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Diet and genotype affect plasma calcium, magnesium and phosphorus concentrations in the periparturient cow

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ABSTRACT

The literature is inconsistent with regard to the effect of diet in the periparturient period on the health and production of dairy cows, and there is little or no data on the effect of genotype. Fifty-six dairy cows of two different genotypes (Overseas Holstein-Friesian (OSHF) and New Zealand Holstein-Friesian (NZHF)) were randomly allocated to two dietary regimens. Half of each genotype group received a pasture/pasture silage diet pre-calving and a pasture diet post-calving, while the other half received a total mixed ration pre- and post-calving. Cows receiving the total mixed ration pre-calving had a lower ($P<0.05$) plasma calcium concentration on the day of calving and the day following calving. Conversely, cows of both genotypes offered pasture had lower ($P<0.01$) plasma magnesium and phosphorus concentrations pre- and post-calving compared with cows fed a total mixed ration. OSHF cows had lower plasma calcium ($P<0.05$) and magnesium ($P<0.001$) concentrations post-calving. Plasma phosphorus concentrations were unaffected by genotype. Herds with a high proportion of OSHF genetics are at an increased risk of parturient hypocalcaemia and hypomagnesaemia. Recommended daily allowances for these minerals may need to be increased to allow for this predisposition.

Keywords: Holstein-Friesian; periparturient; non-lactating; calcium; magnesium; phosphorus.

INTRODUCTION

There has been considerable debate on the nutrient requirements of dairy cows during the progression from a state of net tissue deposition to one of mobilisation (transition period). It seems logical that nutritional management of dairy cows before calving should be an important component in the minimisation of stress associated with the transition to lactation. Dairy producers in many other parts of the world have changed to more controlled, intensively managed feeding during the dry period. This is because they are convinced that the transition period, centred round calving, is one of the most important periods in the life cycle of a cow (Grummer, 1995). However, recommendations for feeding during this period are equivocal (Stockdale & Roche, 2001) and much of what is recommended for grazing cows is based either on research from vastly different systems or from theoretically perceived nutrient requirements.

As parturition approaches, the provision of energy to dry cows must account for more than just maintenance of the cow (Bell, 1995; Grummer, 1995) as requirements escalate significantly in the final month of pregnancy (Moe & Tyrrell, 1972; Leury *et al*., 1990). Bell (1995) reported that, in apparent harmony with the increased foetal demand during the final stages of gestation, blood flow to the mammary gland increased by 200%, and the uptake of glucose and acetate by the mammary gland increased by 400% and 180%, respectively, in the week prior to parturition.

At the same time as energy requirements increase, a gradual decline in pre-calving dry matter intake has been reported (Grummer, 1995), but this decline does not always occur. The depression in DM intake of non-lactating cows fed pasture/pasture hay (Roche, 1999) was negligible until 2 days before calving. These findings agree with others (Forbes, 1977; Vazquez-Anon *et al.*, 1994). Several studies have suggested that reducing forage-concentrate ratios will increase pre-partum DMI (Vandehaar & Donkin, 1999). However, Emery *et al.* (1969) and Coppock *et al.* (1972) have reported increases in metabolic problems in periparturient animals that were fed concentrates pre-calving. These results tend to dispute the rationale for feeding concentrates pre-calving. Therefore, the perceived need for energy-dense feeds during the late dry period to overcome a depression in dry matter intake, may not be necessary when pasture is the main component of the diet.

Much inconsistency exists in the literature regarding the effects of feed type in the periparturient period on the health and production of dairy cows. This paper reports the effect of a pre-calving diet based on pasture/pasture silage or a total mixed ration (TMR) on mineral homeostasis in Holstein cows of differing genotypes.

MATERIALS AND METHODS

Experimental design and treatments

This experiment was conducted at No 1 Dairy at Dexcel Ltd (formerly: The Dairying Research Corporation), Hamilton, New Zealand (37°46'S 175°18'E). All procedures were approved by the AgResearch Animal Ethics Committee, Ruakura, Hamilton, New Zealand.

The effects of genotype, diet, and genotype x diet interactions on plasma mineral concentrations in periparturient cows were investigated. Fifty-six cows (16 primiparous and 40 multiparous) were used that were already involved in a multiyear comparison trial comparing Holstein-Friesian (HF) cows of either New Zealand (NZ) or Overseas (OS) origin. Both genotypes (OSHF and NZHF) either grazed pasture (GRASS) or were fed a TMR according to a 2 x 2 factorial design. OSHF cows were imported as embryos from Holland and consisted of Dutch (50%) or United States (50%) genetics, while less than 12.5% of genetics in the NZHF cows originated from outside New Zealand. Cows were allocated to treatment prior to first calving on the basis of genetic merit, sire and live weight. Each treatment was comprised of equivalent proportions of animals in their 1st (21%), 2nd (21%) and 3rd

(48%) lactations.

Feeds and feeding

Pre-calving. All cows received 1.8 (± 0.35) % of pre-calving liveweight of a 50:50 pasture and pasture-silage diet until 3 weeks prior to calving. One group remained on this pasture/pasture-silage diet until calving (GRASS) while the other was gradually introduced to a pre-calving TMR over a 10-d period. Once adjusted to the TMR, TMR comprised the whole diet for the 10 d prior to calving. Both NZHF and OSHF cows were offered the same TMR mix and were fed to achieve an intake of 2% body weight in the 10 d prior to calving.

Post-calving. After calving, the grazing cows (GRASS) were offered *ad libitum* pasture and the comparative treatment were offered a TMR formulated for early lactation. Again, NZHF and OSHF cows received the same TMR mix and were fed to achieve a 10% refusal rate.

Grazing treatment. Grazing cows were offered a fresh break of pasture twice daily at 0700 and 1500 h. The aim was to feed the lactating cows in the grazing treatment generously on pasture, i.e., an allowance of >45kg DM/cow/d. The experiment did not test NZHF and OSHF in a confined pasture system. Rather, cows were offered optimal paddocks at No. 1 Dairy (total area 60 ha) for grazing and were followed by a non-treatment herd of cows to maintain pasture quality. The pastures used in this experiment had 5-6 weeks regrowth and were grazed at a pre-grazing mass of 2300 (±350) kg DM/ha. Post-grazing residuals were 1500 (±100) kg DM/ha. The nutrient characteristics of the pasture and pasture silage offered are shown in Table 1. Grazing cows received 12g of supplementary magnesium/cow/day, in the water trough pre-calving and as a drench post-calving.

TMR treatment. Before calving, the TMR cows were confined to one of three sheltered loafing paddocks (0.25 ha/paddock). After calving, TMR cows were confined to a free-draining feed pad (11.5m^2 per cow), which was sheltered from the wind. The TMR was fed between 0800 and 0900 h and between 1500 and 1630 h in 5-m long mobile fibreglass troughs. The feeds were mixed in a Jaylor vertical mixing wagon.

The nutrient profiles of the pre and post-calving TMR diets are shown in Table 2. The criteria used to formulate the TMR were: i) to supply the required nutrients and ii) to use ingredients that were typical of diets fed in North American and European systems, within which the OSHF cows were selected. The TMR was not a least-cost ration, but a standard control. Cows were fed according to NRC (1989) dairy cow feed requirements for high production. Rations were formulated using the Spartan ration formulation program (van de Haar *et al.*, 1992) and the Cornell Net Carbohydrate and Protein System model (Fox *et al.*, 1992). The TMR diets were based on maize silage (40 and 25%), grass silage (13 and 19.5%), hay (11 and 7.5%), whole cottonseed (6 and 10%) and a compounded concentrate (24 and 38%) for late-dry and early-lactation cows, respectively. The pelleted concentrate (10 mm in length) was formulated to balance nutrients supplied by the forages.

TABLE 1: Mean chemical composition (% of DM[1]) of pasture and pasture-silage offered to dairy cows during the late dry period and during early lactation.

Item	Pasture	Pasture Silage	Total Diet
DM (g/kg)	125	320	220
DOMD[2]	85	71.3	78.2
ME (MJ/kg DM)	12.1	11.4	11.8
CP	26.2	13.1	19.7
ADF	18.0	33.2	25.6
NDF	37.7	50.9	44.3
NFC[3]	14.0	10.0	12.0
Fat	4.8	4.4	4.6
Ash	10.4	20.9	16.7
Ca	0.38	0.44	0.41
P	0.38	0.37	0.38
Mg	0.22	0.25	0.24
K	4.1	3.1	3.6
Na	0.24	0.63	0.56
Cl	1.0	1.1	1.1
S	0.33	0.25	0.29
DCAD (mEq/kg)[4]	667	601	634
Co (ppm)	0.02	0.07	0.05
Cu (ppm)	13	10	12
Fe (ppm)	120	191	156
I (ppm)	0.1	0.25	0.18
Mn (ppm)	62	72	0.67
Se (ppm)	0.02	0.05	0.04
Zn (ppm)	44	28	36
pH	-	4.3	-
Lactic acid	-	5.3	-
Ammonia-N (ppm)	-	1083	-
Ammonia-N[5]	-	5.05	-

[1] Unless otherwise stated
[2] Digestibility of organic matter in the dry matter
[3] NonFiber Carbohydrate (NFC) = 100-%NDF-%CP-%Fat-%Ash
[4] DCAD (mEq/kg) = Na (mEq/kg) + K (mEq/kg) – (Cl (mEq/kg) + S (mEq/kg))
[5] Ammonia-N as a fraction of total N

TABLE 2: Chemical composition (% of DM[1]) of the Total Mixed Ration fed to dairy cows during the late dry period and during early lactation.

Item	Late dry	Early lactation
DM	45.2	50.3
ME (MJ/kg)	10.6	12.1
CP	14.2	17.9
RUP	33.1	34.9
RDP	66.9	65.1
Soluble Protein	30.6	29.5
ADF	23.8	21.7
NDF	38.4	32.2
Effective NDF	30.9	26.5
Forage NDF	94	82.1
NFC[2]	35.2	35.3
Starch	23.3	23.8
Fat (not incl. Protected fat)	5.8	6.7
Protected Fat	0	0.4
Ash	6.5	8.2
Ca	0.58	0.86
P	0.64	0.54
Mg	0.41	0.3
K	1.05	1.28
Na	0.38	0.21
Cl	0.5	0.28
S	0.29	0.22
DCAD[3] (mEq/kg)	185	203
Co (ppm)	0.1	0.2
Cu (ppm)	14	13
Fe (ppm)	61	182
I (ppm)	0.5	0.5
Mn (ppm)	30	31
Se (ppm)	0.55	0.49
Zn (ppm)	27	26
Vitamin A (kIU/kg DM)	6	5
Vitamin D (kIU/kg DM)	0.5	0.5
Vitamin E (kIU/kg DM)	13	13

[1] Unless otherwise stated
[2] NonFiber Carbohydrate (NFC) = 100-%NDF-%CP-%Fat-%Ash
[3] DCAD (mEq/kg) = Na (mEq/kg) + K (mEq/kg) – (Cl (mEq/kg) + S (mEq/kg))

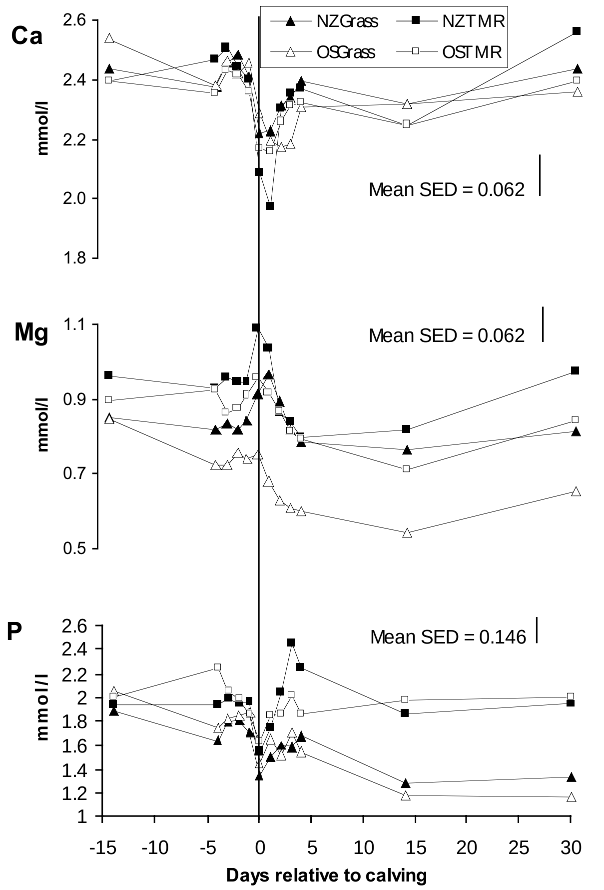
Measurements

Feed offered and refused for each treatment group was recorded daily. Pasture allocations were visually assessed and assessors were calibrated weekly through cutting a range of pasture yields, representative of pre- and post-grazing yields (O'Donovan, 2000).

Representative samples of TMR (offered and refused), pasture and pasture silage were taken weekly for chemical analysis. Pasture samples were collected by 'plucking' pasture to grazing height from paddocks due to be grazed. Samples for dry matter analysis were dried at 105°C. Samples of all feeds were dried at 60°C for 72 hours, ground to pass through a 0.5-mm sieve and analysed for crude protein, neutral detergent fibre, acid detergent fibre, soluble sugars, fat, ash and digestibility (DOMD) by Near Infra-Red (NIR) Spectroscopy. Weekly feed samples were bulked monthly for mineral analysis by inductively coupled plasma emission spectroscopy.

Blood samples were collected from all cows two weeks and one week prior to expected calving date, and on each day between 4 d pre- and 4 d post-calving. Cows were also sampled on d 14 and d 30 post-calving. Calving date was determined from mating records and pregnancy diagnosis. Blood was collected by coccygeal venipuncture into heparinised vacutainers and analysed for calcium (o-Cresolphthalein complexone), magnesium (xlidyl blue reaction) and phosphorus (molybdate reaction). All assays were performed on the Hitachi 717 analyser (Roche) at 30°C by Alpha Scientific Ltd (Hamilton, New Zealand). The inter-assay and intra-assay coefficient of variation was <5% for all assays.

FIGURE 1: Effect of genotype (OSHF and NZHF) and diet (GRASS and TMR) on plasma concentration of calcium, magnesium and photphorus in periparturient cows



Statistical analysis

All data were analysed using analysis of variance for a factorial design using the statistical procedures of Genstat V (1997) with cows as the experimental unit. Main effects (genotype and feed) and interactions were examined.

RESULTS

The effect of treatment on plasma Ca, Mg and P homeostasis is presented in Figure 1. Concentrations of Ca and P declined on the day of calving, rising again the following day. Conversely, magnesium concentration increased on the day of calving, declining again on the subsequent day. Cows fed TMR had a lower ($P<0.05$) plasma Ca concentration on the day of calving and the day following calving and also tended to have a lower ($P=0.13$) plasma calcium concentration 2 weeks post-calving. OSHF cows had a lower ($P<0.05$) plasma calcium concentration on d-2, 3 and 30 following calving than their NZHF counterparts. Magnesium concentrations were higher ($P<0.01$) in cows fed TMR than in the contrasting GRASS treatment, both before and after calving. OSHF cows had lower a ($P<0.01$) blood magnesium concentration at calving and following calving and tended ($P=0.07$) to be lower during the three days prior to calving. Plasma P concentration was not affected by genotype. However, cows offered TMR had higher plasma P concentrations than grazing cows prior to and following calving.

DISCUSSION

The continuing debate over the nutrition of the periparturient cow has led to variable recommendations being presented to dairy farmers. As most dry-cow feeding systems have traditionally been designed to simply maintain the cow during the dry period, much emphasis has been placed on the need for improved nutrition as an aid in the prevention of metabolic diseases, such as milk fever. This study provided a novel comparison of the effect of diet and dairy cow genotype on mineral homeostasis.

Butler (1999) reported a variable effect of pre-calving concentrate feeding on plasma mineral concentrations. He found that plasma calcium, phosphorus and magnesium were unaffected by pre-calving concentrate feeding. In the current study, the higher concentration of phosphorus in plasma is likely due to the greater concentration of phosphorus in the TMR than in the pasture/pasture silage offered to the grazing cows. Underwood and Suttle (1999) reported that phosphorus is absorbed extensively if in soluble form and not on a demand basis like calcium. This dietary concentration theory is supported by the lack of a difference in blood phosphorus concentration fourteen days before calving (Figure 1), while the TMR cows were still receiving approximately 30% of their diet from pasture.

Magnesium status is influenced somewhat by genetically determined factors (Underwood and Suttle, 1999) and this has made animal studies of magnesium related issues very difficult. In the work reported here, it is clear that OSHF have significantly lower ($P<0.01$) plasma magnesium concentrations than their NZHF counterparts, thus increasing the risk of grass tetany and other metabolic diseases, such as milk fever, associated with low blood magnesium status. Such an increased risk of milk fever (reduced plasma calcium) was seen 2-, 3- and 4-d post-calving and again 30 d following calving in OSHF ($P<$ 0.05).

Plasma magnesium concentration was also significantly lower in grazing cows than in those receiving TMR. This again would be expected due to the higher magnesium concentration in the diet of the TMR cows and the lower concentration of potassium, which can reduce the absorption of available magnesium by as much as 80% (Schonewille *et al*., 1999).

In contrast, plasma calcium concentrations were significantly reduced in TMR-fed cows on the day of calving and the day following calving. Although plasma calcium levels were high in all groups, these cows were young and, therefore, would not be expected to have low plasma calcium at calving (Underwood & Suttle, 1999). The reason for the reduced plasma calcium in the TMR cows is unclear. One possible reason is a greater loss of calcium in colostrum immediately post-calving. Cows on the TMR treatment produced greater quantities of colostrum than grazing cows (24.9 vs. 19.1; $P<0.01$) and, as protein concentrations did not differ, they would be expected to secrete significantly more calcium in milk. However, this increased milk yield was not due to the feeding of TMR during the transition period *per se*, but rather due to the feeding of TMR during previous lactations (Roche, unpublished). Although there was no difference in milk production between treatments in first-lactation animals there was a trend ($P=0.08$) towards reduced plasma calcium in those fed TMR. This indicates an effect of TMR on plasma calcium status beyond that of simple milk production.

Even though Emery *et al.* (1969) also found an increased incidence of hypocalcaemia in non-lactating periparturient dairy cows when a large proportion (>48%) of their diet consisted of non-forage, concentrate-based inputs, no reasons for the hypocalcaemia were given. In comparison, Butler (1999) found no difference in blood calcium concentration when 30% of the diet fed consisted of concentrates. Coppock *et al.* (1972) showed increases in periparturient metabolic problems when concentrates constituted more than 25% of the diet, a similar level to that which Butler (1999) fed. In the current experiment, only 24% of the pre-calving TMR was concentrate but maize silage constituted 40% of the diet, thereby raising starch inclusion rate to over 23%. Roche (1999) also found an enigmatic negative calcium balance in cows receiving 30-40% of their diet as crushed barley. It is possible that the type or level of concentrate that Butler (1999) fed was not enough to elicit a hypocalcaemic response. More research is required to fully elucidate the effect of concentrate-based diets on calcium metabolism.

CONCLUSION

Feeding a TMR pre-calving may increase the predisposition to hypocalcaemia. OSHF were more prone to hypocalcaemia post-calving and hypomagnesaemia than NZHF. The need for increased levels of magnesium in the diet of grazing cows was also highlighted.

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