Effect of partially replacing silage with straw-barley-soybean meal mixtures on cow-calf performance

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Charmley, E. and Duynisveld, J. L. 2004. **Effect of partially replacing silage with straw-barley-soybean meal mixtures on cow-calf performance**. Can. J. Anim. Sci. **84**: 237–244. Forty-eight multiparous, medium-framed cows, calving between Jan. 02 and Mar. 05 were used in a 3 × 2 factorial experiment with three totally mixed ration (TMR) formulations and two levels of protein supplementation. The TMRs were formulated to contain 75, 50 or 25% silage (DM basis). The balance of the diet comprised barley, barley straw, soybean meal and urea, such that all TMRs were formulated to be isoenergetic and isonitrogenous. Supplemental protein was supplied as soybean meal at either 0 or 0.44 kg DM d^{-1}. Diets were fed from Jan. 11 to turnout on May 26. Intake and performance were monitored during this period, and performance at pasture was recorded until weaning on Sep. 03. The only interactions between TMR and protein supplementation were a positive response to protein for DM intake ($P < 0.05$) at the 50% silage level and for blood urea N ($P < 0.05$) at the 25% silage level. Reducing the amount of silage in the TMR had no effects on calf performance or milk production, except that milk protein concentration was higher when the TMR contained 50% silage (quadratic effect; $P < 0.04$) . However as the percentage of silage in the TMR declined, cows lost less body weight (linear effect; $P < 0.001$) and appeared to improve in condition. The interval between calving and conception increased linearly as the percentage of silage in the TMR declined ($P < 0.05$). Supplemental protein had no major effects on performance, but limited the loss of body condition during the feeding period ($P < 0.03$), although this was offset by increased loss of condition on pasture ($P < 0.01$). There were no effects of protein supplementation on calf performance or reproductive efficiency. It is concluded that silage can be successfully replaced with other ingredients in winter beef rations, provided the nutrient concentration is balanced. Supplemental protein had little effect on any parameters of performance.

Key words: Beef cow, cow-calf, silage, straw, gains, weaning weight, reproduction

Charmley, E. et Duynisveld, J. L. 2004. **Remplacement partiel de l'ensilage par un mélange de paille, d'orge et de tourteau et soja et incidence sur le rendement des veaux de naissage**. Can. J. Anim. Sci. **84**: 237–244. Les auteurs ont utilisé 48 vaches multipares à ossature moyenne qui avaient mis bas entre le 2 janvier et le 5 mars dans le cadre d'une expérience factorielle 3 × 2 sur trois rations mélangées et deux suppléments protéiques. La ration était formulée pour contenir 75, 50 ou 25 % d'ensilage (selon la matière sèche). Le reste se composait d'orge, de paille d'orge, de tourteau de soja et d'urée, de manière à produire une ration iso-énergétique et iso-azotée. Le supplément de protéines (tourteau de soja) ajouté à la ration correspondait à 0 ou 0,44 kg de matière sèche par jour. Les rations ont été servies du 11 janvier au 26 mai. Durant cette période, les auteurs ont suivi la prise d'aliments et le rendement des animaux; ils ont aussi mesuré leur performance au pâturage, du sevrage au 3 septembre. Les interactions entre la ration et le supplément protéique se résument à une réaction positive de l'ingestion de matière sèche ($P < 0,05$) aux protéines avec 50 % d'ensilage et pour la concentration de N uréique dans le sang ($P < 0,05$) avec 25 % d'ensilage. Réduire la quantité d'ensilage dans la ration n'a aucune incidence sur le rendement du veau ni la production laitière, si ce n'est que le lait renferme plus de protéines quand la ration est constituée à 50 % d'ensilage (effet quadratique; $P < 0.04$). Néanmoins, quand la proportion d'ensilage dans la ration diminue, les vaches perdent moins de poids (effet linéaire; $P < 0,001$) et leur condition semble s'améliorer. L'intervalle entre le vêlage et la conception s'accroît de façon linéaire quand la proportion d'ensilage baisse ($P < 0,05$). Le supplément protéique n'a aucun effet majeur sur le rendement, mais il ralentit la détérioration du corps pendant la période d'engrais ($P < 0,03$), bien que l'état de l'animal se dégrade plus rapidement une fois celui-ci mis à l'herbe ($P < 0,001$) . Le supplément protéique n'a aucune incidence sur le rendement des veaux ni les aptitudes à la reproduction. On en conclut que d'autres ingrédients peuvent très bien remplacer l'ensilage dans la ration des bovins de boucherie en hiver, afin de procurer une proportion équilibrée d'éléments nutritifs. Les suppléments de protéines influent peu sur les paramètres du rendement

Mots clés: Vache de boucherie, naissage, ensilage, paille, gain, poids au sevrage, reproduction

The nutrient requirements of the lactating beef cow are low relative to other classes of ruminant livestock [National Research Council (NRC) 1996]. Often the challenge is not to increase nutrient density of the diet in order to meet requirements, but to successfully formulate diets of lower nutritive value, yet which are balanced for the cows' needs for metabolizable energy (ME), degradable protein (DIP) and undegradable intake protein (UIP). In wet climates, where silage is the preferred conservation method, this can be a challenge. Silage harvested at optimum growth stage for ME concentration can contain excessive amounts of soluble protein (Charmley 2001). This is especially a problem

Abbreviations: **ADF**, acid detergent fibre; **BUN**, blood urea nitrogen; **CP**, crude protein; **DIP**, degradable intake protein; **DM**, dry matter; **NDF**, neutral detergent fibre; **ME**, metabolizable energy; **MP**, metabolizable protien; **TMR**, totally mixed ration; **UIP**, undegradable intake protein in silages with high legume content. One option is to dilute the silage with a lower protein feed, such as straw or grain. This approach also serves to extend silage supplies in times of feed shortage, such as after drought, and has been used in eastern Canada in recent years.

Simple substitution of silage with a feed of lower nutritive value, not only alters the nutrient density of the diet, but also the source of those nutrients. Thus the effect of nutrient density on beef cow performance is confounded by the nature of those nutrients. For example, utilization of ME is better from a mixed forage-grain energy source than from an all-forage energy source (Steen and Robson 1995; Kirkpatrick et al. 1997). Similarly the DIP/UIP ratio in crude protein (CP) can be appreciably altered by choice of protein source [Agricultural Research Council (ARC) 1984]. Protein from fermented forages, like silage, is highly soluble whereas protein from protein meals is less soluble.

In this, the first of two studies involving the dilution of silage with other dietary ingredients, the nutrient density of the diets was held constant. However, the source of energy was altered by reducing silage inclusion and increasing proportions of a straw, rolled barley, soybean meal and urea mixture. These ingredients were chosen to maintain a similar DIP/UIP ratio across all diets. The objective of these treatments was to determine the effect of source of energy on beef cow performance, without the confounding effects of nutrient concentration or differences in DIP/UIP ratios.

The high concentration of CP in silage usually exceeds requirements for lactating beef cows based on NRC (1996). Despite this, Charmley et al. (1999) observed a marked response in calf performance when silage, fed to the dam from calving in January to turn-out to pasture in May, was supplemented with either 400 g d^{-1} corn gluten meal or 475 g d^{-1} soybean meal (SBM) on an as-fed basis. They concluded that this was due the highly soluble nature of the CP in silage, combined with insufficient ruminally available energy, resulting in poor efficiency of utilization of non-protein N for microbial protein synthesis. In the United Kingdom (ARC 1984), feeding standards use a lower microbial N yield for silage (1.0 g N MJ^{-1} ME) than for mixed diets (1.4 g N MJ^{-1} ME). Thus research has shown there to be a response to supplemental protein in growing cattle (Veira et al. 1994) and lactating dairy cattle fed silage-based diets (Robinson et al. 1992). Consequently, a second nutritional factor, supplemental SBM fed at the same rate as in the previous study of Charmley et al. (1999), was imposed across the three silage inclusion levels. We hypothesized that a response to supplemental protein would be greater in diets with more silage, due to poor utilization of silage CP. The objective of feeding supplemental protein, therefore was to determine if there was an interaction between the proportion of ME in the diet from silage and supplemental CP.

MATERIALS AND METHODS

Design of the Trial

The experiment was conducted with 48 multiparous beef cows. Prior to the trial, between weaning in the fall and calving, all cows were grazed until late October and then fed round bale hay and 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. Calves had creep access to good quality timothy hay at all times, but were unable to access the Calan gates. Cows calved between Jan. 02 and Mar. 05. Cows were blocked according to breed (≥½ Hereford or <½ Hereford) and calving date (Before Jan. 31 or after Jan. 31). They were assigned within block to one of three TMR treatments and two levels of protein supplementation in the second week of January. Cows were weighed and condition scored in the second week of January and thereafter at 2-wk intervals until turn-out to pasture.

Diet Formulation

Silage used in the study was grown at Nappan, NS (45°N latitude, 64°W longitude) and harvested from a naturalized sward comprising (based on visual assessment) principally of grasses [timothy (*Phleum pretense* L.), meadow fescue (*Festuca pratensis* Huds.) and Kentucky bluegrass (*Poa pratensis* L.)] with approximately 20% legumes [white clover (*Trifolium repens* L.) and red clover (*Trifolium multiflorum* L.)]. The sward was harvested in early July at a relatively advanced stage of maturity, in order to optimize higher yield with lower digestibility as appropriate for lactating beef cattle. The crop was wilted for 24 h before precision chopping and ensiling in a bunker silo. Barley straw was grown near Charlottetown, PE (46°N latitude, 63°W longitude) and baled as large round bales. Straw was chopped before incorporation into a TMR.

The dietary ingredients (Table 1) were mixed in a TMR mixer (Lucknow model 350, Helm Welding, Lucknow, ON) with water added to equalize the DM concentration of the TMR. Soybean meal was top-dressed in the bunks at a rate of 0.44 kg DM d^{-1}. All diets were offered ad libitum with daily amount adjusted to allow for approximately 5% uneaten feed. Cows remained on these diets until May 26, at which time they were turned out to pasture. At turn-out all cows and calves were grazed under rotational grazing management until weaning on Sep. 03.

Animals were cared for in accordance with guidelines suggested by the Canadian Council on Animal Care (1993).

Oestrus Synchronization and Reproductive Efficiency

Breeding began in April and continued for 45 d. For first service, cows were synchronized in two groups, 2 wk apart (Early and Late). Cows were injected with GnRH (gonadotrophin releasing hormone; 100 µg gonadorelin acetate tetrahydrate i.m., Cystorelin®, Merial, Athens, GA) on Mar. 26 and Apr. 06 for early and late groups, respectively. Seven days later they received an injection of prostaglandin $F_{2\alpha}$ (500 µg cloprostenol sodium i.m., Estrumate, Schering Canada Inc., Pointe Claire, QC) and 48 h after, a second injection of GnRH. Cows were inseminated 16 h after the last GnRH injection. For subsequent services, cows were bred to observed heat either naturally or by artificial insemination. Reproductive performance was assessed based on the percentage of cows exposed to breeding pro-

Table 1. Ingredient and chemical composition of silage, straw and the totally mixed rations

			Silage in total mixed ration (%)		
	Silage	Straw	75	50	25
Ingredient composition of the TMR (g kg^{-1} DM)					
Silage	–	–	758	513	268
Straw	–	–	107	216	321
Rolled barley	–	–	116	235	358
Soybean meal	–	–	13	26	39
Urea	–	–	4	8	12
Mineral[z]	–	–	2	2	2
Chemical composition					
Dry matter (g kg^{-1})	314	780	373	447	468
Acid detergent fibre (g kg^{-1} DM)	367	539	347	319	317
Neutral detergent fibre (g kg^{-1} DM)	601	836	525	514	513
CP (g kg^{-1} DM)	118	51.9	134	133	136
TCA insol N (g kg N^{-1})	262	–	350	302	335
Ammonia N (g kg^{-1} total N)	158	–	–	–	–
Volatile fatty acids (g kg^{-1} DM)	45.6	–	–	–	–
Lactic acid (g kg^{-1} DM)	38.5	–	–	–	–
pH	4.68	–	–	–	–
Gross energy (MJ kg^{-1} DM)	19.5	19.7	19.6	19.6	19.7

[z]Containing (g kg^{-1}); dicalcium phosphate; 199, magnesium sulphate; 400, TM salt; 199, calcium carbonate; 199, copper sulphate; 3 and (mg kg^{-1}) selenium 8.

ducing live calves the following season (calving proportion) and the calving to conception interval of these animals.

Milk Production

All cows were milked in March for the determination of milk production and composition. Milking procedures were the same as described by Charmley et al. (1999) except that cows were milked out on 2 consecutive days with calves being separated from cows between the two milkings. Milk production between milkings was recorded and adjusted to a theoretical 24 h milk production. Oxytocin (60 units oxytocin i.m., MTC Pharmaceuticals, Cambridge, ON) was used to encourage milk letdown. Samples of milk were collected from each cow and analyzed for fat, protein and lactose using a Milko-scan analyzer by the Nova Scotia Department of Agriculture and Marketing, Truro, NS.

Determination of Gain and Intake

Weights of cows at calving were estimated by taking the last pre-calving weight and subtracting twice the calf weight to account for the adnexa (ARC 1980). This minimized stress and reduced error associated with atypical feed and water intake, fluid retention/loss etc., around calving. Weights during indoor feeding were taken just after weighbacks had been removed and before new feed was given. Cow and calf weight change between calving and turnout was determined by regression of weight against time. Cows and calves were weighed at turnout to pasture and at weaning, and gains on pasture were determined by difference. Body condition score was assessed by palpation using a 1 to 9 scale (Lowman et al. 1976). Measurements were taken at calving, every 2 wk during the post-calving winter feeding period and at turn-out to pasture and at weaning.

Daily feed intake was determined from the amounts of feed offered and refused each day. The TMR fed was sampled daily, frozen and combined over 14 d for analysis. Fresh silage was analysed as described by Charmley et al. (1999). Protein supplements were sampled every 14 d for analysis of DM and CP. Weighbacks were sampled once a week and combined on a treatment basis for determination of DM and acid detergent fibre (ADF).

Chemical Analysis

Dry matter in feed was determined by oven drying at 50°C for 48 h. Organic matter was determined as weight lost upon ashing at 550°C. Total N was determined using macro-Kjeldahl procedures 7.033-7-037 (Association of Official Analytical Chemists 1990). Crude protein was calculated at 6.25 × % N. Insoluble N was determined in fresh silage using trichloroacetic acid. Ash-free neutral detergent fibre (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). Gross energy was determined from heat of combustion using a Parr adiabatic calorimeter. The concentrations of fat and lactose in milk were determined using an infra-red milk analyzer (Biggs 1967). Blood urea N (BUN) was determined colorimetrically (Diagnostic kit 535-A, Sigma-Aldrich Corp., St Louis, MO).

Statistical Analysis

The trial was a 3 × 2 factorial design and analyzed using the GLM procedure of the SAS Institute, Inc. (1995). The blocking effects of breed and calving date were also accounted for in the analysis. There were no interactions between these latter effects and the treatment factors. A significant interaction between TMR and supplementation was seen only for DM intake and BUN; therefore, interaction means are given only for these variables. The effects on altering the proportion of silage in the ration was assessed using polynomial regression analysis. Analysis of the proportion of cows producing live calves the following year was conducted by χ^2 to determine differences in proportions using the CATMOD procedure of the SAS Institute, Inc. (1995). The pooled standard error of the proportions was determined as the square root of the sum of the standard deviations of the proportion for each treatment.

RESULTS

Nutrient Composition and Intake of the Diets

The silage used in this study was late maturity, first-cut material harvested in early July (Table 1). Consequently, it had low CP and high ADF and NDF concentrations. Also, the proportion of insoluble N was low, suggesting the silage would be highly degradable in the rumen. The fermentation profile suggested a heterolactic fermentation. The chemical composition of the three TMR diets was similar, indicating that attempts to equalize these rations for energy and protein had been successful. According to NRC (1996), these diets would have supplied 9 MJ ME kg^{-1} DM. The CP of the SBM supplemented diets was approximately 10% higher than the unsupplemented diets and estimated to be 146 g kg^{-1} DM.

There was a significant interaction between TMR and protein supplementation for voluntary intake (Table 2; $P < 0.05$). In the presence of supplemental protein cows fed the 50% silage diet consumed more DM than cows fed the other two diets (quadratic response; $P < 0.05$). A similar response was observed when intake was expressed relative to BW ($P < 0.05$). In the absence of supplemental protein, there was no TMR effect on intake. Blood urea N concentration was increased by protein supplementation ($P < 0.01$), especially in cows fed the 25% silage TMR. This resulted in a significant interaction ($P < 0.01$).

Animal Performance

Cows on all treatments lost weight during the indoor feeding period (Table 3). There was a linear reduction in the extent of weight loss in cows as the percentage of silage in the TMR declined ($P < 0.001$). Although a similar numerical trend was observed for BCS, this was not significant. Cows fed supplemental protein tended to loose less condition than those not fed supplemental protein ($P < 0.10$). This resulted in a significantly higher BCS for supplemented cows at turn-out. However, these cows then lost more condition on pasture ($P < 0.01$) such that at weaning, there were no differences in BCS between unsupplemented and protein-supplemented groups. All cows lost excessive weight on pasture due to dry weather conditions in the summer affecting pasture growth.

There was no effect of TMR or protein supplementation on calf gains (Table 3). All calves gained 0.98 kg d^{-1} during the winter, and 0.93 kg d^{-1} subsequently on pasture. Weaning weights averaged 243 kg. Although milk production was similarly unaffected by TMR or protein supplementation (Table 4), milk protein concentration was higher for cows fed supplemental protein ($P < 0.01$). Milk protein also showed a quadratic response to decreasing silage in the TMR ($P < 0.05$), with the concentration being highest for the 50% silage TMR. A similar trend ($P < 0.10$) was observed for milk lactose concentration.

Although all cows were synchronized for the first service, synchronization group was balanced across treatments. Thus the effects of treatment on days to conception reflect the conception rate to first service and the interval between first and subsequent services. As the percentage of silage was reduced in the TMR, the period from birth to conception increased (Table 5; Linear effect $P < 0.05$). Across all treatments, 74% of cows exposed to breeding bore live calves the following year. This percentage was highest for cows fed the 50% silage TMR and lowest for those fed the 25% silage TMR.

DISCUSSION

Voluntary Intake

Ad libitum intakes in this trial averaged 20 g kg^{-1} BW, which was expected, based on the maturity of the silage, and the fact that all TMR mixtures were isoenergetic. Voluntary intake was highest for the 50% silage TMR, when supplemented with SBM, but this effect was not apparent in the absence of supplemental SBM. The two extreme diets (75 and 25% silage) had lower NDF intakes (10 g kg^{-1} BW) than the maximum of 12 g kg $^{-1}$ BW suggested by Mertens (1994). This implied some restriction in intake, not related to fibre concentration. The higher BUN concentration on these two treatments was indicative of excessive absorption of rumen ammonia into the bloodstream and conversion into urea in the liver. High circulating levels of ammonia have been linked to reduced intake of forages (Charmley 2001). We hypothesized that improved microbial protein synthesis as the silage inclusion level in the TMR declined, would have reduced blood ammonia and urea concentration, thus contributing to higher intakes. However, this appeared to hold true only when silage was reduced from 75 to 50% of the TMR. Substitution of soluble CP in silage with urea may have had differing effects in the rumen, thus contributing to higher BUN levels for the high-urea treatment. In silage, soluble CP, unlike urea, contains peptides (Ohshima and McDonald 1978), which are critical for microbial protein synthesis (Cecava et al. 1991). This amount of urea in the 25% silage TMR, while considered safe (NRC 1984), was close to the maximum recommended, and the possibility of sub-acute ammonia toxicosis cannot be ruled out.

Energy Utilization

The estimated ME intake was similar for all treatments and averaged 120 MJ d^{-1}. Based on previous research (Charmley et al. 1999) we expected this level of ME intake to result in no weight change. The NRC (1996) predicted this level of intake to be approximately 10% below requirement. The data showed that cows lost weight, however, as the proportion of silage in the TMR declined, so too did the extent of weight loss. This relationship was not detected by NRC (1996) since source of ME is not considered in the model. Our data suggest that efficiency of energy utilization increased as the proportion of silage in the diet declined. This would agree with

Table 2. Effect of straw inclusion, with or without supplemental protein, on intake and blood urea nitrogen of beef cows

	Without SBM Silage in total mixed ration (%)			With SBM (0.4 kg d^{-1}) Silage in total mixed ration (%)				Probability		
	75	50	25	75	50	25	SEM	TMR	Soybean meal	Interaction
Dry matter intake (kg d^{-1})	13.9	12.2	12.1	12.8	15.4	13.2	1.03	0.442	0.161	0.046
Dry matter intake (g kg BW^{-1})	21.7	17.7	19.1	18	21.3	18.4	1.76	809.0	0.839	0.045
Blood urea N (mg dL^{-1})	24.0	25.0	21.5	27.4	25.8	30.8	1.58	0.855	<0.001	0.011
NRC (1996) predicted values										
Metabolizable energy (MJ d^{-1})	120	110	112	119	143	122	–	–	–	–
Net energy for maintenance (MJ d^{-1})	58	61	57	62	63	62	–	–	–	–
Net energy for lactation (MJ d^{-1})	20	20	23	20	18	17	–	–	–	–
Net energy for gain for gain (MJ d^{-1})	–7	–17	–14	–12	3	–6	–	–	–	–
Diet crude protein (g kg^{-1} DM)	129	141	151	143	151	161	–	–	–	–
Degradable protein supply (g d^{-1})	1244	1225	1330	1332	1672	1507	–	–	–	–
Degradable protein required (g d^{-1})	1033	940	966	1020	1227	1057	–	–	–	–
Undegradable protein supply (g d^{-1})	528	506	541	578	717	635	–	–	–	–
Protein degradability (g kg^{-1})	70	71	71	70	70	70	–	–	–	–
Metabolizable protein supply (g d^{-1})	1048	1006	1051	1117	1358	1183	–	–	–	–

Table 3. Effect of straw inclusion, with or without supplemental protein, on change in body weight and body condition score of beef cows[z]

	Silage in total mixed ration (%)				Response probability		SBM (kg d^{-1})			
	75	50	25	SEM	Linear	Quadratic	0	0.4	SEM	Probability
Body weight change of cows indoors (kg d^{-1})	–0.46	–0.24	–0.07	0.077	<0.001	0.763	–0.23	–0.28	0.071	0.516
Body weight change of cows on pasture (kg d^{-1})	–0.24	–0.32	–0.23	0.073	0.828	0.236	–0.20	–0.33	0.066	0.103
Body condition score at calving (units)	5.94	5.94	5.95	0.245	0.982	0.852	5.77	6.08	0.213	0.247
Body condition score at turn-out (units)	5.67	5.74	5.87	0.306	0.646	0.932	5.4	6.13	0.265	0.019
Body condition score at weaning (units)	3.43	3.59	3.61	0.167	0.459	0.704	3.54	3.54	0.145	0.967
Change in body condition score indoors (units)	–0.265	–0.152	–0.077	0.233	0.562	0.933	–0.37	0.04	0.202	0.109
Change in body condition score on pasture (units)	–2.24	–2.16	–2.26	0.247	0.946	0.718	–1.9	–2.58	0.214	0.006
Milk production (kg d^{-1})	7.27	6.91	7.66	0.725	0.699	0.455	7.74	6.82	0.634	0.237
Fat concentration (g kg^{-1})	32.7	30.1	27.4	3.18	0.235	0.988	30.9	29.2	2.78	0.621
Protein concentration (g kg^{-1})	36.5	40.2	39.2	1.06	0.076	0.038	37.1	40.2	0.932	0.007
Lactose concentration (g kg^{-1})	43.0	41.1	44.2	1.27	0.509	0.063	41.8	43.7	1.11	0.166

[z]No interaction between silage % and supplementation ($P > 0.05$); therefore, main effect means are shown.

other research that has shown higher efficiency for mixed forage-concentrate diets than all-silage diets (Thomas et al. 1988; Steen and Robson 1995). This has been attributed to either higher efficiency of utilization of ME in mixed diets (Thomas et al. 1988), or improved N utilization which favours lean tissue deposition (Steen and Robson 1995).

Protein Utilization

Diets without supplemental SBM supplied approximately 130 g CP kg^{-1} DM. All TMRs were formulated to have high protein degradability, similar to that found in silages. We hypothesized that, as the proportion of silage, and hence fermented ME, in the diet declined, efficiency of microbial protein synthesis would increase (Agricultural and Food Research Council 1992), and a response in milk production and calf growth would occur. This was not the case, even though lower BUN concentration in cows fed the lowest proportion of silage in the TMR indicated that efficiency of microbial protein synthesis may have been improved.

Feeding supplemental protein to silage-fed cows can increase calf performance through a shift in energy partitioning towards milk production (Rusche et al. 1992; Charmley et al. 1999). However, this did not occur in the current trial, even though cows were in good condition (5.9) at calving, and could have mobilized this condition for milk production. Rusche et al. (1992) fed a high level of CP (approximately 170 g kg^{-1} DM), which was judged to be 150% of NRC requirement. They found a response in both milk yield and calf performance to supplying CP in excess of requirement. A lack of response in the current trial was therefore unexpected. However, calf growth rate on all treatments in the current trial was high relative to other studies (Rusche et al. 1992; Charmley et al. 1999). It is possible that calves were unable to elicit greater milk production above control levels, due to a physiological limitation on intake. Milk-fed calves will consume 60 to 80 g DM kg^{-1} $BW^{0.75}$. (ARC 1980). Assuming calves were consuming approximately 0.5 to 1.0 kg hay d^{-1}, then it is unlikely that calves could have consumed much in excess of 8 kg milk d^{-1}. Thus any further CP was used as an energy source by the cow. This is supported by the higher BCS at turn-out of cows fed supplemental CP.

Table 4. Effect of straw inclusion, with or without supplemental protein, in the diet of beef cows on growth rate and weaning weight of their calves[z]

	Silage in total mixed ration (%)				Response probability		SBM (kg d^{-1})			
	75	50	25	SEM	Linear	Quadratic	0	0.4	SEM	Probability
Body weight gain of calves indoors (kg d^{-1})	0.98	0.99	0.99	0.052	0.947	0.972	0.99	0.99	0.05	0.996
Body weight gain of calves indoors by regression (kg d^{-1})	0.96	1.04	1.01	0.073	0.661	0.519	1.00	1.01	0.06	0.841
Body weight gain of calves on pasture (kg d^{-1})	0.93	0.92	1.01	0.049	0.227	0.341	0.95	0.95	0.04	0.969
Calf body weight at birth (kg)	44.6	47	46.6	2.24	0.537	0.531	46.3	45.8	1.94	0.849
Calf body weight at turnout (kg)	155	157	156	7.14	0.939	0.846	155	157	6.2	0.773
Calf body weight at weaning (kg)	248	249	257	9.65	0.475	0.717	250	252	7.8	0.802
Calf body weight adjusted to 200 d (kg)	237	237	247	8.17	0.375	0.613	241	241	7.11	0.993

[z]No interaction between silage % and supplementation ($P > 0.05$); therefore, main effect means are shown.

Table 5. Effect of straw inclusion, with or without supplemental protein, on milk production and milk composition of beef cows[z]

	Silage in total mixed ration (%)				Response probability		SBM (kg d^{-1})			
	75	50	25	SEM	Linear	Quadratic	0	0.4	SEM	Probability
Milk production (kg d^{-1})	7.27	6.91	7.66	0.725	0.699	0.455	7.74	6.82	0.634	0.237
Fat production (g d^{-1})	245	218	221	32.8	0.608	0.656	237	219	28.7	0.613
Protein production (g d^{-1})	262	272	292	25.8	0.412	0.842	283	268	22.5	0.583
Lactose production (g d^{-1})	313	288	340	32.7	0.542	0.248	327	300	28.6	0.421
Fat concentration (g kg^{-1})	32.7	30.1	27.4	3.18	0.235	0.988	30.9	29.2	2.78	0.621
Protein concentration (g kg^{-1})	36.5	40.2	39.2	1.06	0.076	0.038	37.1	40.2	0.932	0.007
Lactose concentration (g kg^{-1})	43.2	41.1	44.2	1.27	0.509	0.063	41.8	43.7	1.11	0.166

[z]No interaction between silage % and supplementation ($P > 0.05$); therefore, main effect means are shown.

Table 6. Effect of straw inclusion, with or without supplemental protein, on reproductive performance of beef cows[z]

	Silage in total mixed ration (%)				Response probability		SBM (kg d^{-1})			
	75	50	25	SEM	Linear	Quadratic	0	0.4	SEM	Probability
Time between calving to conception (d)	68	81	83	4.68	0.029	0.224	79	77	4.04	0.672
Live calves born the following year (%)[y]	73	86	63	2.10	–	–	77	71	2.96	0.956

[z]No interaction between silage % and supplementation ($P > 0.05$); therefore, main effect means are shown.
[y]χ^2 analysis precluded test for linear or quadratic effects. TMR effect $P = 0.179$.

All diets resulted in high concentrations of BUN, indicating that metabolizable protien (MP) was in excess of requirements to meet demand for the milk production achieved. The NRC model (NRC 1996) predicted MP supply to be 9 and 27% in excess of requirements for unsupplemented and protein-supplemented TMRs, respectively (Table 2). This agrees with the higher BUN concentrations from protein-supplemented cows. Rusche et al. (1992) found similar high BUN concentration in beef cows fed a high level of CP, yet in their case this was also associated by a response in calf gains.

Calf Performance

Calf gains during indoor feeding were similar across all treatments and considered good at just under 1 kg d^{-1}. On pasture, gains were somewhat lower, but still satisfactory considering the poor grazing conditions. In previous work we have observed differing responses in calf gains and weaning weight to supplemental protein. Charmley et al. (1999) observed a positive response in calf gains when supplementing the cow's silage diet with 0.4 kg d^{-1} corn gluten meal or 0.48 kg d^{-1} SBM, and Ruche et al. (1992) also obtained a response when either a low or highly degradable protein source was fed to beef cows at 150% of requirement. However, in those instances, calf growth rates on control rations were lower than in the current trial, thus allowing for a potential response. We speculate that a lack of response in the current study may be attributed to high rates of gain in calves from cows not fed supplemental SBM, thus precluding a potential response. Cows were initially in good condition (BCS of 6) and maintained condition after calving. Thus, there was potential for increased milk production given the availability of body reserves for energy and additional CP in the diet for protein. However, the calves were apparently unable to elicit a milk production response, presumably because of limitations in milk intake. Based on our previous work we had hypothesized that cows responded to additional protein by diverting energy from body reserves to milk production, in much the same way as is seen with dairy cows (Robinson et al. 1992). Increased milk production often results in increased calf gains. However, this may hold true only up to a point dictated by the intake limitations of the calf (ARC 1980). Such a barrier is not apparent for the dairy cow.

Reproductive Performance

Most research has clearly shown that conception rate and days to conception are positively influenced by energetic status of the cow (e.g., Sinclair et al. 2002). In addition, some research has suggested that higher concentrate diets, which favour a more glucogenic rumen fermentation can improve reproduction (Lalman et al. 1993; Reed et al. 1997). This is thought to be related to increased levels of plasma insulin and its effect on reproductive hormonal secretion (Sinclair et al. 2002). However, Reed et al. (1997) feeding equal amounts of ME, found no overall effects of forage to concentrate ratio on reproduction. We found that although ME intake was the same across all TMRs, days to conception increased as the percentage of silage in the diet declined.

CONCLUSIONS

Generally, neither altering the proportion of silage in the diet nor providing additional protein had any major effects on performance of suckling beef cows and their calves. There were some effects on the weight change and condition of cows which suggested responses to the nutritional manipulations, but these were either too small, or offset by other factors, to be of major consequence. There was some evidence that altering the forage to concentrate ratio, an inevitable consequence of replacing silage with a straw-barley mixture, influenced energetic efficiency, but a clear effect on reproductive performance was contrary to expectations. There was also evidence that supplemental protein played a small role in reducing weight loss in the cow and boosting milk protein concentration. The absence of a marked response to protein was attributed to the inability of the calf to stimulate increased milk production beyond the already satisfactory levels observed in cows not fed supplemental protein. It is concluded that silage can readily be replaced with other feed ingredients, provided the supply of ME and CP remains the same. The ability of the beef cow to buffer small changes in diet by altering partitioning within the body readily compensates for any altered nutrient status. Thus this approach can be used to extend silage supplies, when these are limited. Under the conditions of this trial, where control calves were gaining at approximately 1 kg d^{-1}, supplemental protein failed to elicit any response in calf growth.

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