Supplementation with concentrates either pre- or post-partum does not affect milk production when diets are iso-energetic

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ABSTRACT

Dairy cow glucose requirements increase dramatically during the weeks preceding calving, suggesting that supplements that increase glucose supply (rapidly fermentable carbohydrates) would reduce precalving mobilisation of body tissue and improve subsequent milk production. Sixty-eight multiparous dairy cows were randomly allocated to one of two diets for 36 ± 8.7 days precalving. All cows were fed pasture and pasture-silage precalving, with one group also receiving 3kg DM of a barley-maize concentrate. Precalving diets were iso-energetic (114 MJ/cow/day). At calving, cows within each precalving feeding treatments were randomly allocated to two dietary treatments for 35 days in a 2x2 factorial arrangement. Postcalving, all cows received pasture and pasture silage with one group also receiving 5.0 kg DM of a barley-maize concentrate. Postcalving diets were also iso-energetic (179 MJ/cow/day). Milk yield and composition, and liveweight (LW) and body condition score (BCS) were assessed weekly for five weeks. Blood was sampled on day -21, -14, -7, 0, 1, 2, 3, 4, 7, 14, 21, 28 and 35 relative to calving, and plasma samples were analysed for indicators of energy status. Average milksolids yield (1.9 kg/cow/d) during the five weeks postcalving was not affected by either pre- or postcalving concentrate supplementation, although protein to fat ratio was higher in supplemented cows. Similarly, concentrate supplementation pre- or postcalving did not affect either LW or BCS change before or after calving. Cows receiving concentrates precalving had higher ($P<0.001$) plasma non-esterified fatty acid (NEFA) concentrations, but otherwise were not different to those receiving an equivalent energy intake from pasture and pasture silage. Postcalving concentrate supplementation increased ($P<0.01$) plasma glucose and NEFA and decreased ($P<0.001$) plasma B-OH butyrate. Results suggests little effect on milk production by replacing energy from structural carbohydrates in high quality pasture with energy from non-structural carbohydrate during the transition period.

Keywords: transition cow; pasture; dry matter intake, gluconeogenesis

INTRODUCTION

The transition period encompasses the period three weeks either side of calving. It has been the subject of much research, particularly in recent decades, because of the high cow wastage during this period (Overton and Waldron, 2004) and the reduced production in animals that were not fed appropriately over the transition period.

The primary challenge facing cows during this period is the sudden and marked increase in nutrient requirements for milk production. This coincides with the rapid development of the pre-term foetus (Van Saun, 1991), placing an extra and considerable nutrient demand on the cow. To compound the difficulty, dry matter intake (DMI) has been reported to decline during the three weeks before parturition (Bertics *et al.*, 1992).

Roche *et al.* (2005a) defined the energy requirements of the grazing dairy cow, but claimed that milk production was only slightly affected by precalving level of feeding, and the effect could be explained by calving condition score. This was subsequently confirmed by Roche *et al.* (2005b), and is consistent with research from intensive feeding systems (Holcomb *et al.*, 2001; Agenas *et al.*, 2003). However others have reported milk production benefits from manipulating dry cow diets. Olsson *et al.* (1998), Keady *et al.* (2001) and McNamara *et al.* (2003) are probably the most relevant studies for grazing cows, where cows offered a basal ration of either pasture silage or hay produced significantly more milk when supplemented with concentrates precalving.

The reason for this effect of precalving concentrate supplementation on milk production is unclear, although it may be a result of increased gluconeogenesis. Bell (1995) reported a four-fold increase in the uptake of glucose by the mammary gland during the final week before calving. Compared with monogastrics, very little glucose is absorbed from the digestive tract in ruminants, and is instead produced by the liver through gluconeogenesis from propionate, amino acids, glycerol and lactate (Young 1977). The observation that only 10-15% of foetal energy is derived from acetate (Comline & Silver 1976), and reports of glucose oxidation accounting for approximately 30% of foetal energy demands (Bell, 1995) suggests that increasing glucose supply could benefit transition cows through sparing of maternal reserves. However little is known regarding the effect of supplementing grazing cows with glucogenic precursors precalving, and whether any benefit is dependent on postcalving nutrition.

The objective of the present study was to determine if there was a positive effect of replacing structural carbohydrate from pasture with non-structural carbohydrates from concentrates pre- and postcalving.

MATERIALS AND METHODS

Experimental design and treatments

Sixty-eight multiparous Holstein-Friesian cross cows, 36 ± 8.7 d (mean ± SD) precalving and selected to calve over a 21-day (d) period (mean calving date of 21 July 2005), 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 (20.5 ± 4.4 kg milk/day; 0.96 ± 0.20 kg milk fat/day; 0.70 ± 0.15 kg milk protein/day), live weight (LW; 429 ± 60 kg), body condition score (BCS; 4.5 ± 0.7), age (4.3 ± 1.3 years) and proposed calving date. Precalving dietary treatments consisted of feeding cows either pasture and pasture silage (PrePast) or by feeding 3 kg DM of concentrates in place of an equivalent amount of energy from pasture and pasture silage (PreConc). Treatments were arranged to supply cows with 110% of their calculated precalving energy requirements (96 MJ ME/day; Roche *et al.*, 2005a). At calving, cows in each precalving treatment were randomly allocated to one of two dietary treatments offered either pasture and pasture silage (PostPast) or an isoenergetic comparison receiving 5 kg DM/d concentrates (PostConc). The 5 kg DM concentrates were introduced gradually over a 5 day period. Energy allocation was based on the PostPast group being unrestricted. The treatment arrangement was a 2x2 factorial.

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 isoenergetic intakes across treatment groups, pasture intakes were restricted in cows supplemented with concentrates, and silage allowance was reduced in proportion to the reduction in grazing area. Therefore different sized grazing areas were allocated daily to each treatment group, based on pasture mass measured prior to paddock division and the number of cows/treatment. Grazing areas averaged 35.6 and 22.6 m^2/cow/day, for PrePast and PreConc groups, respectively, and 71.7 and 35.0 m^2/cow/day for PostPast and PostConc groups, respectively.

Measurements

On three days each week, compressed pasture height was recorded within a 0.125m^2 quadrant representative of the range in pasture mass grazed. Pasture mass was measured within each quadrant by cutting and drying samples as outlined by Roche *et al.* (2005b). Quadrant data (n = 552) were used to develop a regression equation relating pasture height to mass.

Pasture mass (kg DM/ha) = 284.6 x pasture height (cm) + 646.8; r^2 = 0.80;. 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 pasture-height measurements were made in each treatment area. Group intakes were calculated daily as the product of the difference between the pre- and post-grazing pasture mass and area grazed.

Representative samples of pasture were collected daily by 'hand plucking' pasture to grazing height from paddocks due to be grazed. Samples were bulked on a two weekly basis, and duplicate samples were dried at either 100^{O}C, for dry matter analysis, or 60^{O}C for analysis of nutrient composition. The latter samples were then ground to pass through a 1.0-mm sieve (Christy Lab Mill, Suffolk, UK) and analyzed for organic matter digestibility (OMD) by Near Infra-Red Spectroscopy (Corson et al., 1999). Metabolisable energy (ME) was derived directly from predicted OMD, on the basis of an in vitro cellulase digestibility assay which had been calibrated against in vivo standards (Corson et al., 1999).
Liveweight and BCS were recorded weekly at approximately 0900 hours pre- and postcalving. 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. Fat corrected milk FCM) was calculated as;

$$FCM\ (kg/d) = 0.4 \times milk\ (kg/d) + 15 \times fat\ (kg/d)$$

Blood was collected from each cow by coccygeal venipuncture into heparinised (10ml) evacuated tubes prior to treatment allocation (covariate) and on approximately day –21, -14, -7, 0, 1, 2, 3, 4, 7, 14, 21, 28 and 35 relative to calving. Blood was centrifuged (1,120 *g*, 10 min, 4^{O}C) and the plasma harvested analysed for non-esterified fatty acids (NEFA), β-hydroxy butyrate (BOH) and glucose. The NEFA (colorimetric method), BOH (BOH dehydrogenase assay) and glucose (hexakinase method) analyses were all 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.

Statistical analysis

Data were analysed for a factorial arrangement using Residual maximum likelihood (REML) in Genstat 8, with cows as a random effect and pre- and postcalving feeding treatments as fixed effects. The repeated measurements through time were modelled using spline models within the linear mixed model framework as described by Verbyla *et al.* (1999). Treatments, linear trend of time and their interaction were included as fixed effects and Cow, linear trend of time within Cow, spline and the interaction of treatments with spline were included as random effects. The models were fitted using REML (Genstat 8).

RESULTS

Mean daily DM and energy intakes are presented in Table 1. Treatments were imposed successfully, with energy intakes (group intakes ÷ no. of cows per treatment) of 112 and 115 MJ ME/cow/day for PrePast and PreConc treatments, respectively, and 181 and 178 MJ ME/cow/day for PostPast and PostConc, respectively. Pasture and silage intakes were greater in the Pre- and PostPast treatments than their concentrate comparisons, but the pasture:silage ratio in the diet was not affected by treatment.

TABLE 1: Mean daily dry matter (DM) and metabolisable energy (ME) intakes of grazing dairy cows offered a basal ration of pasture and pasture silage (Past) pre- and postcalving. One treatment group was supplemented with 3 kg DM of concentrates for 36 ± 8.7 day before calving and/or 5 kg of concentrates for 35 day after calving (Conc). Standard deviations across days are presented in parentheses.

	Precalving		**Postcalving**	
Intake	Past	Conc	Past	Conc
Pasture, kg DM day	7.8 (1.7)	5.2 (2.0)	13.0 (4.0)	7.9 (2.5)
Silage, kg DM/day	2.5 (1.6)	1.7 (1.2)	2.4 (2.6)	1.3 (1.6)
Concentrate, kg, DM/day	-	2.9 (0.1)	-	5.1 (0.2)
ME, MJ/day	112 (14.8)	115 (18.4)	178 (40.7)	181 (25.6)

TABLE 2: Body condition score (BCS) and milk production of grazing dairy cows offered a basal ration of pasture and pasture silage (Past) pre- and postcalving. One treatment group was supplemented with 3 kg DM of concentrates for 36 ± 8.7 d before calving and/or 5 kg of concentrates for 35 d after calving (Conc). Main effects are presented.

	Precalving		**Postcalving**			**P**		
Variable	Past	Conc	Past	Conc	SED[1]	Pre	Post	Pre x Post
BCS at calving	4.5	4.5	-	-	0.13	0.91	-	-
BCS at Wk 5	4.1	4.2	4.1	4.2	0.14	0.25	0.24	0.53
Milk, kg/d	23.8	23.4	22.9	24.2	0.72	0.60	0.07	0.21
FCM[2], kg/d	26.1	25.8	26.3	25.6	0.75	0.68	0.39	0.32
Fat, %	4.67	4.72	4.99	4.40	0.091	0.57	<0.001	0.32
Fat, kg/d	1.11	1.10	1.14	1.06	0.033	0.75	<0.05	0.44
Protein, %	3.48	3.53	3.48	3.53	0.048	0.31	0.30	0.89
Protein, kg/d	0.83	0.82	0.80	0.85	0.024	0.92	<0.05	0.16
Daily milk value, $[3]	7.71	7.62	7.61	7.72	0.304	0.69	0.62	0.31

[1]Standard Error of the Difference
[2]4% Fat corrected milk = 0.40 x milk yield (kg per day) + 15 x fat yield (kg per day)
[3]Assuming Fat = 238.92c/kg and Protein = 612.62c/kg

Precalving feeding treatment did not affect LW or BCS at calving (Table 2). Cows were 562 kg LW the week of calving (565 and 560 kg LW for PrePast and PreConc, respectively) and calved at BCS 4.5 in both treatments. Table 2 also shows the effect of concentrate feeding pre- and post-partum on mean yield of milk, FCM and milk components, and mean milk composition during the first five weeks of lactation. There was no effect of precalving concentrate on milk production, and no interaction between pre- and postcalving feeding treatments. Milk yield increased (P=0.07) in cows fed concentrates postcalving, but FCM was not affected. Milk fat % and yield declined with concentrate supplementation, and yield of milk protein was increased. Total value of milk supplied was not affected by treatment.

FIGURE 1: Daily yield of fat corrected milk (FCM), fat and protein (kg per day) from cows eating either pasture and pasture silage (--), or pasture, pasture silage and 5 kg DM concentrates (-) postcalving. Diets were isoenergetic. §, *, † and ‡ = *P* < 0.1, 0.05, 0.01 and 0.001, respectively.

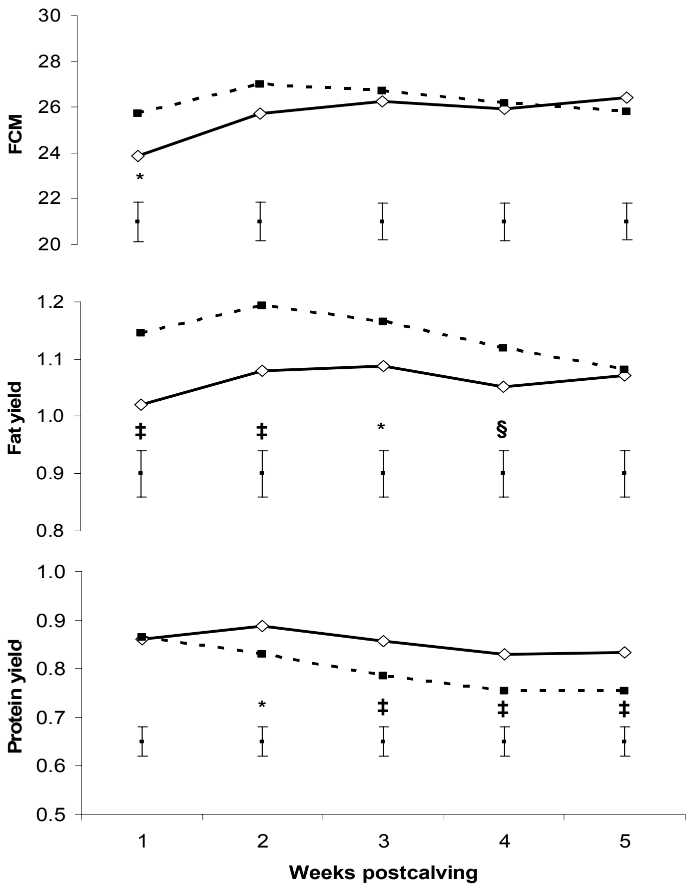
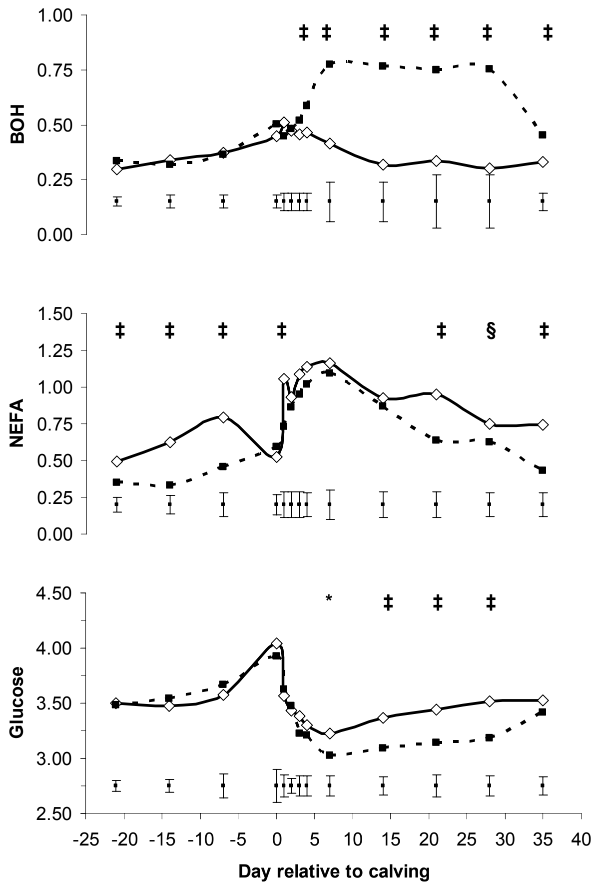


Figure 1 portrays the effect of postcalving treatment on FCM, fat and protein yield during the first 5 weeks of lactation. Fat corrected milk production was greater (P<0.05) in PostPast cows week 1 postcalving but otherwise was not significantly affected by carbohydrate source. Fat yield was higher (P<0.01) for the first three weeks of lactation and tended (P<0.10) to be higher on week 4 in the group not receiving concentrate. Milk protein yield was less (P<0.01) in PostPast group for the entire experimental period other than week 1.

FIGURE 2: Plasma β-hydroxybutyrate (BOH), non-esterified fatty acid (NEFA) and glucose concentration (mmol/L) of cows eating either pasture and pasture silage (--), or pasture, pasture silage and concentrates (-) pre- (3kg DM/d) and postcalving (5 kg DM/d). Treatment diets were isoenergetic pre- and postcalving. §, *, † and ‡ = *P*<0.1, 0.05, 0.01 and 0.001, respectively.



Plasma NEFA, BOH and glucose concentrations are presented in Figure 2. Precalving, NEFA concentrations were elevated ($P<0.001$) in PreConc cows, but BOH concentrations were not affected by treatment. After calving plasma NEFA concentrations were higher ($P<0.01$) in PostConc cows during week 3, 4 and 5 postcalving, while plasma BOH was higher ($P<0.001$) in the PostPast group. Glucose concentrations were not affected by precalving treatment, but were higher postcalving in the PostConc treatment. There was no interaction between pre- and postcalving feeding treatment on plasma metabolite concentration.

DISCUSSION

Replacing 40 MJ ME/cow/day from pasture and pasture silage with 40 MJ ME/cow/day from concentrates daily precalving did not affect BCS pre- or postcalving or milk production postcalving, but did increase plasma NEFA concentrations precalving. In comparison, with lactating cows replacing 70 MJ ME/cow/day from pasture and pasture silage with an equivalent amount of energy from concentrates increased milk yield, but not that of FCM, decreased milk fat yield and increased milk protein yield. The value of milk supplied was not different between diet types. Cows receiving concentrates postcalving had higher blood glucose and NEFA concentrations, and lower BOH. There was no evident interaction between pre- and postcalving dietary regimen.

The requirement for glucose increases significantly during the final month precalving, with a rapidly growing foetus (Van Saun, 1991) and the onset of lactogenesis (Bell, 1995). It was hypothesised that by supplying a supplement that provided more glucogenic precursors, the foetal and maternal requirement for glucose would be satisfied and the requirement for mobilisation of energy stores would be reduced and subsequent milk production increased. Up to 90% of ruminant glucose requirements at the tissue level must be provided by gluconeogenesis (Young, 1977) and the major factor determining the amount of glucose formed is the quantity of glucogenic precursors available to liver (Fahey and Berger, 1988).

The most important glucogenic precursor in fed animals is propionate, although amino acids take the position of primary importance in animals deprived of feed (Herdt, 1988). Feeds containing rapidly fermentable carbohydrates are known to shift the rumen fermentation pattern in favour of propionate, thereby increasing the precursors available for gluconeogenesis (Van Soest, 1982). The failure of concentrate supplementation precalving to increase plasma glucose concentration, or elicit any positive animal production response either pre-or postcalving suggests that glucose supply for maternal maintenance requirements, foetal development, and lactogenesis is adequate in cows receiving their defined energy requirement (Roche *et al.*, 2005a) from pasture and pasture silage. This is consistent with Roche *et al.* (2002), where cows of different strains receiving either pasture and pasture silage or a total mixed ration (34% non structural carbohydrate) had similar blood glucose concentrations precalving.

In comparison, Keady *et al.* (2001) reported an increase in milk fat% when cows fed pasture silage were supplemented with concentrates precalving. Similarly McNamara *et al.* (2003) reported an increase in the yield of fat and protein and an increase in milk fat % in cows that were supplemented with concentrates precalving compared with those fed pasture silage and straw (75%:25%). This apparent inconsistency is probably due to differences in total energy intake of treatments in their trials. In the reported studies, concentrates were used to supplement pasture silage, thereby increasing the energy intake of the concentrate supplemented group over that of the control group. In the experiment being reported here, concentrate energy was used to substitute for energy in pasture and pasture silage, maintaining isoenergetic diets across treatments. Increasing energy intake precalving will increase the BCS of cows at calving, a factor known to increase the production of FCM, milk fat and in some cases milk protein (Roche *et al.*, 2005a; 2005b). This thesis is supported by the 0.75 unit increase in calving BCS in supplemented cows in the study of McNamara *et al.* (2003). Calving BCS in the current experiment was not affected by precalving concentrate supplementation. Results suggest that precalving energy intake is the important factor affecting calving BCS and subsequent production, and not energy type per se.

The effect of supplementing lactating cows with concentrates was recently reviewed (Bargo *et al.*, 2002). They reported a linear increase in milk production with increasing amount of concentrate (from 1.2 to 10 kg DM/d), and an overall milk response of 1 kg milk/kg DM concentrate. Substituting concentrates for pasture and pasture silage in the current study, while maintaining the same energy intake tended to increase milk yield ($P=0.07$), and milk protein yield ($P<0.05$), but lowered milk fat% and yield, and did not affect FCM. This lack of effect of postcalving energy type on milk production is consistent with results presented by Carruthers *et al.* (1997), who reported no effect of replacing structural carbohydrate in pasture with non-structural carbohydrate in either milk yield, microbial growth or ruminal ammonia production. Similarly Smith *et al.* (2005) reported no effect of carbohydrate source on milk production in TMR cows. This lack of effect of concentrates on milk production explains the poor responses to concentrates achieved when pasture allowance is generous and substitution rate of concentrates for pasture is high (Penno, 2002).

The inconsistency between BOH and NEFA is noteworthy. Plasma concentrations of BOH were significantly higher ($P<0.001$) in PostPast cows, even though NEFA concentrations are lower ($P<0.01$). Both metabolites are used as indicators of the energy status of the animal, and both have been negatively associated with energy balance (i.e. high concentration of metabolite indicates negative energy balance, and vice versa). Non-esterified fatty acids in blood are a direct result of lipolysis, and are either taken up by tissues (such as muscle) as energy sources, or reconverted to triacylglycerol in the liver and relocated to adipose tissue. Therefore NEFA is an effective indicator of body fat mobilisation, and suggest slightly greater tissue catabolism in the cows receiving concentrates postcalving in the current study. This is consistent with the numerically greater BCS loss in these cows (0.1 BCS units). The reason for the higher concentration of BOH in PostPast cows is not known, but considering the opposite trend in NEFA and BCS it is unlikely to be the result of increased lipolysis, and is more likely to result from greater ruminal butyrate production on the all forage diet. This suggests that BOH concentrations in blood are not an effective indicator of the energy status of the animal and should not be used in isolation for this purpose.

Data suggests that cows receiving sufficient energy to meet their ME requirements for maintenance, foetal growth and lactogenesis from forage precalving will not benefit from an altered structural to non-structural carbohydrate ratio. Postcalving replacement of energy from pasture and pasture silage with an equal amount of energy from rapidly fermentable carbohydrate increases milk protein but decreases milk fat, and does not affect the economic value of the daily milk produced.

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