

Influence of post-calving supplemental protein on calf performance and reproductive efficiency for beef cows fed silage

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Charmley, E., Small, J. A. and McRae, K. B. 1999. **Influence of post-calving supplemental protein on calf performance and reproductive efficiency for beef cows fed silage.** *Can. J. Anim. Sci.* **79**: 97–106. Protein supplementation for winter-calving beef cows between calving and turnout to pasture was studied in two trials. Changes in cow body weight (BW) and condition and calf BW gains were recorded from calving to weaning in the fall. Reproductive performance was monitored, and in trial 2, milk production was determined. In trial 1, multiparous silage-fed cows were allocated to one of five levels of corn gluten meal (CGM): 0, 200, 400, 600 and 800 g d⁻¹. In the second trial, cows were allocated to either restricted or ad libitum silage feeding in combination with three protein supplements: no protein, 400 g d⁻¹ CGM or 475 g d⁻¹ soybean meal (SBM). In trial 1, cows gained weight during supplementation, but on pasture they lost weight (linear effect, $P = 0.10$). Calf gains and weights at turnout and weaning showed a quadratic response to protein supplementation ($P < 0.05$). There was a trend toward a linear decline in days to first service with increasing levels of CGM ($P < 0.10$). In trial 2, cows on restricted silage feeding lost weight ($P < 0.05$) and body condition ($P < 0.10$), whereas those fed ad libitum silage gained weight and condition. On pasture, this pattern of weight change was reversed ($P < 0.05$). Protein supplementation did not influence BW change but tended to cause a lower body condition score at turnout ($P = 0.10$). Restricting silage intake to the cow did not affect calf performance, but protein supplementation increased gains both during supplementation and on pasture, thus increasing weaning weights ($P < 0.05$). When silage was fed ad libitum, SBM was more effective than CGM for increasing calf gain. However, when silage was restricted, CGM was more effective. Restricting silage intake did not impair milk production, but feeding CGM increased milk production ($P < 0.05$). For ad libitum-fed cows, protein supplementation increased pregnancy rate; restricting feed had the opposite effect. Our data suggest that protein supplementation to silage-fed beef cows in good body condition can increase calf performance; however, the level of supplementation is critical, and possible adverse effects on breeding have to be taken into account, particularly with cows in negative energy balance after calving.

Key words: Beef cow, protein, milk production, calf gains, silage

Charmley, E., Small, J. A. and McRae, K. B. 1999. **Influence d'une complémentation alimentaire protéique post-vêlage sur les performances du veau et sur l'efficacité de reproduction de vaches d'élevage nourries à l'ensilage.** *Can. J. Anim. Sci.* **79**: 97–106. Deux essais ont été réalisés sur des vaches d'élevage de boucherie pour observer les effets d'une complémentation protéique entre le vêlage en hiver et la mise à l'herbe au printemps suivant. Nous avons mesuré les changements de poids et d'état corporels de la mère et les gains de poids corporel du veau à partir du vêlage jusqu'au sevrage l'automne suivant. En outre, les performances de reproduction étaient contrôlées et dans l'essai 2, on observait également la production de lait. Dans l'essai 1, des vaches multipares nourries à l'ensilage étaient exposées, au hasard à l'un de cinq niveaux de farine de gluten de maïs (FGM), soit 0, 200, 400, 600 et 800 g j⁻¹. Dans l'essai 2, les vaches recevaient une alimentation rationnée ou à volonté d'ensilage, combinée à 3 niveaux de complémentation protéique: pas de complément, 400 g j⁻¹ FGM ou 475 g j⁻¹ de tourteau de soja (TS). Dans l'essai 1, les vaches prenaient du poids durant la période de complémentation, mais en reperdaient au pâturage (effet linéaire, $P = 0,10$). Les gains pondéraux des veaux et leur poids corporel à la mise à l'herbe et au sevrage montraient une réponse quadratique à la complémentation protéique ($P < 0,05$). On constatait un raccourcissement linéaire de l'intervalle vêlage-première insémination, à mesure qu'augmentaient les niveaux de FGM ($P < 0,10$). Dans l'essai 2, les vaches rationnées en ensilage perdaient du poids ($P < 0,05$) et leur état corporel était moins bon ($P < 0,10$), alors que celles recevant l'ensilage à volonté prenaient du poids et amélioraient leur état corporel. Au pâturage, c'était l'inverse qui se produisait ($P < 0,05$). La complémentation protéique n'avait pas d'effet sur l'évolution du poids corporel, mais produisait des notations d'état corporel plus basses à la mise à l'herbe ($P = 0,10$). Le rationnement de l'ensilage n'avait pas de conséquence pour les performances du veau, mais la complémentation protéique se traduisait par de meilleurs gains de poids vif, aussi bien durant la phase de complémentation qu'au pâturage et, par conséquent,

Abbreviations: ADF, acid detergent fibre; AI, artificial insemination; BCS, body condition score; BW, body weight; CGM, corn gluten meal; CP, crude protein; DIP, degradable intake protein; DM, dry matter; ME, metabolizable energy; NDF, neutral detergent fibre; SBM, soybean meal; TCA, trichloroacetic acid; UIP, undegraded intake protein

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par de meilleurs poids au sevrage ($P < 0,05$). En régime d'ensilage à volonté, le TS était plus efficace que la FGM pour augmenter le GMQ du veau, mais c'est l'inverse qui s'observait lorsque l'ensilage était rationné. La production de lait n'était pas diminuée par le rationnement de l'ensilage, mais elle montrait une augmentation en présence de FGM ($P < 0,05$). Chez les vaches servies d'ensilage à satiété, la complémentation protéique améliorait le taux de gravidité. Chez les vaches rationnées en ensilage, c'est l'effet inverse qu'on observait. Il ressort de nos résultats qu'un complément protéique servi à des vaches d'élevage à viande nourries à l'ensilage, en bon état corporel, peut accroître les performances de leur veau. Toutefois, c'est le niveau de complémentation qui est le facteur critique car il peut entraîner des effets négatifs sur la reproduction, notamment chez les vaches montrant un bilan énergétique négatif à la suite du vêlage.

Mots clés: Vache d'élevage à viande, protéine, production de lait, gain de poids du veau, ensilage

Nutrient requirements of beef cows are low relative to other classes of ruminant livestock (National Research Council [NRC] 1989; 1996). Consequently, there is considerable research on exploiting inexpensive feedstuffs of low nutritional value and the problems of undernutrition. There is relatively less research on the feeding of higher quality feedstuffs. Ensiling is the preferred forage conservation method in areas of high summer rainfall and is used by the beef industry in those areas.

Growth rate of the suckled calf depends on the milk production of the cow (Wright and Russel 1986). Modifying nutritional management can increase milk production of the cow and thereby increase calf growth rate. Energy supply and energy partitioning have been exploited for a number of years to increase both growth rate of the calf and reproductive efficiency of the cow. For example, providing better energy nutrition post calving has been shown to improve calf performance (Laflamme and Connor 1992). Feeding to improve condition before calving can increase calf birth weight and subsequent gains by allowing for increased mobilization of body reserves (Houghton et al. 1990). Altering energy intake to manipulate body condition has also been shown to have major influences on reproductive performance (Richards et al. 1986). Cows in poor or declining condition after calving have longer periods of anestrus and are more difficult to breed than cows in adequate condition (Laflamme and Connor 1992).

There is little research on the influence of protein supplementation of the cow on calf growth rate, probably because protein requirements of the beef cow are deemed to be relatively low (NRC 1996). Rusche et al. (1993) showed that calf performance can be improved when the dam is fed extra protein, especially if it is of low degradability. Research with dairy cows has clearly shown that supplementation with protein of low to moderate degradability can increase milk yield, especially when the ration is silage based (Robinson et al. 1992). Protein supplementation also influences reproductive efficiency. Inadequate protein supply either pre- or postpartum can severely depress reproductive performance. Randel (1990) reviewed a number of papers, all of which showed lower pregnancy rates with an inadequate protein supply. With dairy cows, where dietary CP concentration is high (>20%), excessive protein in the diet can also depress reproductive performance (Treacher et al. 1976). Since beef cows are fed diets with CP concentration of much less than 20%, problems of high CP influencing reproduction should be rare. However, beef cows fed good-quality legume silage may be ingesting large amounts of

highly soluble CP. Evidence suggests that it is not just the amount of protein, but also its solubility, that is important (Randel 1990).

We hypothesized that for silage-fed beef cows, ME intake would not limit milk production, but a response in calf performance to protein may be expected, considering the high solubility of silage protein. As well, we were concerned that supplemental protein may adversely influence reproductive performance. To test these hypotheses two feeding trials were planned in which the effects of protein supplementation to the cow on calf growth and cow reproductive efficiency were evaluated.

MATERIALS AND METHODS

Two trials were conducted in successive years (1994 and 1995) with a winter-calving (January/February) beef herd of primarily Hereford or Beef Shorthorn \times Hereford cows. After fall weaning, all cows were grazed until late October and then fed round-bale hay or silage until the beginning of December. From December on, cows were fed precision-chop silage, using a Calan (American Calan, Inc., Northwood, NH) gate feeding system. Treatments began at calving and were continued until turnout (supplementation period). Measurements were taken until weaning in September or October (grazing period).

At turnout, all cows and calves were grazed under rotational-grazing management. Pasture comprised a naturalized permanent sward containing predominantly quackgrass (*Agropyron repens*), Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratense*) and white clover (*Trifolium repens*). Paddocks were grazed to an estimated sward height of 6 cm before cattle were moved on to a new paddock. Conservation cuts were taken from paddocks when grass growth was surplus to cattle demand.

Body condition score was assessed by palpation using a 0 to 9 scale (Lowman et al 1976).

Breeding season commenced on 1 April and lasted 45 d. All cows were bred by AI to first service, and then by either AI or natural breeding using Hereford bulls in subsequent services. In 1994, cows were not synchronized for breeding, whereas in 1995 estrus was synchronized, and in both years blood samples were collected by jugular venipuncture into nonheparinized vacutainer tubes at the time of AI and 21 and 25 d later for progesterone analysis. Cows with serum progesterone concentrations less than 1 ng mL⁻¹ (low) at AI and subsequently greater than 1 ng mL⁻¹ (high) on days 21 and 25 with no subsequent service were considered to have conceived to the first service. Pregnancy rates were deter-

mined by palpation 90 to 120 d after the breeding season. In year 2, real-time ultrasonography was also used at 35 d after first AI to verify first-service conception rates.

In both trials, animals were cared for in accordance with guidelines suggested by the Canadian Council on Animal Care.

Trial 1 (1994)

ANIMALS AND DIETS. Forty-eight multiparous cows were allocated to one of five treatments at calving. Cows were blocked according to breed type, sire of calf, and expected calving date. All cows were fed the same silage (Table 1) once a day between 09:30 and 11:00; the silage was top dressed with the appropriate supplements. Weighbacks were taken each morning before feeding. The dietary treatments comprised ad libitum silage supplemented with either 0, 200, 400, 600 or 800 g d⁻¹ CGM.

The average calving date was 6 February (range 11 January to 12 March). The supplementation period ended at turnout on 25 May. Calves were weaned on 3 October.

During indoor feeding, individual DM intake of cows was recorded daily. Body weight gain and BCS of cows and BW gain of calves were recorded at calving and at 2wk intervals until turnout. After turnout, BW gain of cows and calves and BCS of cows were recorded monthly until weaning.

BREEDING PROTOCOL. Observations of standing heat were made daily by experienced staff beginning 21 d before the breeding season and continuing until the end of breeding (11 March to 15 May). Cows observed in estrus between 06:00 and 10:00 h were bred at 15:00 h, whereas cows observed in estrus between 06:00 h and 10:00 h were bred at 08:00 h the following morning. Cows in standing heat were inseminated with proven Hereford or Shorthorn semen by one of two experienced technicians. Bulls were placed with the cows on 5 May.

Trial 2 (1995)

ANIMALS AND DIETS. Fifty-two multiparous cows were selected for the study and preassigned to treatments on the basis of breed, sire of the calf, and expected calving date. The six treatments were arranged in a 2 × 3 factorial design, with silage intake (ad libitum and restricted [15 g DM intake kg⁻¹ BW]) and protein source (no supplement [control], CGM at 400 g d⁻¹ or SBM at 475 g d⁻¹) as the two factors. Feeding management was the same as for trial 1. Protein supplements were fed at levels designed to supply equal amounts of CP. According to NRC (1996) the SBM would supply a higher proportion of DIP (65% CP) than the CGM (41% of CP). The average calving date was 2 February (range, 13 January to 5 March). The supplementation period ended at turnout on May 24, and the grazing period continued until 11 September, when calves were weaned.

BREEDING PROTOCOL. Estrus was synchronized using a combination of a 9-d ear implant containing 6 mg norgestomet (17 α -acetoxy-11 β -methyl-19-nor-preg-4-ene-3, 20 dione) and a single i.m. injection of 5 mg estradiol valerate and 3 mg norgestomet given at the time of implant insertion

Table 1. Composition of the silages in each year

	1994	1995
Dry matter (g kg ⁻¹)	430	304
Acid detergent fibre (g kg ⁻¹ DM)	347	387
Neutral detergent fibre (g kg ⁻¹ DM)	559	611
In vitro apparent DM digestibility (g kg ⁻¹ DM)	698	650
Metabolizable energy (MJ kg ⁻¹ DM)	10.6	9.86
Crude protein (g kg ⁻¹ DM)	137	135
TCA-insoluble N (g kg ⁻¹ N)	372	354
Ammonia N (g kg ⁻¹ total N)	77	177
Total fermentation acids (g kg ⁻¹ DM)	61	60
Lactic acid (g kg ⁻¹ DM)	48	39
pH	4.49	4.76

(Synchronate-B®; Sanofi, Overland Park, KS). Cows that did not show estrus within 14 d of implant removal were given a single 250- μ g i.m. injection of cloprostenol (Estrumate®, Mallenkrodt, Inc. [formerly Coopers Agropharm Inc.] Ajax, ON). At the time when the synchronization regime was initiated, ovarian structures and uterine involution were determined by palpation. Observations of standing heat were made daily by experienced staff for 35 consecutive days, beginning at the time of implant withdrawal. Cows observed in standing heat were inseminated with proven Hereford or Shorthorn semen by one of two technicians trained and experienced in AI methodology.

MILK PRODUCTION. All cows were milked for determination of milk yield and composition in April and August 1995. Cows were separated from calves at 08:00 and milked using oxytocin to encourage milk letdown. Cows were again milked after an average separation time from calves of 6 h. Milk weight was corrected to a theoretical 24-h milk production. Samples of milk were collected from each cow and analysed for fat and protein with a Milko-scan analyzer by the Nova Scotia Department of Agriculture and Marketing, Truro, NS.

Analysis

Dry matter in silage was determined by toluene distillation (Dewar and McDonald 1961), and in other feeds by oven drying at 50°C for 48 h and correction by drying at 105°C. Organic matter was determined as weight lost upon ashing at 550°C. Total N was determined in fresh silage by Kjeldahl procedures (Association of Official Analytical Chemists 1984). Insoluble N was determined in fresh silage using TCA. Ash-free NDF and ADF were analyzed by methods described by Van Soest et al. (1991). Volatile fatty acids and alcohols were determined in acid extracts of silage using gas chromatography (Varian model 3600 GC, Varian Canada, Mississauga, ON). Lactic acid in acid extracts was determined by the colorimetric method of Barker and Summerson (1941). Silage pH was determined on macerated samples (10 g) in distilled water (200 mL). The concentrations of fat and lactose in milk were determined using an infrared milk analyser (Biggs 1967) by the Nova Scotia Department of Agriculture and Marketing Milk Testing Laboratory, Truro, NS.

Table 2. Intake of DM, CP, estimated ME, BW and BCS change in silage-fed cows supplemented with different amounts of CGM and rate of gain of their calves in trial 1²

	CGM supplementation (g d ⁻¹)					SEM (n = 10; df = 37)	Significance probability	
	0	200	400	600	800		Linear	Quadratic
DM intake (kg d ⁻¹)	13.2	13.3	13.0	13.3	14.2	0.45	0.88	0.37
DM intake (g kg ⁻¹ BW)	21.3	19.8	20.0	20.4	20.7	0.84	0.87	0.24
Total supplemental protein intake (kg)	0	15.6	36.4	53.1	72.7			
CP intake (g d ⁻¹)	1780	1900	1900	2040	2320			
Estimated ME intake (MJ d ⁻¹)	139	141	132	136	150			
Cow BW change during supplementation (kg d ⁻¹)	0.77	0.69	0.76	0.98	0.50	0.129	0.60	0.19
Cow BW change on pasture (kg d ⁻¹)	-0.05	0.1	0.16	0.13	0.22	0.051	0.10	0.95
BCS at calving	5.89	5.75	5.56	5.50	5.72	0.21	0.41	0.26
BCS at turnout	6.27	6.12	6.31	6.00	6.00	0.21	0.29	0.83
BCS at weaning	6.22	6.50	5.88	6.00	6.21	0.21	0.44	0.42
Calf BW gain during supplementation (kg d ⁻¹)	0.78	0.83	0.91	0.86	0.76	0.052	1.00	0.03
Calf BW gain on pasture (kg d ⁻¹)	1.19	1.27	1.40	1.25	1.26	0.074	1.00	0.06
Calf BW gain overall (kg d ⁻¹)	0.92	1.05	1.04	0.98	0.88	0.041	0.22	<0.01
Calf birth weight (kg)	38	42	43	42	42	1.77	0.18	0.19
Calf turnout weight (kg)	116	124	135	127	117	5.05	0.84	<0.01
Calf weaning weight (kg)	248	264	284	265	240	8.88	0.43	<0.01

²Protein supplied from calving to 25 May (mean feeding period; 108 d)

Table 3. Reproductive performance of silage-fed cows supplemented with different levels of CGM in trial 1

	Level of CGM supplementation to silage fed ad libitum (g d ⁻¹)					SEM	Response	
	0	200	400	600	800		Linear	Quadratic
Days to first service	80	75	66	70	65	5.8	0.04	0.49
Days open	83	75	72	75	83	7.1	0.81	0.22
Calving interval (d)	367	362	358	359	366	7.0	0.81	0.22

Serum was removed from blood and stored frozen until analysis of progesterone concentrations, which were determined by radioimmunoassay (Coat-a-count®; Diagnostic Products Corporation, Los Angeles, CA). Concentrations of progesterone were determined in a single assay each year with 7% and 0.07 ng mL⁻¹ and 9% and 0.09 ng mL⁻¹ intra-assay variation and sensitivity in 1994 and 1995, respectively.

Statistical Analysis

In trial 1, the effects of level of CGM supplementation were tested for linear and quadratic trends by ANCOVA, using Genstat 5 release 3 (Genstat 5 Committee 1993). The full model was used to assess the significance of pen effects, sex of calf, and length of feeding period as covariates. Nonsignificant effects were dropped from the model for estimating the treatment effects, reported as being statistically different in the text at $P < 0.05$, unless noted otherwise. Because of the imbalance of animals in treatment groups for trial 2, the statistical procedure of residual maximum likelihood, REML in Genstat 5, was used to calculate the fixed effects of cow age, breed and calving date, before assessing the effects of energy level and protein supplementation on production parameters. The experimental factors were tested sequentially using the Wald statistic, and the significance levels are given in the tables. In both trials, estrus detection, first-service conception, and pregnancy rates were tested using chi-square analysis.

RESULTS

In each year for silage, forage was harvested from mixed swards containing timothy, quackgrass (*A. repens*), Kentucky bluegrass and white clover. Table 1 summarizes the composition of the silages used in the 2 yr of experimentation. Differences in DM concentration reflect variations in drying conditions between years. All silages were of similar feeding value, with ME values, calculated from in vitro digestibility, of around 10 MJ kg⁻¹ DM and CP averaging 136 g kg⁻¹ DM. Silage fermentations were judged to be restricted and heterofermentative. Protein solubility was high, as shown by the low TCA-insoluble N concentration.

Trial 1

Total DM intake during the supplementation period averaged 20 g kg⁻¹ BW and was not influenced by level of protein supplementation (Table 2). As a consequence of ad libitum feeding of good-quality silage, all cows gained weight between calving and turnout (Table 2). On pasture cows lost weight, but treatment had little effect on the magnitude of weight loss, although there was some evidence of greater weight loss in cows that had received the most protein over the winter ($P = 0.10$). Cows were in moderate body condition at calving (5.7) and gained approximately 0.5 units during silage feeding. Body condition score remained unchanged over the summer with no treatment effects. During the supplementation period, calf gains ranged

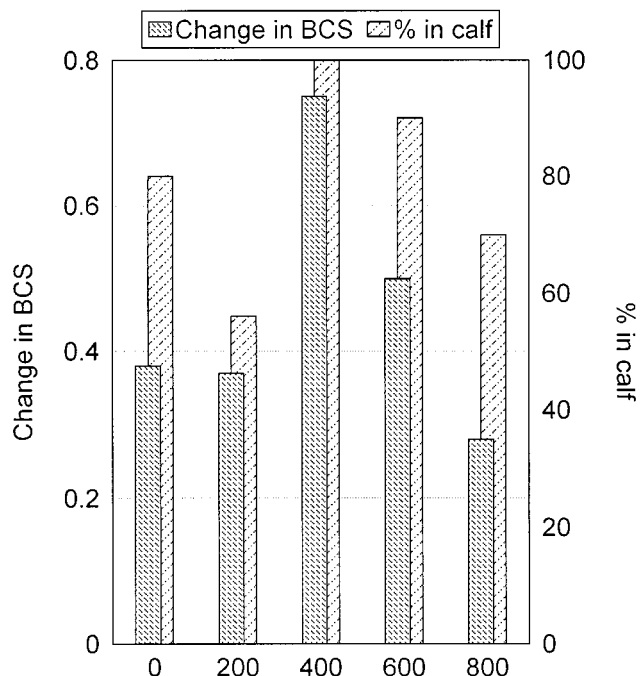


Fig. 1. Percentage of cows confirmed in calf in August and the change in body condition between calving and turnout (trial 1).

between 0.76 and 0.91 kg d⁻¹, with higher gains for calves of cows fed intermediate levels of protein. On pasture, this pattern was repeated, resulting in a trend toward a quadratic response to protein supplementation ($P = 0.06$). Consequently, a significant quadratic response to protein in calf weights at turnout and weaning was found; calves from cows fed 400 g CGM d⁻¹ were 36 and 44 kg heavier at weaning than calves from cows fed 0 or 800 g d⁻¹ CGM, respectively.

There was a negative linear effect on days to first service with increasing level of CGM feeding (Table 3), although overall rates of estrus detection (87%), first-service conception (67%), pregnancy (78%) and nonpregnancy (22%) did not differ among treatment groups (data not shown). However, all repeat service (6%) occurred in CGM groups, and the difference between the interval to first service and the interval to pregnancy tended to be highest ($P = 0.09$) for cows given 800 g d⁻¹ CGM. Although there were no effects of treatment on calving interval, it was 10 d shorter for cows fed 400 g d⁻¹ CGM than for those fed 0 or 800 g d⁻¹ CGM. The percentage of cows pregnant was also highest for cows fed the intermediary levels (400 and 600 g d⁻¹) of CGM (Fig. 1).

Trial 2

Total DM intake during the supplementation period for cows fed silage ad libitum was slightly less than in trial 1, averaging 18 g kg⁻¹ BW (Table 4). At the restricted level of feeding, total DM intake was approximately 75% of ad libitum feeding. Protein supplementation increased total DM intake by about 1 kg in cows fed ad libitum, indicating that

protein supplementation increased silage intake. During the supplementation period, cows on restricted silage feeding were in negative energy balance and lost weight and body condition ($P < 0.10$), whereas those fed ad libitum silage gained weight (Table 4). However, once on pasture, cows fed restricted silage over winter gained more weight than those fed ad libitum silage over winter. Protein supplementation did not influence BW change but tended to result in lower BCS at turnout ($P = 0.10$).

Restricting the cow's silage intake did not affect calf performance (Table 4). Rates of gain and weaning weights were the same for calves from cows having an estimated ME intake ranging from 80 to 125 MJ d⁻¹. Protein supplementation, on the other hand, increased gains both during supplementation and on pasture. Consequently, weaning weights were higher in calves from cows that had received supplemental protein. There was a strong interaction between the effect of protein supplementation and level of silage feeding. When silage was fed ad libitum, SBM was more effective than CGM for increasing calf gain. However, when silage was restricted, the opposite was true, with CGM being more effective.

Restricting silage intake did not reduce milk production (Table 5). In April, there was some evidence of increased production of milk ($P = 0.09$) and its components (fat, $P = 0.08$; protein, $P = 0.14$) in response to protein supplementation, but because of the high variability in milk production, this difference was not significant. However, if the contrast between the control and CGM treatments is considered, the response in milk and milk fat production was significant ($P = 0.04$ and 0.05, respectively). Protein concentration in milk tended to be reduced ($P = 0.06$) by supplementation, largely due to low values when SBM was fed. In August, milk production was less than half that of April. There appeared to be a carryover effect of feeding CGM before turnout, with cows on these treatments producing more milk fat than other cows.

Reproductive performance was influenced by level of silage feeding such that cows fed restricted silage had fewer days to estrus and subsequent calving than cows fed ad libitum (Table 6). The effect of level of silage feeding on pregnancy rate appeared to be modified by protein supplementation (interaction, $P = 0.09$) (Fig. 2). Although the percentage of cows responding to estrus synchronization (74%), overall estrus detection rate (87%), and overall pregnancy rate including returns (64%) did not differ among groups, when silage was fed ad libitum supplemental protein improved first-service pregnancy rate, whereas when silage was restricted supplemental protein tended to lower first-service pregnancy rate (Table 7). Nonpregnancy was primarily due to failure to establish pregnancy with ad libitum silage feeding (8 out of 10 cows) and anestrus with restricted silage feeding (4 out of 7 cows).

The number of days postpartum and uterine involution did not differ among treatments when estrus synchronization commenced (data not shown). Cows were 19 to 73 d (54.4 ± 15.3 d [mean \pm standard deviation]) postpartum, and involution was 60 to 100% ($91.6 \pm 11.4\%$). Treatment had no effect on ovarian structures; a corpus luteum and/or fol-

Table 4. Intake of DM, CP, estimated ME, BW and BCS change in cows fed silage at two levels of intake without or with supplemental SBM or CGM and rate of gain of their calves in trial 2^z

	Ad libitum silage			Restricted silage			SEM	Probability		
	Control	SBM	CGM	Control	SBM	CGM		Protein (P)	Silage (S)	P × S
DM intake (kg d ⁻¹)	11.3	12.7	12.2	8.15	8.54	8.50	0.536	0.01	<0.01	0.32
DM intake (g kg ⁻¹ BW)	17.2	19.4	18.3	13.5	14.0	13.3	0.09	0.09	<0.01	0.33
Total supplemental protein intake (kg)	0	45	41	0	43.0	42				
CP intake (g d ⁻¹)	1503	1879	1830	1084	1324	1334				
Estimated ME intake (MJ d ⁻¹)	111	125	120	80	84	84				
Cow BW change during supplementation (kg d ⁻¹)	0.37	0.00	0.17	-0.26	-0.28	-0.17	0.161	0.43	0.01	0.50
Cow BW change on pasture (kg d ⁻¹)	0.05	0.25	0.28	0.33	0.44	0.31	0.075	0.18	0.01	0.21
BCS at calving	6.53	5.90	6.48	6.51	6.68	5.98	0.249	0.55	0.53	0.03
BCS at turnout	6.81	6.03	6.15	6.18	5.92	5.63	0.292	0.10	0.08	0.64
Calf BW gain during supplementation (kg d ⁻¹)	0.76	0.93	0.85	0.79	0.81	1.00	0.054	0.03	1.00	0.03
Calf BW gain at pasture (kg d ⁻¹)	0.91	1.11	1.00	0.96	0.94	1.13	0.047	0.03	1.00	0.01
Calf BW gain birth to weaning (kg d ⁻¹)	0.58	0.73	0.65	0.62	0.66	0.78	0.054	0.09	0.58	0.01
Calf birth weight (kg)	42.6	41.4	41.2	41.4	42.0	43.8	1.76	0.95	0.65	0.55
Calf turnout weight (kg)	140	136	122	106	127	131	7.86	0.47	0.07	0.03
Calf weaning weight (kg)	221	266	243	232	229	273	9.70	0.01	1.00	0.01

^zProtein supplied from calving to 28 May (mean feeding period; 111 d).

Table 5. Milk production and composition of cows fed silage at two levels of intake without or with supplemental SBM or CGM in trial 2

	Ad libitum silage			Restricted silage			SEM	Probability		
	Control	SBM	CGM	Control	SBM	CGM		Protein (P)	Silage (S)	P × S
April production (kg d ⁻¹)										
Milk	9.0	10.4	13.6	8.8	10.6	12.2	1.88	0.09	0.75	0.90
Fat	0.350	0.37	0.56	0.28	0.35	0.43	0.088	0.08	0.32	0.82
Protein	0.31	0.33	0.42	0.28	0.32	0.39	0.058	0.14	0.58	1.00
April composition (g kg ⁻¹)										
Fat	31.9	30.2	42.8	30.5	33.7	35.8	4.97	0.17	0.75	0.58
Protein	33.8	31.2	31.8	32.9	30.7	32.6	1.08	0.08	0.75	0.74
August production (kg d ⁻¹)										
Milk	4.27	5.39	5.00	5.05	5.20	7.24	0.910	0.29	0.24	0.43
Fat	0.09	0.18	0.17	0.15	0.15	0.24	0.038	0.07	0.34	0.32
Protein	0.16	0.20	0.17	0.20	0.19	0.26	0.031	0.50	0.17	0.32
August composition (g kg ⁻¹)										
Fat	19.9	30.7	33.2	28.6	27.7	37.2	4.49	0.06	0.29	0.82
Protein	37.9	36.9	36.0	39.5	37.2	36.8	1.05	0.06	0.29	0.82

Table 6. Reproductive performance of beef cows fed silage at two levels of intake without or with supplemental SBM or CGM in trial 2

	Ad libitum silage			Restricted silage			SEM	Probability		
	Control	SBM	CGM	Control	SBM	CGM		Protein (P)	Silage (S)	P × S
Days to synchronized estrus ^z	68.6	73.8	69.5	62.6	54.0	64.0	7.4	0.90	0.05	0.45
Days to first service ^y	73.2	74.6	74.0	68.1	60.0	64.8	7.4	0.87	0.08	0.77
Days open	81.0	74.5	81.1	68.2	56.0	75.3	9.7	0.25	0.06	0.73
Calving interval (d)	364.6	356.2	370.5	353.0	340.7	353.6	10.1	0.28	0.06	0.96

^zIncludes only cows that showed estrus in response to synchronization.

^yIncludes all cows inseminated after observation of estrus.

licles (> 6 mm diameter) were present on one or both ovaries of 85% of cows, while 15% of cows had no significant structures on either ovary. The timing of inseminations relative to implant withdrawal was the same for all treatments (2.25 ± 0.44 d). In cows that responded (6 out of 12) to a pick-up dose of prostaglandin, inseminations occurred 3.6 ± 0.51 d after prostaglandin.

DISCUSSION

Silage Quality

The silages used in these trials were all of good quality (apparent digestibility 67.4 % of DM) and capable of supporting a lactating beef cow without supplementation, as shown by cows on control treatments. Although the silages had an average CP concentration of 13.6%, protein supple-

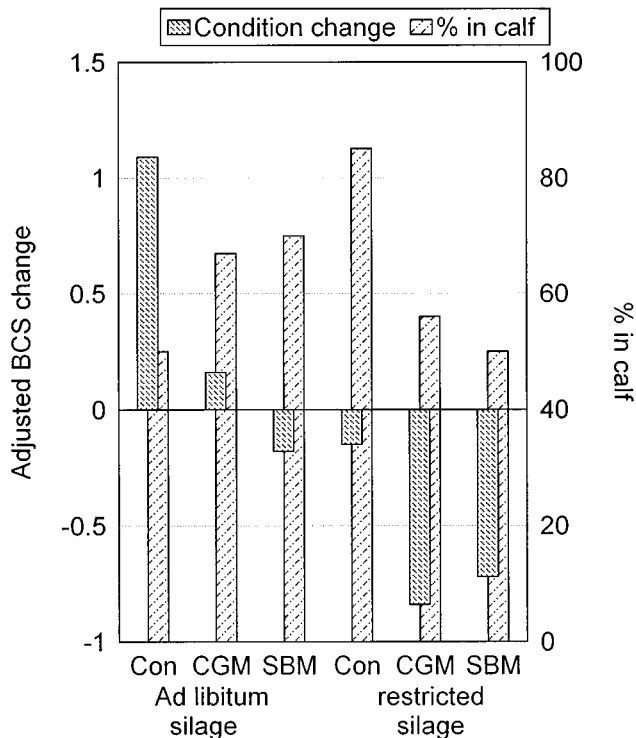


Fig. 2. Percentage of cows confirmed in calf in August and the change in body condition between calving and turnout adjusted for initial body condition (trial 2). To account for differences in initial BCS the following formula was used: $(6 - \text{initial BCS}) + (\text{initial} - \text{final BCS})$.

mentation still benefitted calf performance and cow reproductive efficiency. However, these findings are not surprising in light of the highly soluble nature of protein in silages (Broderick 1995). Research with growing cattle shows that steers fed silage respond to supplemental protein in the diet (Veira et al. 1990, 1994). In the silages used here, TCA-insoluble N accounted for about 36% of total N. Previous research suggests this is indicative of a highly soluble and rapidly degradable protein source in silage (Charmley et al. 1994).

Effect of Protein Level on the Response to Protein

The effect of supplemental protein for beef cows has mostly been examined in cows fed basal diets containing considerably less CP than in our trials (De Gracia and Ward 1991; Rusche et al. 1993; Triplett et al. 1995). In our trials protein intake from silage alone was at least 20% in excess of NRC (1996) requirements; therefore, a response to protein should not have been observed for any level of supplementation. However, NRC (1996) does not discount for a lower efficiency of microbial protein synthesis on silage-based diets. Other protein-evaluation systems account for this (Agricultural and Food Research Council [AFRC] 1992) and our data indicate that for lactating beef cows fed silage, protein supply to the small intestine limits calf growth

because of limited milk production. In dairy cows, silage diets of similar quality can support about 14 kg milk d^{-1} without supplementation (Rae et al. 1987). While this is still considerably higher than the levels predicted here, the higher intake capacity of dairy breeds per unit metabolic weight and their larger frame size must be taken into account.

In both trials, cows were in good body condition at calving (BCS = 6). In trial 1, there was a negative quadratic response to level of protein supplementation. This is similar to the negative quadratic response in cow weight change found by Blasi et al. (1991). In their study, cows grazing smooth brome (*Bromus inermis*) were supplemented with a highly undegradable protein supplement based on CGM and blood meal. Other research has observed a positive relationship between level of UIP and cow weight gain (Wiley et al. 1991; Dhuyvetter et al. 1993; Rusche et al. 1993). However, in those studies energy intake of cows was restricted, either by limit feeding or by forage quality. Under those conditions, the authors concluded that additional protein was serving as an energy source. In our study and that of Blasi et al. (1991), cows were consuming ad libitum forage of high digestibility. Thus, under these conditions any energetic influence of additional protein would be small.

Trial 1 provides evidence for a quadratic response in calf performance as CP concentration of the diet increased from 13.5 to 16.3%. Thus, cows fed intermediary levels of protein supplementation partitioned a greater proportion of gain to calves. The diets in trial 1 supplied between 1450 and 1770 g d^{-1} UIP to cows requiring only 1200 to 1500 g d^{-1} , depending on level of milk production (NRC 1996). In addition, the supply of estimated UIP increased from 360 to 700 g d^{-1} . Maximum calf gains were realized when estimated UIP was about 500 g d^{-1} . Based on the relationship between calf performance and milk production observed in the second trial, it is likely that maximum milk production also occurred at around this level of estimated UIP. Beyond this level, calf performance, and presumably milk production, declined. Blasi et al. (1991) found the same response pattern in cows supplemented with incremental amounts of UIP. Triplett et al. (1995) fed up to 480 g d^{-1} supplemental UIP to grazing Brahman cows but observed a response only up to 370 g d^{-1} . In our study, a decline in performance was not observed until predicted UIP values were somewhat higher, but our data are based on total, not supplemental, UIP. Wiley et al. (1991) showed higher serum insulin concentration in cows fed a diet supplying high levels of UIP relative to a low UIP diet and postulated that this could partition more nutrients toward tissue deposition and away from milk production. Thus, the poor calf performance from cows fed high levels of CGM could be attributed to an insulin effect. This hypothesis is further substantiated by the inverse relationship, albeit weak, between calf and cow gain.

Trial 2 provides clear evidence that the response in calf growth was attributable to protein supply and not energy, since there was no effect on calf performance when ME intake was reduced, on average, from 119 MJ d^{-1} for ad libitum feeding to only 83 MJ d^{-1} for restricted silage feeding. For cows calving in good condition, sufficient energy reserves can be drawn upon to compensate for a limited

Table 7. Pregnancy establishment in beef cows fed silage at two levels of intake without or with supplemental SBM or CGM in trial 2

	Ad libitum silage (%)			Restricted silage (%)			χ probability for level of silage feeding by protein source		
	Control	SBM	CGM	Control	SBM	CGM	Control	SBM	CGM
Estrus detection	87.5	88.9	100.0	85.7	71.4	83.3	0.919	0.375	0.182
First service pregnancy	25.0	66.7	60.0	85.7	57.1	33.3	0.019	0.302	0.696
Pregnancy	50.0	66.7	70.0	85.7	57.1	50.0	0.143	0.696	0.424

energy supply in the diet (Houghton et al. 1990; Marston and Lusby 1995). When energy reserves at calving are insufficient to compensate for a limited energy intake postpartum, responses in calf gain to energy have been observed (Bartle et al. 1984; Houghton et al. 1990; Laflamme and Connor 1992).

Effect of Protein Source on the Response to Protein

The type of protein fed in trial 2 had a consistent effect on milk production during the supplementation period but an inconsistent effect on calf gains. Corn gluten meal increased milk production to a greater extent than SBM. This suggested that the response by cows was from the UIP, rather than from the overall increase in CP concentration. Other research has also shown responses to UIP supply up to a certain level (Blasi et al. 1991; De Gracia and Ward 1991; Rusche et al. 1993; Triplett et al. 1995). On silage-based diets, this can be attributed to low metabolizable protein supply, possibly due to a highly degradable protein source combined with a lack of energy available to rumen microbes for microbial protein synthesis (AFRC 1990). Thus, although there was a response to SBM, there was a bigger response to CGM attributable to the lower degradability of CP in the latter supplement.

Increased milk production in April from ad libitum-fed cows receiving CGM did not translate into increased calf gains; we have no explanation for this.

Effect of ME Intake on the Response to Protein Supplementation

When treatment means from both trials are plotted against ME intake, it appears that the response in BW change to ME intake was less in cows fed supplemental protein (Fig. 3). This relationship is consistent with the hypothesis that protein supplementation at the appropriate level encourages mobilization of body reserves for milk production. However, this relationship may not apply if UIP is in excess. Although protein may influence BW change in cows, the dominant effect remains a strong positive relationship between ME intake and BW gain.

Within individual trials, it is difficult to see any relationship between BCS change and protein supplementation. Indeed, many research trials fail to find significant effects on BCS, because of the small differences relative to the experimental variation of this parameter (Rusche et al. 1993). When the treatment means for BCS in both trials are plotted against ME intake (Fig. 4), the graphical representation clarifies the influence of protein supplementation on

body condition with increasing ME intake. When energy intake is low, protein supplementation elicits greater loss of body condition than with diets not supplemented with protein. When ME intake is higher, protein supplementation appears to have no influence on body condition change.

In both trials, calf gains were increased by protein supplementation. In contrast, energy intake of the cow had no modifying effect on calf response to protein supplementation (Fig. 3). As ME intake increased from around 80 to 140 MJ d⁻¹, calf gains did not change. This clearly demonstrates that for cows in good condition at calving, calf performance is related to protein intake of the cow and not energy intake.

Effects on Reproductive Performance

Reproductive performance of beef cows is closely related to BCS at breeding and the change in BCS prior to breeding (Richards et al. 1986; Laflamme and Connor 1992). Generally, the better the condition at breeding, the greater the breeding success. In trial 1, the results broadly support this hypothesis (Fig. 1). The larger the increase in BCS, the higher the pregnancy rate in August. However, for the cows not receiving additional protein, the pregnancy rate was better than would be expected based on the change in BCS. In this trial, all cows were in positive energy balance between calving and breeding, and breeding was based on observation of standing heat.

In trial 2, the results were somewhat different. For cows fed ad libitum, protein supplementation appeared to improve the percentage of cows pregnant in August and increased mobilization of body reserves (Fig. 2). When ME intake was restricted, protein supplementation actually reduced the percentage of cows pregnant. The figure suggests this was due to excessive loss of condition when protein was fed. When cows are in positive energy balance, protein supplementation may help reproductive performance, but when cows are in negative energy balance, the reverse is true.

In trial 1, 60% of nonpregnancies were due to anestrus, primarily in the unsupplemented group, whereas in trial 2, 65% of nonpregnancies were due to pregnancy failure, primarily in the ad libitum silage-fed cows. Inadequate energy or protein intake generally have influenced reproductive performance by causing prolonged anestrus (Randel 1990), and progesterone priming is necessary to establish regular estrous cycles postpartum. In trial 2, all cows had the benefit of progesterone priming with the norgestomet implant, which has been shown to effectively synchronize estrus and pregnancy in cows as early as 30 d postpartum (King et al. 1988). Excess ruminally degradable protein has been shown

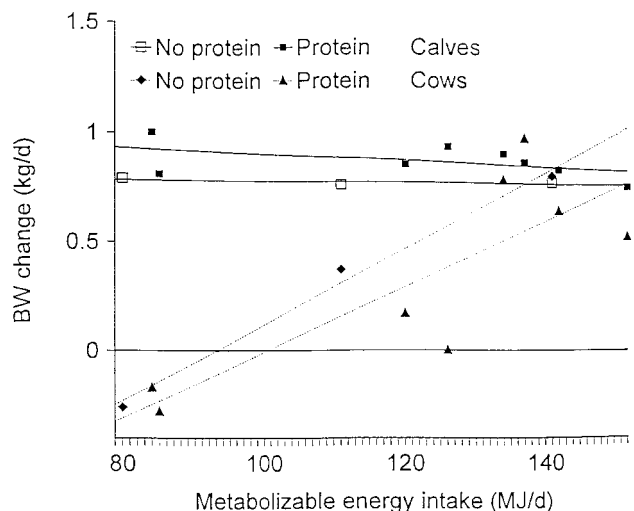


Fig. 3. Relationship between cow (without protein supplement, ◆; with protein supplement, ▲) and calf (without protein supplement, □; with protein supplement, ■) weight change during supplementation and ME intake (treatment means from both trials).

to reduce conception rates in beef (Marston et al. 1995) and dairy cows (Elrod and Butler 1993), especially if inadequate energy is supplied to the rumen. However, the results of our study suggest that the negative effect of protein on pregnancy establishment is dependent on ME relative to protein intake and excessive loss in body condition.

Performance on Pasture

In both trials, treatments imposed during the indoor feeding period had a marked influence on performance of calves on pasture. Calves with the highest rates of gain during the supplementation period also had the highest rates of gain on pasture. These observations are contrary to those of Marston et al. (1995), who found that a response in calf growth to protein supplementation of the cow during the supplementation phase was offset by poorer calf gains after supplementation had stopped. In trial 2, in which milk yield was recorded, it was apparent that milk production was also higher in cows receiving protein supplements during the supplementation period. We conclude that supplemental protein increased peak milk production in these cows and that this increased level of production was sustained through the post-supplementation period. A second hypothesis to consider is that bigger calves from protein-supplemented treatments had a higher demand for milk at turnout, which encouraged elevated milk production in their dams.

As a consequence of the increased calf gains both during and after supplementation, weaning weights were substantially higher in calves from cows fed protein. Thus, in trial 1, the seasonal consumption of CGM in cows fed 400 g d⁻¹ was 36.4 kg. This increased weaning weight by 36 kg. In this particular case, supplementation with CGM was worthwhile. In trial 2, intake of protein supplement averaged between 41 and 45 kg over the season. Across all treatments, the response in weaning weight was 30 kg. The

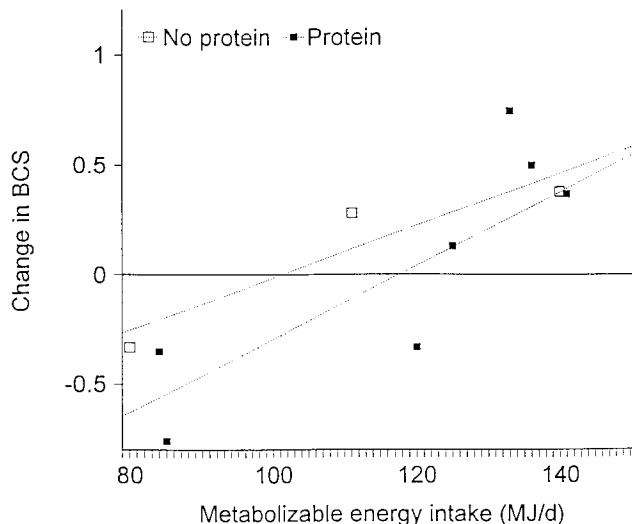


Fig. 4. Relationship between cow BCS change (without protein supplement, □; with protein supplement, ■) between calving and turnout and ME intake (treatment means from both trials).

somewhat smaller benefit in trial 2 cannot be attributed solely to the inclusion of a more degradable protein source among the treatments, since in cows fed ad libitum, SBM produced a greater response in calf weaning weight than CGM.

In both trials, BCS at weaning was similar, regardless of treatment. In cows that had lost condition during the indoor feeding period, the grazing season provided the time and energy availability for this lost condition to be regained. Consequently, in situations in which summer grazing is good, feed intake can be successfully restricted during the winter, thus reducing feed costs of the beef cow.

CONCLUSIONS

On silage-based diets, beef cows respond to supplemental protein in the diet by producing more milk. This can be attributed to silage protein limiting milk production as a result of low the efficiency with which silage protein is utilized in the rumen. When silage is fed ad libitum, the response to supplemental protein may be due primarily to the increased protein supply, both degradable and undegradable. When silage (and hence energy) intake is restricted, the response may be attributed more to increased supply of undegradable protein. In cows fed silage ad libitum, energy for increased milk production comes primarily from the diet. However, when silage and energy intake are restricted, cows in good condition draw on body energy reserves to sustain higher levels of milk production in response to protein supplementation. While the positive effect of supplemental protein on milk production may enhance breeding success when cows are in good condition, it can have the opposite effect when they are not.

Increased milk production translated into better rates of gain in calves and higher weaning weights. This was due to a direct influence during the supplementation period, but

also to a carry-over effect during the pasture season. Our data suggest that protein supplementation to silage-fed beef cows in good body condition can be economically worthwhile. However, the possible adverse effects on breeding have to be taken into account, particularly when cows are in negative energy balance after calving.

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