 6000® gas chromatograph (Varian, Sunnyvale, CA). The stationary column packing was 10% SP/200/1% H_3PO_4 on 80/100 Chromasorb W AW (Supelco, Bellefonte, PA). The carrier gas (N_2) flow was 30 ml/min, inlet temperature was 175°C, column temperature was 110°C, and detector temperature was 170°C. Detection was by flame ionization. A known solution of C_2 to C_5 volatile acids was used as a standard. 4-Methyl valeric acid (Pfaltz and Bauer, Waterbury, CT) was used as an internal standard for each unknown.

Statistical Analysis

Data were summarized and analyzed using SAS (25) by the repeated measures of the general linear models procedure. Repetitions were weekly for milk production and composition. Two repetitions were included for measurements of ruminal and blood samples. The model included diet, period, parity, and all possible interactions. For milk and FCM, a covariant derived during each 3-wk adjustment was included. If a subclass interaction was not significant, the sum of squares for that interaction was returned to the error term. If the probability exceeded .10, the response was considered to be nonsignificant. Orthogonal contrasts were tested to compare dietary effects.

RESULTS

Based on weekly analysis of diet ingredients (Table 2), CP averaged 16.3%, ADF was

TABLE 2. Further description of diets based on weekly ingredient analysis and in situ CP degradability measurements.

	Diet[1]		
Item	SBM	CGM	DBG
DM, %	50.8	50.9	54.4
CP, %	16.0	16.6	16.4
RUP,[2] % of CP[3]	33.6	41.1	41.8
RUP, % of CP[4]			
k_p[5] = 5%/h	37.6	44.0	43.4
k_p = 8%/h	44.6	48.4	50.8
ADF, %	18.9	18.8	18.6

[1] All diets contain soybean meal (SBM), but, in two diets, SBM was partially replaced with corn gluten meal (CGM) or dried brewers grains (DBG).

[2] Ruminally undegraded protein.

[3] According to NRC (16) recommendations.

[4] According to in situ measurements.

[5] Assumed rate of passage from rumen.

TABLE 3. In situ CP degradability of the feedstuffs.[1]

Item	SBM	CGM	DBG	CS	HMC
Incubation	CP Disappearance (%)				
(h)					
0	14.4	3.8	7.1	57.7	26.7
2	17.9	3.2	6.9	60.1	33.3
8	35.8	7.4	23.0	57.3	44.5
24	89.6	8.6	62.2	65.7	74.0
72	99.2	53.4	93.0	73.6	98.2
Degradation parameters					
Readily degraded fraction, %	15.7	4.0	3.1	56.9	24.5
Fraction degraded at measurable rate, %	83.5	49.4	89.8	16.7	73.7
Degradation rate, %/h	6.47	.44	3.81	2.83	4.58
Undegradable fraction, %	.8	46.6	7.1	26.4	1.8
Overall degradability, %					
k_p[2] = 5%/h	62.8	8.1	42.0	63.0	59.7
k_p = 8%/h	53.1	6.6	32.1	61.3	51.3

[1]SBM = Soybean meal, CGM = corn gluten meal, DBG = dried brewers grains, CS = corn silage, HMC = high moisture corn.

[2]Assumed rate of passage from rumen.

18.8%, and RUP was 38.8%. Rates of CP degradability were extremely low for CGM (Table 3). The low rate of degradability of CGM was discussed by Stern and Satter (29) and was attributed to the gelatinous nature and lack of surface exposure in undegradable bags. Instead of using these values for CGM, degradabilities were used as determined by Cozzi et al. (11), who used the same batch of CGM and applied conditions more likely to be expected when CGM is consumed in the diet. When CGM was mixed with NDF straw in the suspended bag, CP fraction B was about 85%, the degradability rate was 2.5%/h, and the resulting RUP was 70 to 75%. Although the correct dietary RUP for the three diets is debatable, the CGM and DBG diets were about 6 to 8% higher in RUP than the SBM diet (Table 2). The AA profile of protein sources (Table 4) agrees reasonably well with published values (6, 21) except for Met. Because of the hydrolytic method, about 35% of Met routinely is lost in our laboratory.

Milk production was greater for cows fed the CGM and DBG diets than for those supplemented with only SBM (Table 5). The DBG appeared to be the superior protein supplement for enhancing milk production ($P < .01$). Weekly averages for milk production over both experimental periods are shown in Figure 1. Production for cows receiving the CGM and SBM diets averaged over both 10-wk periods was similar. However, Figure 2 showed a diet by period interaction ($P < .10$). In both periods, DBG diets resulted in greater milk production. Advantages in milk production for DBG were greater in the first 10-wk period than for other diets. Tests of significance for milk production by week differed ($P < .01$) from wk 4 to 10. The difference in production when SBM and CGM were compared was not clear but tended to reverse from one 10-wk period to the next, which explains the diet by period interaction (Figure 2).

TABLE 4. The AA profile of the protein supplements.[1]

Item	SBM	CGM	DBG
	(g/100 g of CP)		
Arg	7.3	3.3	6.2
His	2.4	1.9	2.1
Ile	4.9	4.6	4.7
Leu	7.2	15.9	7.9
Lys	6.4	1.7	3.8
Met[2]	1.0	1.8	1.2
Phe	5.0	6.5	5.7
Thr	3.2	2.7	3.1
Val	4.6	4.4	5.4

[1]SBM = Soybean meal, CGM = corn gluten meal, DBG = dried brewers grains.

[2]Hydrolytic method in preparation for AA analysis results in Met losses of approximately 35%.

TABLE 5. Milk production, DMI, DM digestibility, and milk components of cows when corn gluten meal (CGM) or dried brewers grains (DBG) partially replaced soybean meal (SBM) in the diet.

	Diet			Parity		Period			Effect				
Item	SBM	CGM	DBG	1	>1	1	2	$\sqrt{\text{MSE}}$[1]	Diet	Parity	Period	Contrasts[2] and interactions	$P <$
Milk, kg/d	30.8	31.7	35.0	31.5	33.5	35.1	29.9	8.2	**	†	**	Contrasts 1 and 2	.01
												Diet × period	.05
3.5% FCM, kg/d	31.4	31.4	33.6	29.8	34.4	35.0	29.2	10.8	NS[3]	**	**	Parity × period	.07
DMI, kg/d	17.4	19.2	18.8	16.0	20.9	19.1	17.8	4.7	*	**	*	Contrast 1	.01
												Diet × parity × period	.07
DM Digestibility, %	67.6	68.4	69.3	70.6	66.3	69.9	67.0	8.3	NS	NS	NS	Diet × period	.03
Milk/DMI	1.8	1.6	1.8	1.8	1.7	1.9	1.7	.5	*	†	**	Contrast 2	.01
Milk composition													
Fat, %	3.7	3.5	3.4	3.7	3.4	3.4	3.6	.6	NS	NS	NS		
Protein, %	3.0	3.0	2.9	3.0	3.0	2.8	3.1	.3	NS	NS	†		
SNF, %	7.9	8.6	8.5	8.4	8.4	8.4	8.3	.5	*	NS	NS	Contrast 1	.02
Lactose, %	4.4	4.9	4.9	4.8	4.7	4.9	4.6	.3	*	NS	†	Contrast 1	.01
Daily production, kg/d													
Fat	1.11	1.10	1.15	1.01	1.20	1.23	1.01	.53	NS	**	**	Parity × period	.06
Protein	.91	.94	1.00	.85	1.04	1.03	.87	.32	*	**	**	Contrast 1	.01
												Diet × parity × period	.04

[1] $\sqrt{\text{MSE}}$ as reported is between cows. SE = $\sqrt{\text{MSE}}/\sqrt{n}$; $\sqrt{n_{\text{diet}}} = 12$, $\sqrt{n_{\text{parity }1}} = 12.7$, $\sqrt{n_{\text{parity }>1}} = 16.4$, $\sqrt{n_{\text{period}}} = 14.7$.

[2] Contrasts for diet effect: 1) SBM vs. CGM + DBG; 2) CGM vs. DBG.

[3] $P \geq .10$.

†$P \leq .10$.

*$P \leq .05$.

**$P \leq .01$.

TABLE 6. Average BW and BW change of cows fed corn gluten meal (CGM) or dried brewers grains (DBG) to partially replace soybean meal (SBM) in the diet.

	Diet			Parity		Period			Effect		
Item	SBM	CGM	DBG	1	>1	1	2	$\sqrt{MSE}$[1]	Diet	Parity	Period
Average BW, kg	551	549	547	515	583	547	551	43	NS[2]	**	NS
BW Gain, kg	.14	.14	.21	.36	−.03	.01	.32	.28	NS	**	**

[1] $\sqrt{MSE}$ as reported is between cows. SE = $\sqrt{MSE}/\sqrt{n}$; $\sqrt{n_{diet}} = 4$, $\sqrt{n_{parity\ 1}} = 4.2$, $\sqrt{n_{parity\ >1}} = 5.8$, $\sqrt{n_{period}} = 6.9$

[2] $P \geq .10$.

**$P \leq .01$.

As expected, production differed by parity ($P < .06$) and by period ($P < .01$) (Table 5). Also, FCM did not differ because of diets, but differences were due to parity and period (Table 5). Parity by period interactions were partially due to the marked milk production advantage by multiparous cows in period 1, which was not different in period 2.

The DMI was greatest for cows fed DBG and CGM diets (Table 5), which partially, but not entirely, corresponded to differences in milk production. Digestibility of DM was similar for the three diets; however, a diet by period interaction was significant. Efficiency of milk production (milk per unit of DMI) was less for CGM. Both SBM and DBG were similar in efficiency. Differences occurred for parity and period.

Milk composition generally was unaffected by diet (Table 5) except for SNF and lactose. Fat content was normal, and percentage of milk protein was marginally low. Production of fat was not different because of diet, but protein production was greater for the high RUP diets, especially DBG. The differences in protein production that were due to diets corresponded largely to the differences in milk production.

Average BW and BW changes were not different for diets (Table 6). First lactation cows had lower BW but had greater BW gains than multiparous cows. Their BW gains were greater in period 2, which was after peak milk production (perhaps better described as midlactation, when positive BW would be expected).

Ruminal pH and total VFA concentrations were in the normal range for all diets (Table 7)

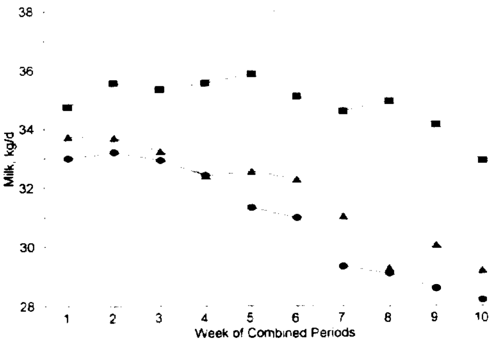

Figure 1. Weekly milk production over both periods by cows fed soybean meal (●) or soybean meal partially replaced by corn gluten meal (▲) or by dried brewers grains (■).

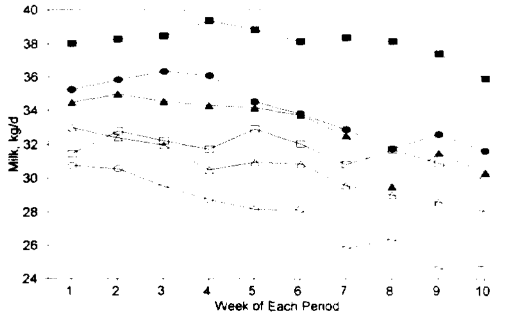

Figure 2. Weekly milk production showing interaction of diet by period by cows fed soybean meal in period 1 (●) or period 2 (○), or soybean meal partially replaced by corn gluten meal in period 1 (▲) or period 2 (△) or by dried brewers grains in period 1 (■) or period 2 (□).

TABLE 7. Ruminal pH, VFA, NH_3 N concentration and plasma urea N of cows when corn gluten meal (CGM) or dried brewers grains (DBG) partially replaced soybean meal (SBM) in the diet.

	Diet			Parity		Period			Effect			Contrasts[2]	
Item	SBM	CGM	DBG	1	>1	1	2	$\sqrt{MSE}$[1]	Diet	Parity	Period	and interactions	$P <$
pH	6.6	6.5	6.6	6.6	6.6	6.6	6.6	.4	NS[3]	NS	NS	Diet × period	.07
Total VFA, m*M*	70.9	75.6	72.9	74.5	71.8	77.0	69.3	19.8	NS	NS	†		
Acetate (A), mol/100 mol	62.7	63.6	62.4	62.0	63.8	63.3	62.5	3.4	NS	*	NS		
Propionate (P), mol/100 mol	20.8	19.2	21.1	21.2	19.6	20.6	20.2	4.4	NS	NS	NS		
Isobutyrate, mol/100 mol	1.0	1.0	.9	.9	1.0	.9	.9	.1	*	*	NS	Contrast 1	.08
												Contrast 2	.03
Butyrate, mol/100 mol	11.8	12.4	12.0	12.2	11.9	11.6	12.6	1.5	NS	NS	**		
Isovalerate, mol/100 mol	2.0	2.2	1.9	2.0	2.1	1.9	2.1	.4	NS	NS	†	Contrast 2	.05
Valerate, mol/100 mol	1.6	1.7	1.7	1.7	1.7	1.7	1.7	.2	NS	NS	NS	Diet × period	.01
												Diet × parity	.04
A:P Ratio	3.2	3.4	3.0	3.0	3.4	3.2	3.2	.8	NS	†	NS	Contrast 2	.06
NH_3 N, mg/dl	41.4	33.6	40.9	36.4	40.9	37.2	40.1	18.8	NS	NS	NS		
Plasma urea N, mg/dl	12.8	15.0	13.0	14.1	13.1	14.8	12.4	5.8	NS	NS	*		

[1] $\sqrt{MSE}$ as reported is between cows. SE = $\sqrt{MSE}/\sqrt{n}$; $\sqrt{n_{diet}} = 5.7$, $\sqrt{n_{parity\ 1}} = 6$, $\sqrt{n_{parity\ >1}} = 7.7$, $\sqrt{n_{period}} = 9.8$.

[2] Contrasts for diet effect: 1) SBM vs. CGM + DBG; 2) CGM vs. DBG.

[3] $P \geq .10$.

† $\leq .10$.

*$P \leq .05$.

**$P \leq .01$.

and were unaffected by diet. The diet by period interaction observed with ruminal pH was due to an increase in pH in the SBM and DBG diets in period 2 relative to that in period 1, and the pH of CGM remained relatively constant. The percentage of contribution of each VFA was as expected. Differences in certain VFA for the CGM and DBG diets were significant compared with each other or with the SBM diet but were unexplained, except for, possibly, isovalerate. The acetate to propionate ratio was higher for the CGM diets and was the result of modest shifts in concentration of ruminal acetate and propionate. Ruminal NH_3 N was unaffected by diet. However, the contrast between CGM and DBG (33.6 vs. 40.9 mg/dl) was significant ($P < .15$). Concentrations of urea in blood were similar across diets and parities but lower in period 2.

DISCUSSION

Relative to cows consuming SBM diets, cows consuming DBG diets produced 4 kg or 13% more milk (Table 5). Seymour and Polan (28) observed an advantage of 1 kg/d ($P < .05$) in milk production (average = 31.8 kg/d) for DBG diets compared with SBM diet. In their study (28), the diet was 20% alfalfa haylage, and fermentability of the diet probably was lower than in the current study because less corn was used. In another study (23) at the Virginia Polytechnic Institute and State University, in which dietary CP was similar to that in our study, cows fed DBG produced more milk (29.4 vs. 26.2 kg/d) than those fed SBM.

In the present study, FCM production was not significantly greater for DBG. Hoffman and Armentano (13) reported 3.5% FCM production averages of 36.7, 37.8, and 36.2 kg/d for cows fed wet brewers grains, DBG, and SBM as the sole protein supplements in alfalfa forage diets. Milk production and milk components were not different among diets.

Cows fed CGM produced slightly more milk than those fed SBM (31.7 vs. 30.8 kg/d). Polan et al. (22) observed less milk production (32.9 vs. 37.4 kg/d) in early lactation when CGM totally replaced SBM in diets based on corn silage. When CGM diets were supplemented with ruminally protected Lys, milk production response was restored to about 35 kg/d. In a similar study, Holter et al. (14) found no milk production advantage when RUP was increased from 35 to 39% CP by addition of CGM to a diet of corn, corn silage, and SBM. Holter et al. (14) suggested that, when corn is dominant in dairy diets, diets that are lower in CP but supplemented with RUP sources that are highly digestible and rich in Lys, Met, and Ile may be desirable. The suggestion to provide intestinally available AA concurs with concepts expressed by Polan (21), Chandler (6), and Chalupa et al. (5).

Schwab (26) calculated Lys and Met (grams per kilogram of CP consumed) available for absorption in the small intestine for several feed sources: 22.6, 13.8, and 8.1 for Lys and 5.1, 9.3, and 15.5 for Met for SBM, DBG, and CGM, respectively. When these values were applied to our diets, the DBG diet provided more Met (12.9 vs. 7.7 g/d) and a similar quantity of Lys (34.1 vs. 34.3 g/d) compared with the SBM diet. The CGM diet supplied more Met (13.0 vs. 7.7 g/d) but less Lys (26.8 vs. 34.3) than the SBM diet. Therefore, when DBG were partially substituted for SBM, the availability of Met for absorption increased without adverse effect on the quantity of Lys. In contrast, partial substitution of CGM for SBM decreased availability of Lys but increased markedly the availability of Met. According to Schwab et al. (27), with corn-based diets, Lys might be expected to be first-limiting and Met probably is second-limiting or colimiting. Evidence for Met demand in our study is indicated by the positive responses for milk production (4 kg/d) and milk protein (120 g/d) that occurred when DBG partially replaced SBM. According to our calculations, an increase of 5.2 g/d of Met was available for absorption for cows fed DBG relative to SBM.

Milk contains .89 g/kg of Met and about 2.7 g of Met/100 g of AA (21). Assuming 56% efficiency for incorporation of luminal AA into milk protein (accounting for absorptive and metabolic losses) (16), 5.2 g/d of Met, if limiting, provide about 100 g of AA or 3 kg of milk. These theoretical calculations correspond fairly well to our observations.

In our study, expected large increase in availability of Met and decrease in Lys when the diet was fed resulted in no responses for milk production or milk protein compared with that of the SBM diet. This lack of response may indicate that Lys was not so critically limiting in the SBM diet. In another study (22), supplementation with protected Lys enhanced milk and milk protein production in cows fed CGM as the sole protein supplement in diets based on corn and corn silage, but protected Met was ineffective.

Chandler (6) and Chalupa et al. (5) indicated that branched-chain AA may be limiting or colimiting for milk production. Based on feedstuff concentrations of branched-chain AA (grams per 100 g of CP), the DBG diet contained somewhat more Leu and Val than the SBM diet and, except for Leu, more than did the CGM diet. Both Ile and Val were lowest in the CGM diet. Considering the bypass potential, the branched-chain AA profile of DBG matches more closely that of milk AA.

Primiparous cows recovered BW more readily than older cows (Table 6). Holter et al. (14) reported that undegraded protein (CGM) spared BW loss for 1 to 8 wk postpartum and enhanced BW recovery as lactation progressed in first lactation cows but had no effect on older cows. No effect was due to diet in our study. However, cows were changed to an alternate dietary protein after 10 wk, which may have obscured longer term BW gains.

Ruminal isovalerate was higher for CGM (2.2 vs. 1.9%) than DBG. Leucine is unusually high in CGM relative to the other branched-chain AA that it contains and relative to the other protein sources fed in this study. Isovalerate is a known predominant degradation product of Leu (2).

CONCLUSIONS

Cows fed diets in which about one-half of supplemental SBM was replaced by DBG produced more milk and milk protein than those fed SBM alone or SBM partially replaced by CGM. The response to DBG was explained by the contribution of RUP that meets AA needs that are limiting or colimiting to production of milk and milk protein.

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