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Effects of feeding level for four weeks precalving on milk production is small and dependent on level of feeding in early lactation

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ABSTRACT

The aim was to quantify the relationship between pre- and postcalving level of feeding and their effect on milk production. Sixty-eight multiparous dairy cows were randomly allocated to two levels of pasture feeding (Low and High; 4.8 and 11.9 kg DM/day) for 29 ± 7.7 days precalving. At calving, cows were randomly allocated (within precalving levels) to two levels of pasture feeding (Low and High; 8.6 and 13.5 kg DM/day) for 35 days postcalving. Daily milk yields were recorded and fat, protein and lactose concentrations determined on 2 days each week for 5 weeks postcalving, and once weekly for an additional 10 weeks post treatment. Body condition score (BCS) at calving was 4.2 and 4.7 for precalving Low and High treatment groups, respectively. Precalving restriction reduced milk fat production by 8.4% during the first five weeks postcalving, but these differences were not evident subsequently. Postcalving feed restriction reduced yields of milk, fat and protein by 25, 21 and 28%, respectively, during the first five weeks postcalving. Decreased ($P < 0.05$) yields of milk, fat and protein (12, 10 and 9%, respectively) were also evident for ten weeks after the feed restriction finished. There was a trend towards a treatment interaction ($P = 0.13$) in milksolids (MS) production during the first five weeks of lactation between pre- and postcalving level of feeding. High-High cows produced 7.1 kg more MS than Low-High cows, but there was no effect of precalving level of feeding in cows that were restricted postcalving. Results confirm that level of feeding postcalving influences the milk production effect of precalving feeding. Nevertheless the effect of precalving energy intake on postcalving milk production is small.

Keywords: transition cow; pasture; dry matter intake.

INTRODUCTION

An increased level of feeding precalving and an associated increase in body condition score (BCS) at calving was generally believed to increase milk yield and milk component yield after calving (Hutton & Parker, 1973; Grainger and McGowan, 1982). However, recent research (Roche *et al.*, 2005) reported only a small and transient effect of precalving dry matter intake (DMI) on postcalving milk production in optimally conditioned cows. This was consistent with the lack of effect of precalving treatment on the plasma concentrations of non-esterified fatty acids (NEFA), growth hormone (GH), insulin-like growth factor-I (IGF-I) or any other physiological measure indicative of a difference in energy balance. Other recent research results (Holcomb *et al.*, 2001; Agenas *et al.*, 2003) also showed no effect of prepartum energy intake on postpartum milk production. In fact cows that had DMI restrictions imposed precalving generally increased DMI and milk yield postpartum at a faster rate than cows consuming the same precalving diet *ad libitum*.

Broster and Broster (1984) suggested that moderate underfeeding before calving could be offset by more generous feeding after calving. In a recent review of literature Stockdale (2001) agreed, concluding that the benefit of higher BCS at calving was possibly dependent on level of feeding postcalving. Stockdale (2004) reported an interaction between calving BCS and level of concentrate supplementation postcalving, with medium-conditioned animals exhibiting a greater response to concentrates than those cows that calved in poor condition. Roche *et al.* (2005) concurred, hypothesizing that the lack of effect of precalving nutrition on postcalving production in their experiment was due to the unrestricted access to high-quality pasture postcalving. These results suggest that the effect of precalving nutrition is dependent on level of feeding postcalving, and that to benefit from improved precalving nutrition cows need to be very well fed postcalving.

The objective of the present study was to determine if the effect of level of feeding during the final four weeks before calving on periparturient blood metabolites and milk production was affected by postcalving level of feeding in grazing systems.

MATERIALS AND METHODS

Experimental design and treatments

Sixty-eight multiparous Holstein-Friesian cross cows, 29 ± 7.7 days (mean ± SD) precalving and selected to calve over a 21-day period (mean calving date of 15 July 2004), were allocated to one of two precalving dietary treatments (34 cows/treatment) on the basis of milk production during early lactation in the previous year (15.6 ± 3.2 kg milk/day; 0.71 ± 0.1 kg milk fat/day; 0.54 ± 0.1 kg milk protein/day), live weight (LW; 523 ± 63 kg), body condition score (BCS; 5.0 ± 0.7) and proposed calving date. Each group of cows was allocated to either Low or High pasture allowances precalving to achieve a proposed DMI of 5 and 12 kg dry matter (DM)/cow/day for four weeks precalving. At calving, cows in each precalving treatment were randomly allocated to one of two levels of feeding (Low or High) in a 2x2 factorial arrangement, to achieve a mean DMI of 10 and 15 kg DM/cow/day, respectively. Following treatment, which was continued for five weeks after calving, cows were grazed together as one group and supplemented with pasture-silage to appetite.

Grazing management

Cows had access to a fresh allocation of pasture daily. Pre- and postcalving, the experimental treatment groups were grazed within the same paddock and separated by double strands of electric fence to control pasture allowances. Backgrazing behind the current day's allocation was prevented using electric fences and the cows had access to water in their respective treatment areas. To achieve different pasture allowances and intakes, areas of different sizes were allocated daily to each treatment group based on Roche *et al.* (2004). Grazing areas averaged 17.2 and 52.9 m^2/cow/day, for precalving Low and High groups, respectively, and 94.5, 98.6, 47.4 and 49.1 m^2/cow/day for High-High, Low High, High-Low, and Low-Low groups, respectively, postcalving.

Measurements

On three days each week, pre- and postgrazing pasture mass and compressed height were calculated by cutting and drying samples representative of available and residual DM, as outlined by Roche *et al.* (2004). Compressed pasture height data (n = 457) were used to develop a regression equation relating pasture height to mass.

Pasture mass (kg DM/ha) = 149.1 x pasture height (cm) + 785.1; $r^2 = 0.75$;. $P < 0.001$

Pasture height was measured (n = 200) in pastures to be grazed, the pasture mass estimated, and treatment grazing area calculated. Each day before grazing, 100 and 200 pasture-height measurements were made in each Low and High treatment areas, respectively. Group intakes were calculated daily as the product of the difference between the pre- and post-grazing pasture mass and area grazed as outlined by Roche *et al.* (2004).

Individual milk yield was recorded twice daily (Westfalia Surge, Oelde, Germany) for 35 days postcalving. Fat, protein and lactose concentrations of milk were determined by Milkoscan (Foss Electric, Hellorod, Denmark) on individual p.m. and a.m. aliquot samples collected on two days each week for the five week postcalving treatment period, and on one day each week during the ten weeks following treatment completion. Live weight and BCS were recorded weekly at approximately 0900 hours pre- and postcalving.

Blood was collected from each cow by coccygeal venipuncture into heparinised (10ml) evacuated tubes prior to treatment allocation (covariate) and on day –21, -14, -7, 0, 1, 2, 3, 4, 7, 14, 21, 28 and 35 relative to calving. Plasma harvested (1,120 *g*, 10 minutes, 4^{O}C) was analysed for NEFA, β-hydroxy butyrate (BOH) and IGF-1. NEFA (colorimetric method) and BOH (BOH dehydrogenase assay) analyses were performed on a Hitachi 717 analyser (Roche, Basel, Switzerland) at 30^{O}C by Alpha Scientific Ltd., Hamilton. The inter- and intra-assay CV was < 2% for all assays. IGF-1 was measured in duplicate by double-antibody RIA (Gluckman *et al.*, 1983) with an inter- and intra-assay CV < 6%. Human IGF-1 antiserum (Lot# 01) and anti-human IGF-1 antiserum (Lot# AFP4892898) was obtained through Dr A.F. Parlow and the National Hormone & Peptide Program (California, United States of America).

Statistical analysis

Data were analysed for a factorial arrangement using REML in Genstat 5.4.1, with cows as a random effect and pre- and postcalving DMI as fixed effects. Log_{10} transformations were performed on blood data to stabilize the variance before statistical analysis. This had no effect on the statistical significance and so untransformed data are presented. Pre-experimental measurements were used as a covariate where significant.

RESULTS

Treatments were imposed successfully with apparent DMI of 4.8 and 11.9 kg DM/day (56 and 139 MJ ME/cow/day) precalving in Low and High treatments, respectively. Apparent DMI postcalving was not affected by precalving treatment (Table 1) and averaged 8.6 and 13.5 kg DM/day in Low and High postcalving treatments, respectively (Table 1; 13.5, 13.6, 8.5 and 8.7 kg DM/cow/day for High-High, Low-High, High-Low and Low-Low groups, respectively).

Restricted cows mobilised body condition precalving, calving 0.5 BCS units lower than well-fed cows (4.7 vs 4.2; P < 0.001). Cows on the low precalving feeding level lost less BCS postcalving than cows that had been fed well precalving (0.06 vs 0.13 BCS units; P < 0.05). Level of feeding postcalving did not affect BCS change during the first five weeks of lactation.

Table 1 shows the effect of feeding level pre- and post-partum on mean yield of milk, fat corrected milk (FCM) and milk components, and mean milk composition during the first 15 weeks of lactation. Milk yield was not affected by precalving level of feeding but yield of FCM tended (P < 0.1) to be lower (1.5 L/day) during week 1 to 5 in cows restricted precalving. This was caused by the lower (P < 0.001) milk fat content for the low precalving feeding level during week 1 to 5. Milk protein content was also lower during the first five weeks in the latter group, but protein yield was not affected beyond week 1. Effects of precalving feeding level were not evident beyond the week 4 of lactation.

In comparison, milk yield and yield of milk components were very sensitive to level of feeding postcalving, being lower with the lower level of feeding. This depression extended 10 weeks beyond the period

TABLE 1: Mean dry matter intake (DMI), body condition score (BCS) and milk production of grazing cows offered either a high or low feed allowance for 29 ± 7.7 days before calving and/or a high or low feed allowance for 35 days after calving. Main effects are presented.

Variable	Time[1], week	Precalving High	Precalving Low	Postcalving High	Postcalving Low	SED	P Pre	P Post	P Pre x Post
DMI, kg/day	-4 to 0	11.9	4.8	-	-	0.20	< 0.001	-	-
	3 to 5	11.0	11.1	13.5	8.6	0.44	0.73	< 0.001	0.94
BCS	0	4.7	4.2	4.5	4.4	0.09	< 0.001	0.59	
	+5	4.3	4.0	4.1	4.1	0.09	< 0.001	0.99	
Milk, kg/day	1 to 5	22.1	21.7	25.0	18.7	0.66	0.56	< 0.001	0.24
	6 to 10	23.2	22.9	24.7	21.4	0.85	0.76	< 0.001	0.42
	11 to 15	24.0	24.2	25.4	22.8	0.80	0.97	< 0.01	0.39
FCM[2], kg/day	1 to 5	24.9	23.4	27.2	21.0	0.79	0.07	< 0.001	0.20
	6 to 10	24.3	23.6	25.5	22.3	0.91	0.44	< 0.001	0.42
	11 to 15	25.7	25.7	26.9	24.5	0.79	0.82	< 0.01	0.54
Fat, %	1 to 5	4.88	4.54	4.58	4.83	0.09	< 0.001	< 0.01	0.93
	6 to 10	4.33	4.24	4.25	4.31	0.08	0.26	0.45	0.89
	11 to 15	4.50	4.46	4.42	4.54	0.07	0.50	0.08	0.39
Fat, kg/day	1 to 5	1.07	0.98	1.15	0.90	0.04	< 0.05	< 0.001	0.19
	6 to 10	1.00	0.96	1.04	0.92	0.04	0.30	<0.01	0.44
	11 to 15	1.07	1.07	1.12	1.03	0.03	0.68	<0.05	0.67
Protein, %	1 to 5	3.60	3.50	3.62	3.48	0.05	<0.05	<0.01	0.66
	6 to 10	3.32	3.34	3.29	3.37	0.03	0.63	<0.05	0.28
	11 to 15	3.50	3.52	3.45	3.56	0.03	0.57	<0.001	0.52
Protein, kg/day	1 to 5	0.79	0.76	0.90	0.65	0.02	0.18	<0.001	0.09
	6 to 10	0.76	0.77	0.81	0.72	0.03	0.99	<0.01	0.27
	11 to 15	0.83	0.85	0.87	0.81	0.03	0.72	<0.05	0.34

[1] Week relative to calving
[2] Fat corrected milk (= to 4%) = 0.40 x milk production (kg per day) + 15 x fat yield (kg per day)

of restriction, at which point recording ceased. During the five weeks of restriction, the cows on the high postcalving feeding level produced 17.4 kg more milksolids (MS) than their restricted comparison. During the following 10 weeks, when all cows were grazed together, the cows on the high postcalving feeding level continued to out-produce the low feeding level cows by 11.9 kg of MS (0.15 to 0.20 kg MS/cow/day).

Figure 1 portrays the effect of pre- and postcalving feeding level on fat and protein (milksolids; MS) yield during the first 5 weeks. Mean daily MS production was reduced ($P < 0.05$; 0.12 kg MS/day) in cows that were restricted precalving with larger differences resulting from restricted feeding postcalving ($P < 0.001$; 0.50 kg MS/day). There was a trend ($P = 0.13$) for a precalving x postcalving level of feeding interaction on MS yield during the first five weeks of lactation. Cows that were well fed pre- and postcalving produced 7.1 kg more MS than cows that were well fed postcalving but restricted precalving. In comparison, the depression in MS yield in cows that were restricted postcalving was not affected by level of feeding precalving.

Precalving plasma NEFA and BOH concentrations were elevated and IGF-1 concentration was depressed in restricted cows (Figure 2). After calving NEFA concentrations tended ($P < 0.1$) to be higher in cows that had been well fed precalving and this is consistent with the higher BOH ($P < 0.05$) concentrations in these cows.

Imposing a feed restriction postcalving caused an increase in plasma NEFA and BOH, but had no effect on IGF-1 concentration. There was an interaction ($P < 0.01$) between levels of feeding pre- and postcalving on plasma BOH concentration measured postcalving, with High-Low cows exhibiting higher BOH concentrations than the other three treatments, which did not differ from each other.

FIGURE 1: Daily milksolids production of High-High (◆), Low-High (◇), High-Low (■)and Low-Low (□) cows. Treatment diets were imposed for 29 ± 7.7 days precalving and 35 days postcalving. Twice the standard error of the difference is represented by the vertical bar. The *, † and ‡ imply significance at P < 0.05, 0.01 and 0.001, respectively

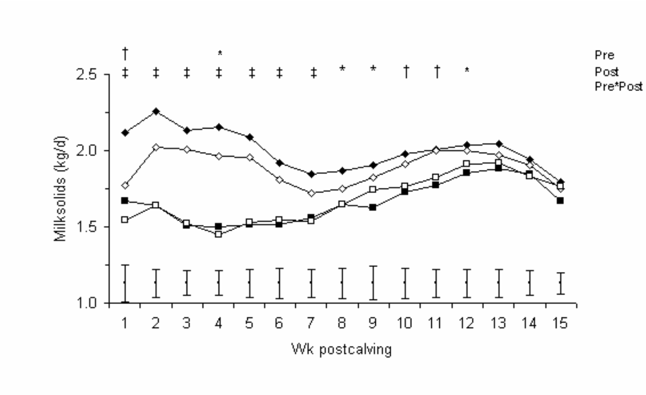
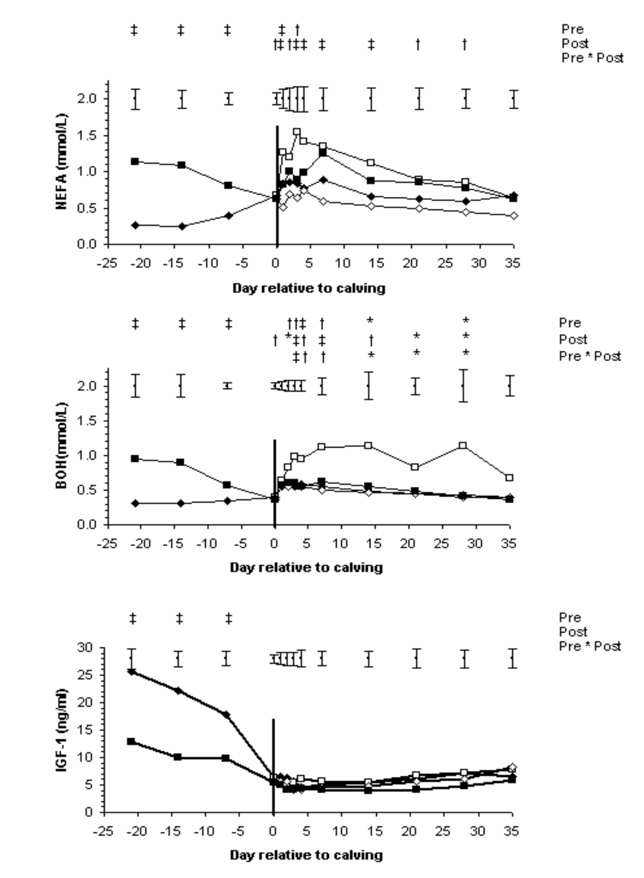


FIGURE 2. Plasma non-esterified fatty acids (NEFA), β-hydroxybutyrate (BOH) and insulin-like growth factor-1 (IGF-1) of High-High (◆), High-Low (◇), Low-High (□) and Low-Low (■) cows. Treatment diets were imposed for 29 ± 7.7 days precalving and 35 days postcalving. Twice the standard error of the difference is represented by the vertical bar. The *, † and ‡ imply significance at P < 0.05, 0.01 and 0.001, respectively.



DISCUSSION

Cows on the low feeding level precalving calved in poorer BCS than their well-fed counterparts (0.5 BCS units). Data presented show a tendency for this precalving restriction to lower BCS and reduce milk solids production, but only in cows that were well fed postcalving. There was no effect of precalving feeding or BCS at calving on cows that were severely restricted postcalving. In comparison, a restriction in energy intake postcalving significantly reduced milksolids production during the period of restriction, irrespective of precalving nutrition, and a depression in milksolids production was also evident for 10 weeks following cessation of treatment.

Blaxter (1956) drew attention to the possibility that current nutritional management could affect future milk production. Broster and Broster (1984) referred to this residual effect as "the prolongation of the effects of differential feeding" after differential feeding had ceased, and provided evidence from numerous grazing studies on the extent of this effect (see Broster & Broster, 1984). The magnitude of the residual effect relative to the immediate effect (40%) measured in the current study is similar to the 41% reported by Trigg *et al.* (1980) for a similar level of feed restriction in early lactation. This residual effect is not to be confused with the carry-over effect summarised by Penno *et al.*, (1998), where approximately 50% of the immediate response to supplementary feed is seen following cessation of supplementation. That carry-over effect is suggested to be a result of increased BCS gain from the supplementary feeding. However, in the current experiment there was no effect of feeding level on the amount of condition lost in early lactation. The residual effect reported in the current study was therefore more likely a result of less mammary secretory cells or less active mammary secretory cells in the low allowance cows. The decline in the residual effect in successive weeks (Figure 1) supports the earlier findings of Bryant and Trigg (1979).

Roche *et al.* (2005) reported only a small effect (5.25 kg MS) of precalving feeding level on postcalving milk production in cows that were well fed postcalving. Broster and Broster (1984) suggested that the effect of precalving feeding may be less evident in cows fed well postcalving. This is in contrast to results reported here, where cows restricted precalving (averaged across both postcalving feeding levels) produced 4.1 kg less MS than their well fed counterparts, but the effect of precalving level of feeding was only evident in the cows that were fed well on the higher feed allowance post-calving (7.1 kg MS/cow; Figure 1). Cows on the lower feed allowance postcalving were not affected by precalving level of feeding or calving BCS in the present study. The proposed hypothesis that the effect of precalving DMI on milk production is dependent on level of feeding postcalving is therefore correct, but in the opposite direction from what was expected.

The current experimental design does not allow the separation of any effect of BCS at calving from the effects of precalving DMI. However, the measured difference in MS (7.1 kg) between High-High and Low-High treatments during weeks 1 to 5 is consistent with previously measured milk production differences resulting from the lower condition (0.5 BCS units) of precalving restricted cows in the current study (Grainger & McGowan, 1982). This implies that there is little effect of precalving energy intake beyond the effect of resultant condition score at calving.

Results also suggest that the difference in BCS at calving was only important when cows were well fed postcalving. Consistent with this, Grainger *et al.* (1982) found that the milk production differences associated with different BCS at calving were greater when cows were better fed postcalving, possibly because of greater partitioning of additional energy towards milk production in fatter cows (Stockdale, 2001). Similarly, when Thomson *et al.* (1997) offered 0 or 3 kg barley to cows grazing at a pasture allowance of 22 kg DM/cow/day, they found that cows in greater BCS tended to respond to a greater degree than thinner cows. More recently, Stockdale (2004) also reported greater milk production responses to concentrates at medium (approximately 5) versus low (approximately 3.5) BCS at calving.

The elevated NEFA and BOH, and depressed IGF-1 concentration in plasma in restricted cows precalving is consistent with a negative energy balance and increased mobilisation of body tissue. Similar results were reported by Roche *et al.* (2005) and are supported by the change in BCS precalving. What is interesting from the data presented here is the interaction between level of feeding pre- and postcalving in plasma BOH concentration. Animals that were either well fed precalving or calved at a higher BCS were more likely to succumb to ketosis, than thinner cows or those that had been restricted precalving. Once again it is not possible to separate the effect of precalving level of feeding and BCS at calving with the current experimental design. The effect of 'overconditioning' at calving on periparturient metabolic disorders is well published (Blowie, 1999). However, precalving well-fed cows in the present study were not excessively fat (BCS at calving of 4.7 as compared with the industry standard of 5). The precalving x postcalving level of feeding interaction ($P < 0.01$) in plasma BOH concentration indicates a failure of High-Low cows to adapt to the postcalving feed restriction or the rapid loss in LW postcalving (Cows on the high precalving feed allowance lost 5.4 kg/day during the first week postcalving compared with 2.0 kg/day for cows that were on the low feed allowance; $P < 0.01$).

Results raise important issues for consideration when planning the nutrient requirements of the pasture-based transition cow. A severe energy restriction in the month prior to calving had only a small negative effect on subsequent milk production, and only if cows were fully fed postcalving. In comparison, feeding cows surplus to their requirement precalving in a pasture-based system, with its inevitable early lactation feed restriction may predispose cows to metabolic disorders such as ketosis. In a farm system, where total feed allowance is limited, priority for feed should be given to the lactating cow.

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