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Effect of precalving feeding level on the milk production of grazing dairy cows

J.R. ROCHE, J.K. KAY[1], E.S. KOLVER, P.W. ASPIN, J. LEE, B. SUGAR AND A.R. NAPPER

Dexcel Ltd., Private Bag 3221, Hamilton New Zealand

ABSTRACT

Fifty-two multiparous dairy cows were allocated to four treatments with an apparent daily intake of 5.8, 8.9, 10.0 or 11.2 kg dry matter (DM)/cow/day of pasture for 27±9.6 days precalving. This equated to 1.3, 2.0. 2.3 and 2.6% of liveweight (not including the conceptus weight; LW). Following calving, all cows were fed generously on pasture. Daily milk yields were recorded postcalving and fat, protein and lactose concentrations determined on 2 days each week for 5 weeks. Blood was sampled 17 days precalving, on the day of calving and on days 1, 2, 3, 4, 7, 14, 28 and 35 postcalving. Precalving plasma concentrations of insulin-like growth factor-1 (IGF-1) increased ($P<0.05$) quadratically with increasing pasture intake. Concentrations of growth hormone declined ($P<0.05$) linearly and concentrations of non-esterified fatty acids declined ($P<0.001$) quadratically with increasing DM intake. Plasma concentrations of these metabolites postcalving showed no effect of precalving feeding. Level of feeding precalving did not affect milk yield or the yield of fat, protein or lactose in milk, but postcalving DM intake was negatively ($P<0.1$) related to precalving DMI. These results indicate that 0.93 MJ metabolisable energy/kg $LW^{0.75}$ was required in the final three weeks of gestation to maintain cow energy balance.

Keywords: transition cow; pasture; energy balance.

INTRODUCTION

An increased level of feeding precalving and an associated increase in body condition score (BCS) at calving generally increases milk yield after calving (Grainger and McGowan, 1982). Hutton & Parker (1973) also reported that higher liveweight gains in late gestation were associated with greater yields of milk components and higher DMI. Bertics *et al.* (1992), Grummer (1995) and Putnam *et al.* (1997) also reported positive correlations between DMI precalving and DMI and lactation performance postcalving. The physiological measurements of Kobayashi *et al.* (1999) support this relationship. They reported lower concentrations of growth hormone receptor-1A in liver tissue in cows underfed around calving, and consequently found an elevated concentration of growth hormone and a lower concentration of IGF-1 in blood.

However, Broster & Broster (1984) suggested that although the effects of precalving feeding could be observed throughout lactation, 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 is dependent on level of feeding postcalving. Recent research results (Holcomb *et al.*, 2001; Agenas *et al.*, 2003) have shown that prepartum energy intake did not affect postpartum milk production. In these experiments, 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*.

The objective of the present study was to quantify the effect of level of feeding during the final four weeks before calving on periparturient blood metabolites and milk production in grazing dairy cows, and establish the energy requirements of precalving grazing cows. This data will then be used to evaluate the effectiveness of NRC (2001) and Holmes *et al.* (2002) in predicting the requirements of the near-term cow.

MATERIALS AND METHODS

Experimental design and treatments

Fifty-two multiparous Friesian-Jersey cross cows, 27 ± 9.6 days precalving (mean ± SD), were randomly allocated to one of four dietary treatments (13 cows/treatment) on the basis of milk production in the previous lactation (4109 ± 754 kg milk; 200 ± 33.9 kg milk fat; 150 ± 25.6 kg milk protein), liveweight (LW; 480 ± 64 kg), body condition score (BCS; 5.1 ± 0.63), age (4 ± 1.2 yr) and proposed calving date. Each group of 13 cows were allocated to one of four precalving pasture allowances to achieve a precalving energy intake of 60, 90, 120 and 150 MJ metabolisable energy (ME)/cow/day. In attempting to achieve these intakes, cows were offered either 7±0.2, 10±0.4, 15±0.9 or 24±2.4kg DM/cow/day of fresh pasture, respectively. Following calving, all cows were grazed together and offered fresh pasture to appetite.

Grazing management

The cows were rotationally grazed and had access to a fresh allocation of pasture daily. Precalving, the four experimental treatment groups were grazed within the same paddock and separated by double strands of electric fence to control pasture allowances. Backgrazing beyond 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 hence intakes, areas of different sizes were allocated daily to each treatment group. Precalving

[1]The University of Arizona, Tucson, AZ, 85721, USA

grazing areas averaged 16.5, 25.8, 37.3 and 59.6 m^2/cow/day, for cows consuming the proposed 5.5, 8.0, 10.5 and 13.0 kg DM, respectively.

Postcalving, cows from all four treatments were grazed together as a single herd for 35 days precalving and were fed fresh pasture to appetite. Pre- and postgrazing mass averaged 2697 (±551) and 1983 (±361) kg DM/ha, respectively.

Measurements

On 3 days each week precalving, pre- and postgrazing pasture mass was determined for each treatment by cutting and drying samples representative of available and residual DM. Precalving 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.* (1996).

Representative samples of pasture were collected by 'plucking' pasture to grazing height from paddocks due to be grazed. Samples were bulked fortnightly, dried at 60^{O}C for 48 h, ground to pass through a 1.0-mm sieve (Christy Lab Mill, Suffolk, UK) and analyzed for ME by Near Infra-Red Spectroscopy.

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 2 days each week. Precalving, LW and BCS were recorded fortnightly at approximately 0900 hours, before being offered fresh pasture. After calving, LW and BCS were recorded weekly following the a.m. milking.

Blood was collected from each cow by coccygeal venipuncture into heparinised (10ml) evacuated tubes prior to treatment allocation (covariate) and on day 17 ± 9.6 precalving (day 10 of treatment), on the day of calving and on days 1, 2, 3, 4, 7, 14, 28 and 35 postcalving. Blood was sampled at approximately 0900 hours. Plasma was harvested (1,120 *g*, 10 min, 4^{O}C) and analyzed for non-esterified fatty acids (NEFA; colorimetric method). Analyses were performed at 30^{O}C on a Hitachi 717 analyser (Roche, Basel, Switzerland) by Alpha Scientific, Hamilton. Growth hormone (GH; Downing *et al.,* 1995) and insulin-like growth factor-1 (IGF-1; Gluckman *et al.,* 1983) were measured by double-antibody RIA.

Calculations

In the paper presented here, cow LW refers to cow LW measured prior to beginning the study, less the conceptus weight. Conceptus weight (NRC, 2001) = (18 + ((Days Pregnant – 190) x 0.665)) x Calf Birth Weight/45). Days pregnant was back calculated from calving date (assuming calving was day 279 of gestation).

Precalving energy requirements were calculated as the sum of the requirements for maintenance and pregnancy. Maintenance of dry pregnant grazing dairy cows was assumed to be 0.55 MJ/kg $LW^{0.75}$ from Holmes *et al.* (2002) and 0.45 MJ ME/kg LW from NRC (2001). An additional energy requirement for grazing of 0.002 * LW was added to the maintenance requirement of NRC (2001).

The energy requirements of pregnancy were calculated as;
42.9 x CBW/40 (Holmes *et al.*, 2002) or
4.186*((0.00318 x t – 0.0352) x (CBW/45))/0.218 (NRC, 2001)
where t = day of gestation and CBW = calf birth weight. Gestation length was assumed to be 280 d.

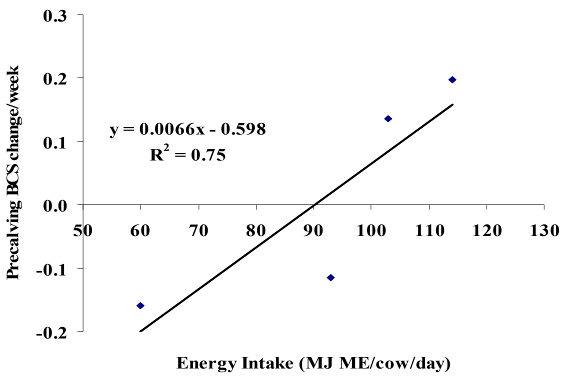
Mean postcalving DMI was calculated from milk energy output plus cow maintenance requirements, minus the contribution from true LW loss, assuming energy for milk production (k_m) is used with 65% efficiency, energy from LW mobilisation (k_g) is used with 80% efficiency, and the maintenance requirements for lactating grazing dairy cows was 0.6 MJ/kg $LW^{0.75}$ (Holmes et al, 2002).

Because tissue mobilization in early lactation occurs as feed intake is increasing, decreases in LW can be masked by enhanced gut fill, such that LW changes do not reflect changes in adipose and lean tissue weight (NRC, 2001). True LW loss was therefore calculated from changes in BCS between week 1 and week 5, assuming 1 BCS unit for Friesian-Jersey crossbred cows = 32.5 kg (calculated from Holmes *et al.*, 2002).

Statistical analysis

Data were analyzed using restricted maximum likelihood (REML), with cows as a random effect and linear and quadratic effects of precalving DMI as fixed effects. All data were analyzed using the statistical procedures in Genstat 5.4.1. Pre-experiment measurements were used as a covariate where significant.

FIGURE 1: The relationship between precalving energy intake and body condition score (BCS) change precalving in 445 kg multiparous dairy cows.



RESULTS

Precalving intake of DM and energy increased (P<0.001) linearly with increasing pasture allowance, although data is indicative of a quadratic increase (P=0.07). On average, cows consumed 5.8, 8.9, 10.0 and 11.2 kg DM, equivalent to 1.3, 2.0, 2.3 and 2.6% of precalving LW (minus the conceptus weight). These equated to 60, 93, 103 and 114 MJ ME/cow/day, respectively.

Changes in LW and BCS before calving were positively (P<0.001) associated with precalving energy intake (Figure 1), with cows eating 1.3 and 2.0% of LW in negative energy balance, as measured by BCS change, and cows consuming 2.3 and 2.6% LW in positive energy balance. This resulted in significant treatment effects on calving condition score. Postcalving, changes in LW and BCS were both negatively associated (P<0.001 and P<0.1, respectively) with level of energy intake prior to calving. However milk yield and composition during the first 5 weeks of lactation were not affected by precalving DMI (Table 1). GH concentrations peaked on the day of calving in all treatments and declined to base levels by day 7 (Table 2).

There was a negative relationship between precalving plasma GH (linear; P<0.05) and NEFA (quadratic; P<0.001) concentrations and precalving DMI. On the day of calving and on the first four days of lactation, plasma GH concentration was quadratically elevated (P<0.01) at the lower precalving feeding level, with cows eating 1.3% LW precalving displaying higher (P<0.001) levels compared with the other 3 treatments, which did not differ from each other. Following calving, there was no effect of precalving level of nutrition on plasma concentrations of NEFA.

Precalving, IGF-1 concentration declined curvilinearly with level of feeding. Cows consuming 1.3% LW had lower (P<0.01) IGF-1 concentrations in blood than cows in the other 3 feeding levels, which did not differ significantly from each other (Table 3). Although inconsistent, concentrations of IGF-1 in plasma during the colostrum period were negatively associated with precalving DMI (P=0.06 and P<0.05 on day 2 and 3, respectively), but were not affected subsequently by precalving DMI.

TABLE 1: Mean daily dry matter intake (DMI), milk yield and milk composition and pre-and postcalving liveweight (LW) and body condition score (BCS) change, of dairy cows consuming a range of pasture intakes (1.3, 2.0, 2.3 or 2.6 % precalving LW minus conceptus) for 27 ± 9.6 d precalving.

	DMI (%LW)					*P*-value		
Variable	1.3	2.0	2.3	2.6	SED[2]	DMI	L[3]	Q[4]
Precalving								
DMI[1], kg/day	5.8	8.9	10.0	11.2	0.90	<0.001	<0.001	0.08
Energy Intake (MJ ME)	60	93	103	114	0.18	<0.001	<0.001	0.08
LW change (kg/day)	-1.2	-0.1	0.5	0.9	0.36	<0.001	<0.001	<0.001
BCS change (per week)	-0.16	-0.12	0.14	0.20	0.110	<0.01	<0.01	<0.001
Calving LW	424	441	458	468	8.1	<0.001	<0.001	<0.001
Calving BCS	4.7	4.9	5.4	5.6	0.25	<0.01	<0.01	<0.001
Postcalving								
Milk yield, kg/d	19.7	21.1	19.3	20.6	1.48	0.85	0.45	0.98
Fat, %	4.79	4.81	5.10	5.05	0.238	0.75	0.48	0.53
Protein, %	3.72	3.79	3.77	3.77	0.078	0.55	0.30	0.58
Lactose, %	4.93	5.00	4.88	4.94	0.037	0.78	0.52	0.69
DMI[5], kg/d	12.8	13.2	12.2	11.4	1.27	0.44	0.16	0.50
DMI, %LW	3.0	3.0	2.8	2.6	0.29	0.26	<0.06	0.49
LW change (kg/day)	-1.0	-1.3	-1.6	-2.0	0.27	<0.001	<0.001	0.99
BCS change (per week)	-0.19	-0.19	-0.26	-0.27	0.29	0.29	0.08	0.85

[1]Precalving group intakes were calculated daily as the product of the difference between the pre- and post-grazing pasture mass and area grazed.
[2]Standard Error of the Difference
[3]Linear effects
[4]Quadratic effects
[5]Postcalving DMI was calculated from the energy required for milk production and maintenance, discounted for energy supplied from body tissue mobilisation (Holmes *et al.*, 2002)

TABLE 2: Concentrations of plasma growth hormone (ng/ml), IGF-1 (ng/ml) and NEFA (mmol/L) in cows eating either 1.3, 2.0, 2.3 or 2.6 % liveweight (LW) as pasture for 27 ± 9.6 d precalving, measured on 10 occasions .

	Day relative to calving									
	-17	0	1	2	3	4	7	14	28	35
Growth Hormone										
1.3% LW	6.0	34.3	24.7	22.4	17.1	13.3	8.5	6.1	5.9	7.9
2.0% LW	4.0	11.4	12.6	9.9	6.5	6.3	5.6	5.8	5.5	7.0
2.3% LW	3.9	11.7	12.1	9.2	7.3	4.1	6.3	4.0	7.2	6.6
2.6% LW	3.8	14.2	9.1	10.2	9.5	6.4	6.9	5.8	6.3	7.0
SED[1]	0.89	4.25	4.312	3.35	3.22	2.49	2.25	1.50	2.15	2.58
P(L)[2]	<0.05	<0.001	<0.001	<0.001	<0.05	<0.01	0.49	0.49	0.44	0.44
P(Q)[3]	0.27	<0.001	0.14	<0.01	0.01	0.01	0.29	0.37	0.94	0.67
IGF-1										
1.3% LW	10.9	5.3	7.0	6.5	5.3	7.5	7.5	6.4	6.6	6.9
2.0% LW	15.6	5.5	6.7	6.8	6.5	4.9	6.6	6.4	7.0	8.4
2.3% LW	20.0	5.9	6.4	9.8	7.1	6.0	8.6	6.4	6.8	7.9
2.6% LW	17.0	5.4	8.7	8.8	8.6	7.7	8.4	7.4	7.8	8.0
SED[1]	2.38	1.20	1.47	1.68	1.22	1.08	1.21	1.02	1.27	1.23
P(L)[2]	<0.001	0.85	0.32	0.06	<0.05	0.61	0.26	0.42	0.36	0.49
P(Q)[3]	<0.001	0.61	0.24	0.53	0.78	<0.01	0.78	0.50	0.86	0.47
NEFA										
1.3% LW	0.90	0.70	0.53	0.62	0.65	0.70	0.77	0.71	0.86	0.60
2.0% LW	0.45	0.76	0.48	0.57	0.72	0.74	0.95	0.74	0.85	0.55
2.3% LW	0.23	0.42	0.68	0.82	0.86	1.06	1.10	0.92	0.85	0.71
2.6% LW	0.24	0.42	0.62	0.73	0.74	0.76	0.92	0.79	0.91	0.67
SED[1]	0.09	0.14	0.17	0.15	0.14	0.13	0.15	0.19	0.18	0.12
P(L)[2]	<0.001	<0.05	0.42	0.26	0.38	0.25	0.28	0.49	0.79	0.34
P(Q)[3]	<0.001	0.76	0.96	0.86	0.42	0.09	0.14	0.59	0.78	0.98

[1]Standard Error of the Difference [2]Linear effects [3]Quadratic effects

DISCUSSION

The feeding treatments imposed prior to calving achieved a range of precalving DMI and energy balances, as illustrated by the changes in LW, BCS and blood metabolites. The energy required to maintain pregnancy without gain or loss of maternal body tissue was calculated to be 76 (NRC, 2001) and 88 (Holmes *et al.*, 2002) MJME/cow/day. Therefore, cows consuming 60, 93, 103 and 114 MJME/cow/day, respectively ate approximately 80, 120, 135 and 150 % of daily ME requirements and 70, 105, 115, and 130 % of daily ME requirements, as calculated from NRC (2001) and Holmes *et al.* (2002), respectively.

In the current study, 90 MJ ME/cow/day or 0.93 MJ ME/kg $LW^{0.75}$ was required to ensure zero change in BCS precalving. This is in agreement with Holmes *et al.* (2002) who recommended 88 MJ ME/cow/day for 445 kg animals producing 32.5 kg calves. This infers that current NRC (2001) recommendations underestimate the energy requirements of the grazing dairy cow in late gestation, and that calculated values require an upward revision of approximately 16%. The reason for the different recommendations is not clear, as the assumed efficiency of utilisation of energy by the foetus is similar in both systems (0.14 and 0.13 in NRC, 2001 and Holmes *et al.*, 2002, respectively) and neither system appears to account for the increased energy uptake of the mammary gland during the final two weeks before calving (Bell, 1995).

Even though precalving level of feeding had significant effects on calving BCS, milk production was not affected by precalving feeding level. This is in contrast to Grainger & McGowan (1982) who, in a summary of New Zealand research, reported that cows on a higher precalving feeding level subsequently produced more milkfat (approximately 80g/cow/day; Hutton & Parker, 1973). However, precalving feeding levels may be more important in pasture-based systems where cows are restricted during the first 6 to 8 weeks of lactation because of insufficient pasture to meet demands. In the present study, cows were fed pasture to appetite postcalving. Grainger & McGowan (1982) acknowledge that the effect of precalving feeding is less likely to be evident in cows that are well fed postcalving. This view is supported by the recent review of Stockdale (2001) and the research results of Holcomb *et al.* (2001) and Agenas *et al.* (2003) where prepartum energy intake did not affect postpartum milk production when cows were fed to appetite postcalving. Further research is required to understand the interaction between pre- and postcalving level of feeding on milk production.

The lack of a difference in milk production can be partially explained by examining the endocrine data in Table 2. Although precalving energy balance affected the concentration of GH and IGF-1, potentially because of effects on GH receptor expression (Brier, 1999; Block *et al.*, 2003), the effects were not evident following the colostrum period. The quadratic change in IGF-1 and the lack of a difference in the concentration of these metabolites and GH in cows eating greater than 2% of LW suggests that there was no GH receptor advantage to feeding energy in excess of requirements precalving.

In conclusion, cows that were underfed precalving mobilised body reserves of fat and protein and had higher concentrations of growth hormone and NEFA, and lower concentrations of IGF-1 in plasma before calving. Based on LW change data, cows required 0.93 MJ ME/kg $LW^{0.75}$ (20 MJ ME/100kg LW) daily precalving to maintain zero energy balance. This equates to 100 MJ/cow/day for a 500 kg cow or 9 kg/day of 11.0 MJ ME pasture. However, precalving level of feeding did not affect postcalving milk production, at least in cows that were well-fed postcalving and were not metabolically compromised.

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