The partial replacement of silage with straw, with or without barley or soybean meal, in rations for winter calving beef cows

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Charmley, E. and Duynisveld, J. L. 2004. **The partial replacement of silage with straw, with or without barley or soybean meal, in rations for winter calving beef cows**. Can. J. Anim. Sci. **84**: 245–253. The effects of partially replacing grass-legume silage with barley straw, without or with either supplemental energy or protein, were assessed in 72 lactating beef cows. Diets were fed from calving in January–February until turnout to pasture in late May. Performance of cows and their calves was measured over this period, and weight and body condition were measured at weaning in September. Apparent digestibility and N balance of these diets was also assessed in growing steers. Replacing half the silage with barley straw reduced diet digestibility ($P < 0.05$), intake ($P < 0.05$), body weight (BW) gain ($P < 0.001$) and body condition ($P < 0.001$) of cows but did not affect BW gain or weaning weights of calves. Reproductive performance was also unaffected, although overall production efficiency (kg weaned calf kg^{-1} cow BW) was impaired ($P < 0.10$). When the silage-straw diet was supplemented with barley, metabolizable energy (ME) intake was increased to the level supplied by the all-silage diet. However, there was a tendency for cows to partition more ME to calf growth and less to body reserves as indicated by body condition score ($P < 0.05$). This may have been related to better N utilization, since N losses in urine were lower for steers fed the barley-supplemented mixture than those fed silage ($P < 0.01$). When the silage-straw was supplemented with soybean meal (SBM) to increase crude protein (CP) to equal the all-silage diet, there were no benefits for the cow or calf, because SBM reduced intake relative to silage fed alone ($P < 0.001$). Thus, although supplementing with SBM improved N balance, relative to silage ($P < 0.01$), there was no response in calf performance, probably because of insufficient ME intake in the cow. Although silage appears not to be well balanced for the nutrient requirements of lactating beef cows, attempts to optimise nutrient supply did not markedly improve growth performance of the calf or reproductive performance of the cow.

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 de la paille avec ou sans orge ou tourteau de soja dans les rations d'hiver des vaches de boucherie allaitantes**. Can. J. Anim. Sci. **84**: 245–253. Les auteurs ont évalué l'incidence de la substitution partielle d'un ensilage de graminées et de légumineuses par de la paille d'orge, enrichie ou pas d'énergie ou de protéines, sur 72 vaches de boucherie en lactation. Les rations ont été servies du vêlage, en janvier-février, à la mise à l'herbe à la fin de mai. Durant toute cette période, on a mesuré le rendement des vaches et de leurs veaux, puis établi leur poids et leur état d'engraissement au sevrage, en septembre. On a aussi évalué la digestibilité apparente et le bilan azoté des rations pour les bouvillons en croissance. Lorsqu'on remplace la moitié de l'ensilage par de la paille d'orge, on note une baisse de la digestibilité de la ration ($P < 0,05$), de la prise d'aliments ($P < 0,05$), du gain de poids ($P < 0,001$) et de l'état d'engraissement ($P < 0,001$) des vaches, sans incidence sur le gain de poids et le poids au sevrage des veaux. Les aptitudes à la reproduction ne sont pas touchées, bien que le rendement global (kg de poids du veau sevré par kg de poids de la vache) diminue. Quand on enrichit le mélange d'ensilage et de paille avec de l'orge, la quantité d'énergie métabolisable absorbée augmente pour atteindre le niveau observé avec la ration uniquement composée d'ensilage. Toutefois, les vaches ont tendance à laisser plus d'énergie métabolisable pour la croissance du veau et moins pour leurs réserves corporelles, comme le révèle l'indice d'engraissement ($P < 0,05$). On pourrait le devoir à une meilleure assimilation du N, car les pertes de N dans l'urine sont plus faibles chez les bouvillons recevant la ration enrichie avec de l'orge que chez ceux nourris d'ensilage ($P < 0,01$). L'addition de tourteau de soja au mélange de paille et d'ensilage pour amener la concentration de protéines brutes à celle de la ration entièrement faite d'ensilage ne se traduit par aucun avantage pour la vache ou le veau, car le tourteau réduit la prise d'aliments, comparativement à l'ensilage ($P < 0,001$). Par conséquent, même si le tourteau de soja améliore le bilan azoté par rapport à l'ensilage ($P < 0,01$), le rendement des veaux ne change pas, sans doute parce que la vache n'ingère pas assez d'énergie métabolisable. Bien que l'ensilage ne semble pas satisfaire aux besoins nutritifs de la vache en lactation, l'optimisation de la ration n'améliore pas de façon marquée la croissance du veau ni les aptitudes à la reproduction de la vache.

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

In areas of high summer rainfall, silage is often used as the sole feed for lactating beef cows over winter. However, the feeding value of silage is often considered to be too high for beef cows. The ME requirement for a 550 kg beef cow producing 7 kg of milk is approximately 112 MJ d^{-1} [National Research Council (NRC) 1996]. Ad libitum intake of high-quality silage can supply up to 150 MJ d^{-1} (Charmley et al. 1999). Research has shown that the response in either milk yield (Lowman et al. 1979) or calf performance (Laflamme and Connor 1992; Charmley et al. 1999) to increasing ME

Abbreviations: **ADF**, acid detergent fibre; **CP**, crude protein; **DM**, dry matter; **GE**, gross energy; **NDF**, neutral detergent fibre; **ME**, metabolizable energy; **TMR**, totally mixed ration intake from silage-based diets is small to non-existent. Rather, excess energy is stored by the cow as body reserves. As with energy, the CP content of silage is higher than requirements given in feeding standards (NRC 1996). However, in contrast to energy, beef cows often exhibit a response in milk production and calf performance when diets are supplemented with protein. This is most apparent in low protein diets (de Garcia and Ward 1991; Wiley et al. 1991; Dhuyvetter et al. 1993), but has also been observed in diets of higher protein concentration, where the protein is highly degradable in the rumen (Rusche et al. 1993; Charmley et al. 1999; Charmley and Duynisveld 2004).

In order to optimise utilization of silage diets by lactating beef cows, the concentration of ME could be reduced while the concentration of CP could be enhanced. Utilization of CP could alternatively be increased by reducing the degradability of protein. Under commercial conditions, it is frequently impractical to reduce energy intake by limit-feeding silage. One approach is to dilute the silage with a forage of lower quality, such as straw. This mixture can then be supplemented with a protein source to meet the requirements for milk production and successful breeding. This approach not only makes more efficient use of supplied energy and protein but may also increase energy utilization, by provision of a mixed diet (Steen and Robson 1995; Kirkpatrick et al. 1997). On the farm, it is also an effective way to extend silage supplies, where these may be limited.

To test the hypothesis that silage has a poor balance of ME and CP for lactating beef cows, an all-silage diet was compared with one where the silage had been diluted by substitution with barley straw and was judged not to meet requirements for adequate performance. The objective of this comparison was to consider the effects of a straight dilution of energy and protein on cow-calf productivity and reproductive performance. This "diluted" diet was then either supplemented with energy (as barley) or protein [as soybean meal (SBM)], such that the two supplemented diets were equal to the silage in either energy or protein. The extent and nature of the response to either energy or protein supplementation was then compared with the performance from the all-silage diet.

MATERIAL AND METHODS

Production Trial with Cows and Calves

The trial utilized 24 primiparous (BW at calving (±SE) 529 ± 24.7 kg) and 48 multiparous cows [BW at calving (±SE) 641 ± 29.8 kg) from a winter (January/February) calving beef herd of primarily Hereford or Beef Shorthorn × Hereford cows. Prior to the trial, cows had been on pasture until October and then group-fed silage to appetite until December. Subsequently, cows were fed silage or a silage-straw mixture. Silage was made without additives from wilted, precision-chop, mixed grass/legume forage which had been harvested in late June and stored in bunker silos. Round-bale barley straw was stored under cover and chopped before feeding. A Calan gate feeding system (American Calan, Inc., Northwood, NH, USA) was used that allowed cows to consume forage from individual bunks but prevented access by their calves. Calves were offered timothy hay from racks in calf creep areas not accessible to cows. Cattle were blocked according to parity (primiparous vs. multiparous), breed type (> 50% Hereford vs. < 50% Hereford) and expected calving date (up to and including Feb. 04 vs. after Feb. 04). Within blocks, cows were nominally assigned to one of four dietary treatments according to expected calving date. The feeding of treatment diets began at calving. The treatments comprised: (a) ad libitum forage, fed without supplement as all grass/legume silage (silage); (b) ad libitum forage fed without supplement as an equal mixture [dry matter (DM) basis] of silage and barley straw (mixture); (c) the silage/straw mixture supplemented with 2.7 kg d^{-1} barley; and (d) the silage/straw mixture supplemented with 0.9 kg d^{-1} SBM. The barley-supplemented mixture was formulated to be iso-energetic to the silage diet, whilst the SBM-supplemented mixture was formulated to be iso-nitrogenous to the silage diet. The forage portion of the diet was mixed in a horizontal auger mixer (Lucknow Model 350, Helm Welding, Lucknow, ON, Canada). Water was added to diets containing straw to reduce the DM of the mixture to equal that of silage and to facilitate mixing. Barley and SBM were mixed with the totally mixed ration (TMR) in the feed trough. All cows received 150 g hd^{-1} d^{-1} of a mineral mix top-dressed onto the forage, containing (g kg^{-1}): dicalcium phosphate, 199; magnesium sulphate, 400; sodium chloride, 199; calcium carbonate, 199; copper sulphate, 3; and (mg kg^{-1}) selenium, 8. Feeding occurred once daily at 1030. Uneaten feed was removed for weighing and sampling weekly. Cows remained on these diets until May 23, at which time they were turned out to pasture. At turnout all cows and calves were grazed a mixed grass/legume sward under rotational grazing management until weaning on Sep. 12. The same mineral as used in the winter was available free-choice.

Determination of Intake and Gain

Cows and calves were weighed every 2 wk from early January to turnout. Cow and calf weight change between calving and turnout was calculated by regression of body weight (BW) over time and from turnout to weaning by difference. During the winter feeding period, weights of cows and calves were taken in the morning prior to feeding, just after any uneaten feed had been removed. Turnout and weaning weights of cows and calves were taken after an overnight period without feed. These weights were used to calculate BW change on pasture. Body condition score was assessed by palpation using a 1 to 9 scale, with 1 being emaciated and 9 extremely obese. Measurements were taken at calving, every 2 wk during the post-calving winter feeding period, at turnout to pasture, and at weaning.

Samples of silage, straw and the mixture were taken daily at feeding, frozen and combined over 14 d for analysis. Silage and the mixture were analysed before drying for total N, trichloro-acetic acid (TCA) insoluble N, ammonia N, pH, lactic acid and volatile fatty acids. Forages and uneaten feed were dried at 50°C for 48 h. Dried forages and concentrates were subsequently analysed for DM, N, acid detergent fibre (ADF), neutral detergent fibre (NDF) and gross energy

(GE). Uneaten feed was sampled once a week and combined on a treatment basis for determination of DM and ADF.

During the indoor period, feed intake was determined from the amounts of feed offered daily and adjusted by subtracting 1/7th of the weekly accumulated, uneaten feed.

Oestrus Synchronization and Reproductive Performance

Breeding began in April and continued for 45 d. For first service, cows were synchronized in two groups based on previous calving date, 2 wk apart (early and late). Cows were injected with gonadotrophin releasing hormone (GnRH; 100 μg gonadorelin acetate tetrahydrate i.m., Cystorelin®, Merial, Athens, GA, USA) on Mar. 28 and Apr. 08 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, Canada) 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 and producing live calves the following season (calving proportion) and the calving to conception interval of these animals. Overall efficiency was calculated as:

(Calving proportion × mean weaning weight)/mean cow BW at calving

Milk Production

Milk production and composition were determined in all cows on one occasion between Mar. 10 and 15. Cows were machine milked on 2 consecutive days. Oxytocin (60 units oxytocin i.m., MTC Pharmaceuticals, Cambridge, ON, Canada) was used to encourage milk letdown. Calves were separated from cows between the two successive milkings. During this time they had access to water and timothy hay. Milk weight was corrected to a theoretical 24-h milk production. Samples of milk were collected from each cow and analysed for fat, protein and lactose.

Digestibility Trial with Growing Steers

Six Hereford-cross steers weighing approximately 350 kg were used in a double incomplete Latin square design trial with four diets, four periods but only three animals per square. Cattle were adapted to housing in individual pens (3 m × 6 m) and collection cages (1 m × 2 m) and to silage-based diets prior to the trial. At the start of the study, cattle were randomly assigned to square, and within square, diet.

Each period of the trial was 21 d, with total collection of faeces and urine taking place over the last 7 d of each period. Steers were housed in individual pens with complete freedom of movement for 14 d and then confined by a head yoke within metabolism cages. The cages were fitted to allow separation and collection of urine and faeces. Water was available at all times and lights were left on 24 h d^{-1}.

Steers were fed the same forage rations as the cows; silage or a 1:1 mixture (DM basis) of silage and straw with water added to equalize the DM concentration between the two forage types. Forages were fed ad libitum. For steers allocated to barley or SBM supplements, the supplements were placed on top at 1.35 and 0.45 kg d^{-1} (DM basis), respectively. These rates were chosen to ensure a similar forage:concentrate ratio in the digestibility study and the cow-calf trial.

Total faecal and urinary output was collected on a daily basis with urine acidified by the addition of 150 mL 4 M H_2SO_4 to collection containers. Each day, an aliquot of faeces and urine was taken and pooled over the 7-d collection periods.

Animal Care

In both trials, animals were cared for in accordance with guidelines suggested by the Canadian Council on Animal Care (1993).

Chemical Analysis

Dry matter in feed was determined 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 using macro-Kjeldahl procedures 7.033–7.037 [Association of Official Analytical Chemists (AOAC) 1990]. Crude protein was calculated at 6.25 × N. Insoluble N was determined in fresh silage using trichloroacetic acid (Siddons et al. 1979). Ash-free NDF and ADF were analysed by methods described by Van Soest et al. (1991). Ammonia N was determined using a Technicon Autoanalyser and procedure 7.025 (AOAC 1990). Volatile fatty acids and alcohols were determined in acid extracts of silage using gas chromatography (Varian model 3600 GC, Varian Canada, Mississauga, ON, Canada). Lactic acid in acid extracts was determined by the colorimetric method of Barker and Summerson (1941). Silage pH was determined on 10-g samples macerated in 200 mL distilled water. 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 analyser (Biggs 1967).

Statistical Analysis

The production variables measured in the cow-calf trial were analysed by standard analysis of variance procedures of the SAS Institute, Inc. (1995) using the general linear model with treatment, breed type (Hereford or cross) parity (primiparous or multiparous) and calving date (early or late) as factors. No interactions were observed between treatment and other blocking factors, and interactions were omitted from the final analysis of variance. Analysis of the proportion of cows producing live calves the following year was conducted by χ^2, using the CATMOD procedure of the SAS Institute, Inc.(1995) to determine differences in proportions. 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.

The digestibility trial was a double incomplete Latin square design with four periods, four treatments and six animals. Analysis of variance was used to determine the effects of treatment, animal and period on digestibility and N balance using the GLM model of the SAS Institute, Inc. (1995).

RESULTS

Nutrient Composition, Intake and Digestibility of the Diets

Silage was judged to be of good nutritive value, based on fibre and protein concentrations. A relatively high proportion of N was present as TCA insoluble N and the fermentation was predominated by lactic acid (Table 1). Thus, the preservation quality of the silage was also good. The protein concentration of barley was typical of crops grown in maritime Canada. The barley straw had unexpectedly high concentrations of CP and ADF.

Apparent digestibility coefficients of silage in steers were higher than that of the mixture ($P < 0.05$). When supplements were fed with the mixture, digestibility of DM and GE in the whole diets was increased to values similar to those in the silage (Table 2).

Steers fed silage consumed more N than those fed the silage-straw mixture ($P < 0.05$). Supplementation of the mixture with barley increased N intake to equal that from silage, while supplementation with SBM resulted in the highest N intake ($P < 0.05$). Faecal and urinary N losses (g d^{-1}) were greater for steers fed silage than those fed the unsupplemented mixture ($P < 0.05$). When these losses were related to N intake, steers fed the unsupplemented mixture lost proportionally more N in faeces ($P < 0.05$) and a similar proportion in urine ($P > 0.05$) to the silage-fed steers. In consequence, the unsupplemented mixture resulted in a negative N balance, while the silage, although supplying considerably more N, resulted in only a small positive N balance. Supplementation of the mixture with barley increased N balance, relative to the unsupplemented mixture ($P < 0.01$), largely through increased N intake without a concomitant increase in urinary N loss. Thus, N intake from the barley-supplemented mixture was the same as from silage, but urinary N losses were only 62% of those from silage-fed steers. The N retention (g d^{-1} and g kg^{-1} N intake) in steers fed the mixture supplemented with SBM was the highest of all treatments.

The CP concentration of the diets fed to cows was estimated from the actual forage and supplement intakes and their component CP concentrations (Table 3). The ME content of the diets fed to cows was calculated from the DE values measured in the balance trial, with ME equal to 0.82 DE. As planned in the design, the ME concentration of silage and the barley-supplemented mixture was similar (10.2 MJ kg^{-1} DM), whilst CP concentration of the silage and SBM-supplemented mixture were also similar to each other (134 g kg^{-1} DM). The unsupplemented mixture had lower CP and ME than the silage.

Ad libitum intake by cows was greater for silage than the mixture fed either alone ($P < 0.05$) or with SBM ($P < 0.01$; Table 4). Supplementation of the mixture with barley increased total DM intake to the same level as the silage, because inclusion of barley did not reduce intake of the forage compared to the unsupplemented mixture ($P < 0.05$). However, supplementation with SBM did not increase total DM intake. Expressing intake on a BW basis did not alter the interpretation of the data. The ME intake was the same from the silage and barley-supplemented mixture, averaging 134 MJ d^{-1}. Metabolizable energy intakes for the unsupplemented- and SBM-supplemented mixtures were approximately 22 MJ d^{-1} lower ($P < 0.01$) than the silage and barley-supplemented mixture and not different from each other ($P < 0.05$). The highest intake of CP was observed for the silage and the lowest for the unsupplemented mixture ($P < 0.001$). As a result of lower DM intake for the SBM-supplemented mixture, intake of CP on this treatment was less than for the silage ($P < 0.001$).

Animal Performance

The maximum difference among treatments in mean calving date was 10 d; however, this was not significant (Table 5). Cows fed silage alone gained weight during the feeding period, whilst those fed the unsupplemented mixture lost weight ($P < 0.001$; Table 5). Cows fed both supplemented mixtures maintained their weight. Even though ME intake for silage-fed cows was the same as that for cows fed the barley-supplemented mixture, the latter group did not gain as much weight ($P < 0.01$). At pasture, cows previously fed silage gained the least weight and those fed the unsupplemented mixture gained the most weight. All cows were in good condition at calving (BCS of 5.7) and there were no differences among treatments ($P > 0.05$). Body condition score at turnout to pasture reflected the previous weight changes. For example, the body condition of cows fed silage was 1.35 times greater than that of cows fed the unsupplemented mixture ($P < 0.001$). Silage-fed cows had gained condition, whilst feeding the mixture alone caused loss of condition. Body condition was higher for barley- than SBM-supplemented cows ($P < 0.05$). At weaning, treatment effects on condition score were less than at turnout, but condition score was still higher in cows fed silage in the winter compared with those fed the unsupplemented or SBM-supplemented mixtures ($P < 0.05$). Nevertheless, all cows were considered to be in satisfactory condition at weaning.

In spite of higher DM intake by silage-fed cows, calf gains were not different between cows fed silage or the unsupplemented and SBM-supplemented mixtures ($P > 0.05$; Table 6). Barley supplementation produced numerically the highest gains in calves at 0.97 kg d^{-1}; these were different to gains of calves from cows fed the unsupplemented mixture ($P < 0.05$). During winter feeding, supplementation of the mixture with SBM failed to increase calf gains, relative to other treatments. However, on pasture there appeared to be a residual effect with calves previously on this treatment having higher rates of BW gain than calves previously on the silage treatment ($P < 0.05$). Weaning weights averaged 265 kg and were not different among treatments.

Milk production averaged 5.14 kg d^{-1} and was not influenced by treatment (Table 7). Similarly, production of milk components was not influenced by treatment. Protein concentration varied widely among treatments. Silage-fed cows had the highest milk protein concentration (39.1 g kg^{-1}), while those fed the unsupplemented mixture had the lowest

Table 1. Chemical composition of dietary ingredients

	Silage	Straw	Silage/straw mixture	Barley	Soybean meal
Dry matter (g kg^{-1})	332	848	330	922	898
Acid detergent fibre (g kg^{-1} DM)	450	582	504	–	–
Neutral detergent fibre (g kg^{-1} DM)	554	813	670	–	–
CP (g kg^{-1} DM)	133	66.8	102	132	503
TCA insoluble N (g kg N^{-1})	616	915	712	–	–
Ammonia N (g kg^{-1} total N)	120	–	–	–	–
Total fermentation acids (g kg^{-1} DM)	128	–	–	–	–
Lactic acid (g kg^{-1} DM)	95.4	–	–	–	–
pH	4.55	–	–	–	–
Gross energy (MJ kg^{-1} DM)	19.4	19.8	19.7	18.8	20.8

Table 2. Apparent digestibility and N balance measured in growing steers fed the same diets as used in the cow-calf study

		1:1 silage straw mixture (DM basis)			
	Silage only	No supplement	Plus barley	Plus soybean meal	SEM
Dry matter intake (kg d^{-1})	7.13*b*	5.74*a*	8.26*c*	6.79*b*	0.314
Dry matter digestibility (g kg^{-1})	658*b*	604*a*	646*ab*	660*b*	16.2
Gross energy digestibility (MJ GJ^{-1})	663*b*	614*a*	646*ab*	671*b*	15.8
Estimated metabolizable energy (MJ kg^{-1} DM)	10.54*ab*	9.92*a*	10.23*ab*	10.94*b*	0.249
N intake (g d^{-1})	132*b*	79*a*	131*b*	155*c*	6.09
N in faeces (g d^{-1})	69.7*b*	53.0*a*	71.3*b*	56.6*a*	4.15
N in urine (g d^{-1})	47.5*b*	28.3*a*	29.7*a*	41.3*b*	2.57
N retained (g d^{-1})	15.1*ab*	–2.12*a*	30.7*b*	57.8c	7
N in faeces (g kg^{-1} N intake)	548*b*	673*c*	554*bc*	395*a*	40.9
N in urine (g kg^{-1} N intake)	368*b*	363*b*	224*a*	277*a*	26
N loss (g kg^{-1} N intake)	916*bc*	1037*c*	779*ab*	674*a*	54.7
N retained (g kg^{-1} N intake)	83.3*ab*	–37.1*a*	221*bc*	327*c*	54.7

a–c Means within rows not having a common letter differ ($P < 0.05$).

Table 3. Calculated metabolizable energy and crude protein concentration of the diets fed to beef cows and predictions of energy and protein supply and requirements according to NRC (1996)

		1:1 silage straw mixture (DM basis)		
	Silage only	No supplement	Plus barley	Plus soybean meal
Metabolizable energy (MJ kg^{-1} DM)	10.5	9.04	9.93	10.9
Crude protein (g kg^{-1} DM)	134	102	105	134
NRC (1996) predicted values				
Metabolizable energy in diet (MJ kg^{-1} DM)	10.1	8.82	9.66	9.2
Net energy for maintenance (MJ d^{-1})	52	51	54	51
Net energy for lactation (MJ d^{-1})	13	13	13	13
Net energy for gain for gain (MJ d^{-1})	17	–5	13	–6
Diet crude protein (g kg^{-1} DM)	130	98	105	136
Degradable protein supply (g d^{-1})	1156	613	823	840
Degradable protein required (g d^{-1})	1106	843	1103	823
Undegradable protein supply (g d^{-1})	495	479	573	577
Protein degradability (g kg^{-1})	700	562	590	592
Metabolizable protein supply (g d^{-1})	1104	921	1163	990

($P < 0.001$). Relative to the unsupplemented mixture, barley supplementation increased milk protein ($P < 0.01$) but SBM supplementation did not.

Reproductive Performance

All cows were synchronised for first service. However, synchronisation group (early or late) was balanced across treatments. Thus the effects of treatment on days to conception reflect the conception rate to first service and interval between first and subsequent service. Statistically, there were no treatment effects on reproductive performance (Table 8). However, the calving proportion was highest for cows fed silage and lowest for those fed the unsupplemented mixture. Overall efficiency was lower for cows fed the unsupplemented mixture than for cows fed either the silage or the barley-supplemented mixture ($P < 0.05$).

DISCUSSION

Diet Composition, Digestibility and N Balance

The apparent DM digestibility of barley straw was estimated by extrapolation to a theoretical diet of 100% straw, to be approximately 550 g kg^{-1}. This value was higher than expected (NRC 1996), and probably reflects the inclusion of some grasses and weed species in the straw. This supposition is also supported by the higher than expected CP content of straw. However, an associative effect of silage on the

Table 4. Effect of straw inclusion, with or without supplemental energy or protein, on dry matter intake of beef cows

		1:1 silage straw mixture (DM basis)			
	Silage only	No supplement	Plus barley	Plus soybean meal	SEM
Dry matter intake (kg d^{-1})	12.7*b*	11.1*a*	13.3*a*	10.4*a*	0.613
Dry matter intake (g kg^{-1} BW)	21.8*b*	18.9*a*	21.8*a*	18.7*a*	0.949
Forage dry matter intake (kg d^{-1})	12.7*b*	11.1*a*	10.5*a*	9.53*a*	0.613
Metabolizable energy intake (MJ d^{-1})	133*b*	110*a*	135*b*	114*a*	6.35
Crude protein intake (kg d^{-1})	1.69*c*	1.12*a*	1.44*b*	1.42*b*	0.07

a–c Means within rows not having a common letter differ ($P < 0.05$).

Table 5. Effect of straw inclusion, with or without supplemental energy or protein, on change in body weight (BW) and body condition score (BCS) of beef cows

		1:1 silage straw mixture (DM basis)			
	Silage only	No supplement	Plus barley	Plus soybean meal	SEM
Julian calving date	32	30	40	36	5.31
Liveweight gain of cows indoors (kg d^{-1})	0.55*c*	–0.46*a*	0.12*b*	0.00*b*	0.14
Liveweight gain of cows on pasture (kg d^{-1})	0.28*a*	0.54*c*	0.36*ab*	0.48*c*	0.07
Body condition score at calving (units)	5.72	5.90	5.59	5.46	0.231
Body condition score at turn-out (units)	5.98*b*	4.60*a*	5.56*b*	4.94*a*	0.294
Body condition score at weaning (units)	6.09*b*	5.27*a*	5.87*ab*	5.34*a*	0.291
Change in body condition score indoors (units)	0.26*c*	–1.31*a*	–0.02*c*	–0.52*b*	0.23
Change in body condition score on pasture (units)	0.26*a*	0.96*b*	0.50*ab*	0.71*ab*	0.26

a–c Means within rows not having a common letter differ ($P < 0.05$).

Table 6. Effect of straw inclusion, with or without supplemental energy or protein in the diet of beef cows on growth rate and weaning weight of their calves

		1:1 silage straw mixture (DM basis)			
	Silage only	No supplement	Plus barley	Plus soybean meal	SEM
Liveweight gain of calves indoors (kg d^{-1})	0.90*ab*	0.83*a*	0.97*b*	0.87*ab*	0.05
Liveweight gain of calves on pasture (kg d^{-1})	1.06*a*	1.13*ab*	1.09*ab*	1.18*b*	0.05
Calf liveweight at birth (kg)	41.4	43.2	43.8	43.2	1.8
Calf liveweight at turnout (kg)	125*ab*	118*a*	130*b*	117*a*	5.56
Calf liveweight at weaning (kg)	260	260	272	267	9.76
Calf liveweight adjusted to 200 d (kg)	236	242	251	248	9.95

a–c Means within rows not having a common letter differ ($P < 0.05$).

digestibility of straw would also have played a role by supplying ruminally available N for fibrolytic bacteria [Agricultural and Food Research Council (AFRC) 1993]. In spite of the composition of straw being better than expected, the digestibility of silage at 658 g kg^{-1} was higher than that of the silage-straw mixture (604 g kg^{-1}). Supplementation of the mixture with barley or SBM increased digestibility. The SBM effect on GE digestibility was greater than expected and may have been due to the additional protein promoting improved fibre digestion in the rumen. This effect is frequently observed with lower quality roughages (Males et al. 1982; Alawa et al. 1986). Based on the negative N balance observed in steers fed the unsupplemented mixture, it is reasonable to expect that protein may have been limiting ruminal digestion. This is further supported by the apparent insufficiency of degradable protein supply in the cows, as predicted by NRC (1996). Using the data from the current trial as inputs, NRC predicted a supply of approximately 600 g d^{-1}, relative to a requirement of over 800 g d^{-1} (Table 3).

Although the CP content of silage was 133 g kg^{-1}, N balance was only marginally positive with 83 g N retained kg^{-1} N intake. This is typical for silage, where the high protein solubility results in poor utilization of N in the rumen and excessive N losses in the urine (Broderick 1995). The silage used in this trial was actually of lower solubility than previously observed at our centre (Charmley et al. 1999; Charmley 2002). Nevertheless, removal of half the silage protein and replacement with less-soluble protein in straw, and especially SBM, increased N retention to 327 g kg^{-1} N intake. This was due to a reduction in both faecal and urinary N losses. When steers were given a combination of straw and silage alone, N balance was negative due to the low level of CP in the diet (102 g kg^{-1} DM). This diet had been formulated to be deficient in N, in order that a response to supplemental N from SBM or barley could be compared with a response to the same level of N, but from silage. Barley, which in this study had a CP concentration similar to the silage, elicited a much stronger improvement in N balance than was seen when all CP in the diet originated from silage. This was attributed solely to a reduction in urinary N loss, as opposed to a combined faecal and urinary N loss reduction as was seen with the SBM.

Effect on Cow-calf Performance of Replacing Half the Silage with Straw Alone

The ME concentration of the silage/straw mixture without any supplement was 86% of the silage. Although this differ-

Table 7. Effect of straw inclusion, with or without supplemental energy or protein, on milk production and milk composition of beef cows

		1:1 silage straw mixture (DM basis)			
	Silage only	No supplement	Plus barley	Plus soybean meal	SEM
Milk production (kg d^{-1})	4.93	5.82	5.19	5.09	0.695
Fat production (g d^{-1})	154	168	165	176	33.6
Protein production (g d^{-1})	171	167	184	165	25.6
Lactose production (g d^{-1})	168*a*	236b	209*ab*	191*ab*	28.9
Fat concentration (g kg^{-1})	33.5	31.3	31.1	33.8	4.36
Protein concentration (g kg^{-1})	39.1*c*	29.3*a*	36.0*bc*	33.0*ab*	1.69
Lactose concentration (g kg^{-1})	37.2*a*	40.5*b*	41.0*ab*	37.7*ab*	1.58

a–c Means within rows not having a common letter differ ($P < 0.05$).

Table 8. Effect of straw inclusion, with or without supplemental energy or protein, on days to conception and the percentage of cows exposed to breeding producing live calves the following season

		1:1 silage straw mixture (DM basis)			
	Silage only	No supplement	Plus barley	Plus soybean meal	SEM
Live calves born in following year (cow^{-1})	0.87	0.65	0.81	0.74	0.04
Calving to conception (d)	74.3	76.4	78.8	80.8	8.26
Production efficiency (kg weaned calf BW kg^{-1} dam BW)	0.344*b*	0.215*a*	0.348*b*	0.300*ab*	0.060

a,b Means within rows not having a common letter differ ($P < 0.10$).

ence was less than planned, it nevertheless effected significant responses in production variables. Voluntary intake of the mixture was reduced in response to the higher NDF in the diet (Mertens 1994). Lower energy density, coupled with reduced intake, combined to reduce ME intake from 133 MJ d^{-1} for silage-fed cows to 110 MJ d^{-1} for those cows fed the unsupplemented mixture. Cows responded to this restriction in ME intake by losing weight and condition between calving and turnout to pasture. Charmley et al. (1999) observed a similar response in an earlier study and the difference in weight change is consistent with the shortfall in dietary ME intake (Wright and Russell 1984).

Although restricting ME and CP intake by feeding the unsupplemented mixture after calving had a dramatic effect on body weight and body condition change, neither milk production nor calf gains were affected. This response is frequently seen in beef cattle when plane of nutrition is reduced (Lowman et al. 1979; Laflamme and Connor 1992). Our results exemplify the ability of the beef cow to maintain performance of the calf at the expense of her own body reserves. They also show that the potential of the beef cow is limited by the growth rate of her calf and not nutritional limitations.

While replacing high-quality silage with lower-quality barley straw had no effect on performance of the calf, reproductive efficiency appeared to be compromised. If this reproductive efficiency is combined with current calf performance (i.e., the treatment-influenced data), then an overall measure of efficiency can be expressed. This measure showed a production efficiency (kg weaned calf BW kg^{-1} dam BW) of 0.21 for cows fed the unsupplemented mixture as compared with 0.34 for cows fed silage (Table 8). These findings are consistent with the literature, which has shown the sensitivity of reproductive performance to energy status of the cow prior to breeding (Richards et al. 1986; Houghton et al. 1990; Laflamme and Connor 1992; Sinclair et al. 2002).

Effect on Cow-calf Performance of Replacing Half the Silage with Straw and Supplementing with Barley

Supplementation of the silage-straw mixture with barley increased the ME concentration of the diet and the resulting ME intake was equal to that obtained when feeding silage alone. Feeding barley did not reduce intake of the forage. Supplementing the mixture with barley increased total DM intake, with 2.7 kg barley replacing only 0.7 kg of forage. Even though the estimated ME intake from the barley-supplemented diet was similar to that of the silage, cows did not gain as much weight as their silage-fed counterparts. However, their calves gained 1.08 times faster. This indicated that cows fed the mixed diet of silage, straw and barley partitioned more energy to milk and less to maintaining body reserves. Statistically, milk production was not increased. However, production of milk, fat and protein were all numerically higher for cows given the mixed diet. Research with growing cattle has shown that mixed diets promote higher levels of BW gain than all-forage diets when fed at the same ME intake (Thomas et al. 1988; Steen and Robson 1995). This has been attributed to a shift away from fat deposition and towards protein deposition, in response to changed protein characteristics of the mixed diet (Steen and Robson 1995). Data from the balance study indicated that urinary N losses in cattle fed the barley-supplemented mixture were only 60% of those in cattle fed silage, indicating improved N utilization in this diet. In the lactating cow, better N utilization would manifest itself through improved milk production and reduced fat deposition (Robinson et al. 1992; Dhiman and Satter 1997). We therefore conclude that the partitioning towards calf production and away from body reserves by cows fed the barley-supplemented mixture was attributed to better protein utilization on this diet.

When the silage-straw mixture was fed without barley, reproductive efficiency was poor. However, supplementation with barley, although tending to favour increased calf production over condition score, nevertheless resulted in a satisfactory conception rate and calving to conception interval. Overall efficiency was similar to that observed in cows fed silage alone.

Effect on Cow-calf Performance of Replacing Half the Silage with Straw and Supplementing with Soybean Meal

Soybean meal did not stimulate forage intake but did increase the digestibility of energy in the ration. Nevertheless, intake of ME and CP from the SBM-supplemented ration was less than planned, being only 0.87 of the silage diet. The low intake of this treatment was unexpected and cannot be readily explained. Research has often shown an increase in intake when the solubility of dietary protein is reduced (Beaty et al. 1994; Charmley 2001).

The intakes of degradable and undegradable CP were predicted for experimental diets using NRC (1996). Silage supplied 1156 and 495 g d^{-1} degradable and undegradable CP, respectively, and the SBM-supplemented mixture supplied 840 and 577 g d^{-1}, respectively. In a previous study, Charmley et al. (1999) found that increasing undegradable protein, without reducing degradable protein, produced a response in calf gain. This was achieved in silage-fed cows supplemented with either corn gluten meal or SBM and the cows were in positive energy balance. However, in this trial where an increase in undegradable protein was offset by a reduction in degradable protein supply, and where cows were losing condition, there was no effect on calf gains. Others have concluded that feeding protein to cows does not affect calf performance (Wiley et al. 1991). Thus it would appear that a response to protein supplementation can be modified by the energy status of the cow, as well as the degradability and intake of the protein (Rusche et al. 1992; Dhuyvetter et al. 1993; Triplett et al. 1995; Charmley et al. 1999).

CONCLUSIONS

Restricting ME and CP intake of lactating beef cows by substituting silage with straw did not impact negatively on calf performance. Cows adapted to the lower plane of nutrition by losing body weight and condition, which ultimately had a negative effect on overall efficiency. If the silage-straw diet was supplemented with barley to increase ME intake to the level supplied by the all-silage diet, there was a tendency for cows to partition more ME to calf growth and less to body reserves. The source of dietary energy was therefore affecting partitioning within the cow. If the silage-straw was supplemented with SBM to increase the CP level to that of the all-silage diet, there were no benefits for the cow or calf, because SBM reduced forage intake. Thus, although supplementing with SBM increased intake of undegraded protein, there was no response in calf performance, probably because of insufficient ME intake. Although silage appears not to be well balanced for the nutrient requirements of lactating beef cows, attempts to optimise nutrient supply did not markedly improve growth performance of the calf or reproductive performance of the cow. Straw can be recommended as an effective method of extending silage supplies and reducing winter feed costs. While there may be no negative effects on calf performance, reproductive performance may be compromised.

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