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Restricted postpartum feeding in grazing dairy heifers decreases milk production but does not lengthen anoestrous interval

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ABSTRACT

The aim of this study was to determine the effects of pasture allowance postpartum on the initiation of ovarian activity, metabolite and hormonal secretion, and milk production. After calving, thirty six Holstein-Friesian heifers (BCS 5.0) received either unrestricted pasture allowance (UNR; n=18) or restricted (RES; 73% dry matter intake of the unrestricted group; n=18) pasture allowance. The LW was lower ($P < 0.05$) for the RES group than the UNR group. Body condition score of all heifers decreased after calving in both groups. The mean time to ovulation was similar for UNR 50.0 and RES 50.3 sed. 8.2 days after individual calving date. The daily average from week 2 for milksolids, protein and lactose yield was lower ($P < 0.05$) in the RES group. Plasma concentrations of insulin were lower ($P = 0.0085$) in the RES group when compared to the UNR group. Glucose concentrations was lower ($P = 0.016$) in the RES group. Plasma concentration of NEFA was greater ($P = 0.001$) in the RES group. There was an interaction with treatment differences decreasing by week 11 and 12 for glucose ($P = 0.001$) and NEFA ($P = 0.006$). Plasma concentrations of leptin ($P = 0.013$) and IGF-I ($P = 0.026$) were lower in the RES. No differences, associated with postpartum nutrition, were found for plasma GH. Restricted feeding postpartum had no effect on days to first postpartum ovulation but decreased liveweight, milk production and affected some metabolic hormones during postpartum.

Keywords: postpartum feeding; metabolic hormones; anoestrous; dairy heifers.

INTRODUCTION

A prolonged postpartum anovulatory interval (PPAI) in dairy cows is one of major economic importance in terms of cow productivity. In New Zealand's pasture feeding system, climatic variables can affect feed availability in spring around the period of planned start of calving in the majority of the herds. A decrease in feed availability could have detrimental effects on the productive and reproductive performance of dairy cows.

During early lactation, dairy cows are under nutritional stress because the feed intake does not meet the nutrient demands of lactation (Bauman & Currie, 1980). Negative energy balance (NEB) is considered one of the main factors that reduces milk yield and reproductive performance in dairy cows (Butler *et al.,* 1981). The extent of the NEB is associated with the energy intake and energy reserves (Staples *et al.,* 1990) and the genetic merit for milk production (Berry *et al.,* 2002). NEB has been associated with mobilisation of body reserves (loss in BCS and liveweight), high concentrations of GH and non-esterified fatty acids (NEFA) and ketone bodies (Studer *et al.,* 1993), and with low insulin, IGF-I and glucose concentrations (Grummer *et al.,* 1995; Chagas *et al.,* 2006) all of which may affect cow reproduction.

The benefits of adequate pre- and post-partum feeding for milk production are well known (Grainger *et al.,* 1982). Unrestricted feeding six weeks prepartum decreased PPAI of heifers in low body condition to levels similar to heifers well fed and calving in good body condition (Chagas *et al.,* 2006), suggesting the possibility of a 'endocrine memory', where feeding before calving affects the length of PPAI.

Similar results were observed by Burke *et al*. (2005) in multiparous dairy cows, where increased pasture intake prepartum decreased PPAI and the effect was associated with BCS at calving. In both studies, increased pasture intake after calving had no effect on PPAI. These studies demonstrate the effects of increased feeding prepartum and BCS at calving on PPAI and the possibility that metabolic changes that occur before calving affects the PPAI after calving.

If there is an "endocrine memory", restricting feeding after calving will not affect the PPAI length but it could decrease milk production, as energy required for milk production during early lactation is greatest. This study was designed to test whether restricted feeding postpartum would increase the length of PPAI, decrease milk production and alter hormone and metabolites secretion in heifers calving with a good condition score.

MATERIALS AND METHODS

Experimental design and treatments

Thirty-six Holstein-Friesian heifers (2 yr old) that had conceived on a common date following AI to a synchronized oestrus were used. During the last 5 months of gestation, pasture allowances were managed to ensure the heifers calved at BCS of 5.0 on a 1 to 10 scale (1 = emaciated and 10 = obese). Liveweight (LW) and BCS were assessed weekly from 5 weeks before calving and until 12 weeks after calving. At calving, heifers were randomly allocated to one of two treatments, unrestricted (UNR; n=18) or restricted access to pasture (RES; n=18; approximate 73% dry matter intake (DMI) of the unrestricted group). Allocation to treatment was balanced for LW and breeding worth. The average day of calving was July 10 (± 7 days) for all heifers.

This experiment was conducted at the Dexcel Lye Farm, Hamilton, New Zealand (37°46'S 175°18'E), and all procedures were approved by the Ruakura Animal Ethics Committee, Hamilton, New Zealand.

Grazing Management

Pasture offered was predominantly perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens*), with <20% weeds and other grasses (*Dactylis glomerata; Poa* species). Differences between the DMI for the groups were achieved by adjusting the size of the allocated grazing area. Low postgrazing pasture residuals can be used to restrict DMI in grazing experiments, since dairy stock have difficulty in grazing pasture to ground level (Roche *et al*., 2005). Offering different grazing area allocations facilitates achieving different cow DMI without confounding factors such as time at pasture or weather.

Before calving, all heifers were grazed together and fresh pasture was allocated each morning. Pasture allocations were visually assessed, and the assessment verified weekly by cutting a range of pasture yields, representative of pre- and post-grazing yields (Thom *et al.,* 1986). The DMI of each treatment was calculated daily from pre-grazing and post-grazing pasture mass (Roche *et al.,* 1996). Pre-grazing pasture mass was similar (P > 0.1) for each treatment group 2669± 456 and 2552 ± 485 kg DM/ha for UNR and RES groups, respectively. Post-grazing residual pasture mass was 1713 ± 259 and 1154 ± 249 kg DM/ha for UNR and RES groups, respectively. The restricted RES group had 77 m^2/cow and the UNR 106 m^2/cow, which represent fed intakes of 14.3 ± 1.60 DMI/cow and 11.2 ±1.36 DMI/cow for UNR and RES groups, respectively.

Blood sampling

Coccygeal venipuncture was used to collect blood samples weekly from 6 week prepartum to 10 week postpartum. Blood samples were taken in the morning prepartum, (approximately 0730hrs) before new pasture was offered. After calving, blood samples were taken before milking (commencing at 0630hrs) and new pasture was offered after milking.

All blood samples were collected into 10-mL vacutainer tubes containing sodium heparin and were immediately placed in iced water. Blood samples were centrifuged at 1,120 × *g* for 12 minutes, within 1 hour of collection. Aliquots of plasma were stored at –20°C until assayed for NEFA, glucose, insulin, IGF-1, GH, and leptin concentrations.

Hormone and metabolite assays

Plasma glucose and NEFA were measured by the hexakinase colourimetric method using a Hitachi 717 analyser (Roche, Basel, Switzerland) at 30°C by Alpha Scientific Ltd. (Hamilton, NZ). The intra- and inter-assay coefficients of variation (CV) for both assays were 2 and 3%, respectively.

Insulin was measured in duplicate using a double-antibody radioimmunoassay (RIA; Hales & Randle, 1963). The intra- and inter-assay coefficients of variation were 2 and 3%, respectively. The limit of detection of the assay was 0.89 μU/mL.

Plasma IGF-I was assayed in duplicate by double-antibody RIA (Gluckman *et al.,* 1983). The intra- and inter-assay coefficients of variation were 5.3 and 5.7%, respectively. The limit of detection of the assay was 1 ng/mL.

Leptin was measured in duplicate using a double-antibody RIA (Blache *et al.,* 2000). The limit of detection of the assay was 0.1 ng/mL. The intra- and inter-assay coefficients of variation were 4.8 and 5.7%, respectively.

Plasma was assayed for GH in duplicate by double-antibody RIA (Downing *et al.,* 1995). The intra- and inter-assay coefficients of variation were 6.9 and 8.2%, respectively. The assay detection limit was 0.06 ng/mL.

Concentrations of progesterone in milk were measured using an RIA kit (Coat-A-Count, DPC, CA, USA; (Dieleman & Beavers, 1987). Intra-and inter-assay CV were 6.1 and 8.6%, for standard concentrations of 4.4, 3.0 and 0.4 ng/mL, respectively.

Interval to first ovulation and milk production measurements

Progesterone concentrations were measured in fresh whole milk samples collected twice weekly

before the start of both morning and afternoon milking. The postpartum anovulatory interval or postpartum interval to first ovulation was defined as the interval from calving to the first of two consecutive sampling days when progesterone concentrations in milk were > 3 ng/mL.

Weekly milk yields were measured throughout lactation using in-line milk meters (Tru-Test, Auckland, NZ) and sub-samples were analysed for protein, fat, and lactose concentration (MilkoScan FT120, FOSS, Hillerød, Denmark).

Statistical analyses

The milk data for weeks 2 to 12 of lactation were analysed by calculating the average daily milk, protein, fat, lactose and milksolids yield for each cow over this time and then analysing these summary measures using analysis of variance. Milk data for the first week of lactation was omitted from this analysis because the number of days from calving to the first herd test date varied among the cows. For the metabolite, hormone, liveweight and body condition score data the repeated measurements through time were modelled using spline models within the linear mixed model framework as described by Verbyla *et al*. (1999). Treatment, 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 treatment with spline were included as random effects. Week 1 has been omitted from the analysis using splines of metabolites, hormones, LW and BCS. Residual maximum likelihood (REML) in GenStat 8 was used to fit these models. To illustrate the interactions between time and treatment the weekly means are presented. For consistency all the metabolite, hormone, liveweight and body condition score data is presented in this manner. The length of the postpartum anoestrous interval was analysed using the CENSOR procedure in GenStat.

RESULTS

Postpartum anoestrous interval

The mean time to ovulation was similar for UNR 50.0 and RES 50.3 sed. 8.2 days after individual calving date.

Liveweight and Body Condition

The LW was lower ($P < 0.05$) for the RES group than the UNR group (Figure 1). Body condition score of all heifers decreased after calving in both groups (Figure 1).

Milk Production

The daily average from week 2 for milksolids, protein and lactose yield was lower ($P < 0.05$) in the RES group (Table 1).

Figure 1: Mean (± SEM) for liveweight (LW) and body condition score (BCS) from 5 weeks before calving to 1 weeks after calving for all the heifers and from week 1 until 12 week after calving in heifers calving with BCS of 5.0 and fed unrestricted (UNR; n=18; ○) or restricted access to pasture (RES n=18;■) after calving.

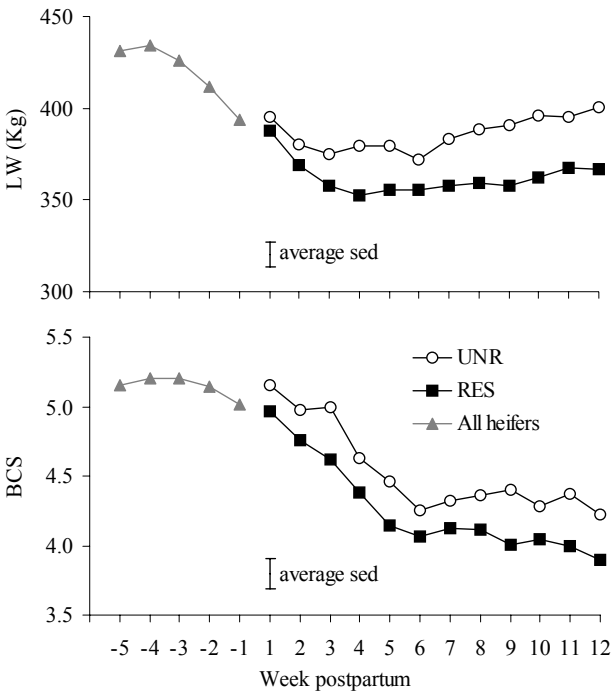


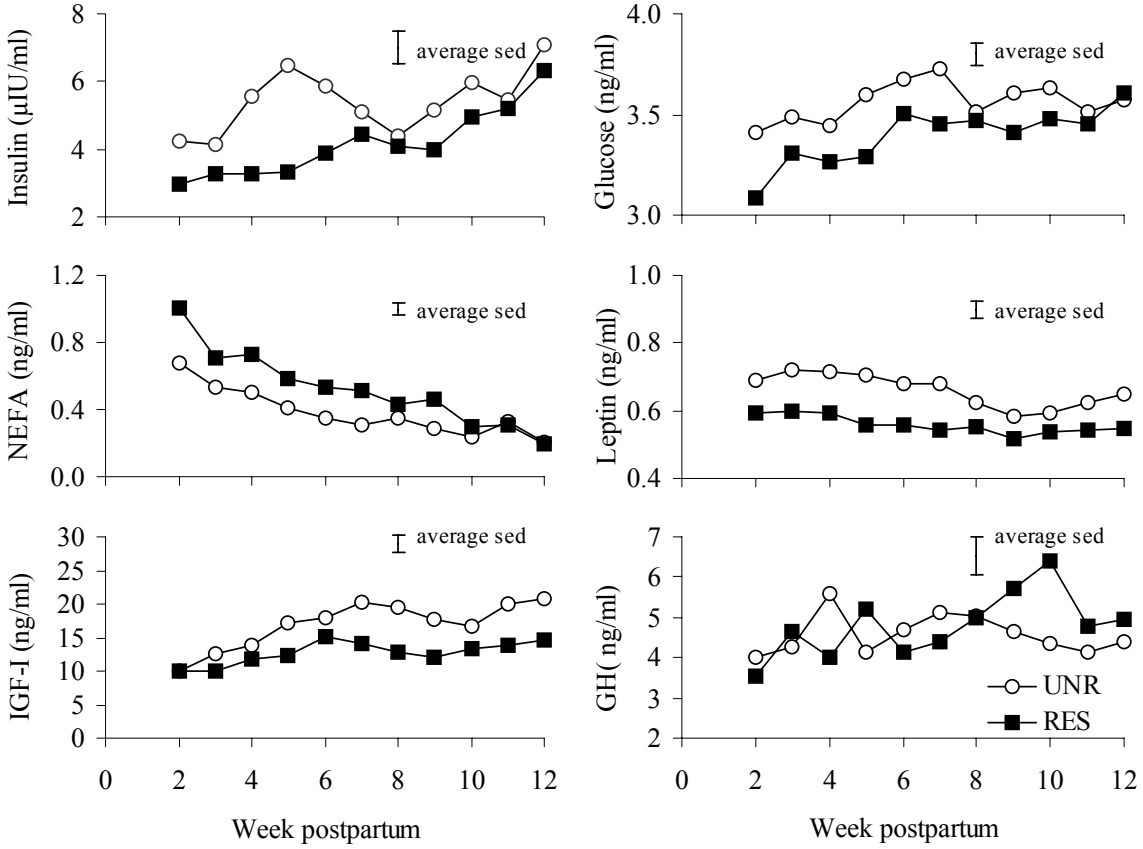
Table 1: Mean milksolids, fat, protein and lactose yield (kg) from week 2 to 12 postpartum in heifers calving with BCS of 5.0 and fed unrestricted (n=18) or restricted access to pasture (n=18) after calving.

Treatment groups	Unrestricted	Restricted	SED	P value
	(kg/cow/day)	(kg/cow/day)		
Milksolids	1.28	1.14	0.06	0.03
Protein	0.54	0.48	0.02	0.01
Fat	0.73	0.65	0.04	0.06
Lactose	0.79	0.71	0.04	0.04

Hormonal and metabolite measurements

Plasma concentrations of insulin were lower ($P = 0.0085$) in the RES group when compared to the UNR group (Figure 2). Glucose concentrations was lower ($P = 0.016$) in the RES group (Figure 2). Plasma concentration of NEFA was greater ($P = 0.001$) in the RES group (Figure 2). There was

Figure 2: Mean values for plasma insulin, glucose, NEFA, leptin, IGF-I and GH concentration from 2 week until 12 week after calving in heifers calving with BCS of 5.0 and fed unrestricted (UNR; n=18;○) or restricted access to pasture (RES n=18;■) after calving.



an interaction with treatment differences decreasing by week 11 and 12 for glucose (P = 0.001) and NEFA (P = 0.006). Plasma concentrations of leptin (P = 0.013) and IGF-I (P = 0.026) were lower in the RES. No differences, associated with postpartum nutrition, were found for plasma GH (Figure 2).

DISCUSSION

Restricted feeding after calving did not decrease the interval from calving to first ovulation in heifers calving in good body condition but it did decrease liveweight and milk production.

The present study suggests that the level of feeding after calving is less important for the initiation of ovulation postpartum than the levels of feeding prepartum and body condition (reflection of energy reserves) at calving. Previously, Chagas *et al.* (2006) showed that adequate prepartum feeding of low body condition heifers resulted in 69% cycling at 100 days postpartum compared with only 20% of heifers on restricted feed prepartum that calved with poor body condition (BCS 4.0). Notably, unrestricted access to good quality pasture after calving did not change the impact of restricted feeding and poor body condition at calving (Chagas *et al.,* 2006). Outcomes of the present study are consistent with previous findings (Burke *et al.,* 2005; Chagas *et al.,* 2006) and demonstrate the importance of prepartum feeding and BCS at calving on the length of postpartum anoestrus interval and milk production.

The present study investigated the potential metabolic signals for the reproductive axis and focused on blood metabolites and hormones that fluctuate during altered states of energy metabolism. The decrease in insulin concentration soon after parturition agrees with previous reports (Diskin *et al*., 2003; Chagas *et al.,* 2006). This is not surprising as insulin plays a central role in the homeostatic control of energy metabolism and its concentration is positively correlated with energy intake and reproduction (Chilliard *et al.,* 1998; Gong *et al.,* 2002). After calving it is normal for a

dairy cow to be in negative energy balance, however, the level of nutrition pre and postpartum influences the degree of negative energy balance because of the utilisation of body reserves. In the present study, after the first 3 weeks after calving, insulin was greater in the unrestricted group and this may reflect a higher energy intake and an earlier recovery from negative energy balance.

Negative energy balance is characterised by low glucose and insulin, and elevated NEFA and GH concentration in early lactation (Studer *et al.,* 1993; Grummer *et al.,* 1995; Chagas *et al.,* 2006). In the present study, an effect of restricted feeding was observed on insulin, glucose and NEFA. The higher levels of NEFA indicate increased NEB and this was associated with reduced leptin concentrations in the RES group. Leptin is another hormone that tends to decrease after calving and during underfeeding (Grummer *et al.,* 1995; Kadokawa *et al.,* 2000; Chagas *et al.,* 2006) and this study agrees with this findings as the restricted group had a lower leptin concentration during 5 wks postpartum. Leptin concentration is a good indicator of body fatness (BCS) in peripartum cows (Kadokawa *et al.,* 2000). In contrast, Holtenius *et al.* (2003) found no relationship between leptin and BCS after calving. Differences among studies could be due to the differences in energy intake, energy balance, and range of BCS among cows, production systems and genetic background. In this study, leptin concentration was lower in the restricted group but no difference occurred in BCS between the groups. In this case, leptin did not reflect the level of BCS, and this could be explained by changes in internal adipose tissue mobilisation that could not be perceived by BCS. Alternatively, visually assessed BCS may not be sufficiently sensitive to detect true differences in body fat reserve. Adipose tissue performs complex metabolic and endocrine functions and leptin production is mainly regulated by insulin-induced changes of adipocyte metabolism (Havel, 2002). The production of leptin and insulin is influenced by nutritional status and it is possible that the sensitivity of the adipose tissue to insulin or to nutrients was set in response to the pre-calving nutritional levels and the body condition at calving.

Dairy cows mobilise adipose tissue in early lactation (Bauman & Currie, 1980). The severity and duration of NEB may be influenced by the energy density or quantity of the feed offered (Staples *et al.,* 1990). Grainger *et al*. (1982) observed that cows with better body condition have a greater milk production response to extra pasture feeding because of greater energy partitioning to milk production. The heifers in the present study calved in good body condition (BCS 5.0) while RES heifers produced less milk and lost more liveweight than the unrestricted group. This highlights the change in energy partitioning to milk production after calving. The unrestricted group used extra energy from feeding to produce more milk and this demonstrated the benefits that farmers could get from heifers calving in good body condition and that are well fed after calving without affecting PPAI.

Dairy farmers should aim to calve heifers in BCS higher than 5.0 and feed their well postpartum to benefit from higher milk production while maintaining a healthy reproductive performance.

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