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Variations in Dietary Nutrients and Blood Metabolites in Dairy Cows During the Peri-Parturient Period in Sub-Tropical Australia

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ABSTRACT: Twenty-three commercial dairies were surveyed to investigate the variation in urine pH and body condition scores prepartum as well as post-partum plasma metabolites in dairy cows grazing in sub-tropical Australia. The electrolyte content and calculated Dietary Cation Anion Difference (DCAD) were determined on a range of feeds fed to dry cows during the prepartum period. The electrolyte content of the main forages was extremely variable across farms in both potassium (1.19 to 4.53% K) and DCAD (-24 to +502 meq/kg DM). The average chloride content was surprisingly high (1.48%), and possibly contributed to the low DCAD content. Supplementary hay and corn silage were lower in both K% and DCAD with farms averaging 1.18% and +37 meq/kg DM respectively. Urine pH varied between farms (5.73 to 8.43), and 83.6% of individual cows had alkaline urine (pH>7.0). There was substantial variation between farms in plasma ionised calcium, total calcium, phosphorus, beta-hydroxybutyrate and body condition score in the periparturient cow. High incidences of sub-clinical hypocalcaemia (28.4% within 24 hours post-partum) suggest that the diet DCAD in the prepartum diet needs to be lowered.

Key Words: Subclinical hypocalcaemia, Dairy Cows, Dietary Potassium, DCAD

INTRODUCTION

Excess dietary sodium and potassium intake during the three weeks prepartum predisposes cows to clinical and subclinical hypocalcaemia (Goff and Horst 1997a). Both electrolytes will increase the dietary cation anionic difference (DCAD), resulting in a rise in blood alkalinity and urine pH (Goff and Horst 1997a). High DCAD diets lead to a reduction in calcium mobilisation and absorption (Goff and Horst 1997a; Leclerc and Block 1989). Particularly large amounts of calcium (Ca) are required for the production of colostrum and milk during the peri-parturient period and if the Ca is not replaced through bone resorption and intestinal absorption, severe hypocalcaemia may occur.

Feeding anions (sulfate and chloride salts), to reduce the DCAD to –10 meq/ kg DM during the prepartum period will cause a mild acidosis, which releases the hormones needed for Ca mobilisation and absorption (Joyce *et al.*, 1997). A decrease in the severity of the decline in plasma Ca during the peri-parturient period has been reported when feeding these negative DCAD diets (Leclerc and Block, 1989; Oetzel *et al.*, 1988). Additional benefits include increased milk yield (Daniels *et al.*, 1990) and improved reproductive performance, lower incidence of ketosis, and retained placenta (Daniel *et al.*, 1990; Oetzel *et al.*, 1988), and mastitis (Horst and Goff 1997a). Hypocalcaemia is also associated with inappetence, hence increased mobilisation of body fat during the periparturient period. Little data is available on the electrolyte and DCAD contents in feeds consumed by dry cows and their associated effect on sub-clinical hypocalcaemia under sub-tropical pasture grazing systems. This paper reports on the variation in dietary nutrients fed to dairy cows from commercial dairies in sub-tropical Australia during the prepartum period. In addition, blood metabolite levels immediately following parturition were investigated in these cows.

MATERIALS AND METHODS

Three hundred and twenty four peri-parturient cows across 23 herds were selected from a range of feeding systems from September 1998 through to April 1999. The majority of cows selected were of the Holstein-Friesian breed. Twenty-one herds participated in a herd recording system. Thirteen herds fed 3–6 kg/cow/d of concentrates, with the remaining ten herds feeding 0–2 kg/cow/d concentrates during the 3-week prepartum period. A total of ten herds (110 cows) incorporated anionic salts into the grain mix and this was fed as a single feed, once per day.

Samples of pasture, forage and concentrate mix were periodically sampled on each farm, dried and analysed for potassium (K), sodium (Na), chloride (Cl) and sulphur (S). The dietary DCAD on all feeds were calculated. DCAD was defined as the summation in milliequivalents of the cations, Na and K, minus the summation of the anions, Cl and S, expressed as meq/kg DM.

Blood was sampled from the tail vein within 24 hours of calving from a total of 271 cows. Blood was collected in lithium heparin vials, centrifuged, refrigerated and measured for plasma ionised calcium (ICa). The plasma was then frozen at -20^{0}C and later analysed for plasma total Ca, magnesium (Mg), phosphorus (P), potassium (K), sodium (Na) and beta-hydroxy butyrate (BHB). Urine pH was measured and body condition score (BCS) was estimated on individual cows prior to calving. BCS was estimated using a scale between 1 and 5.

Simple descriptive statistics were calculated across farms for feed nutrients. Analysis of variance was carried out on all animal parameters and means and standard errors for each farm were derived.

RESULTS

Dietary cations and anions measured in forage and supplementary feeds fed during the prepartum period are shown in Table 1. The main forage source (MFS) was pasture, hay or silage, which supplied the bulk of the diet. Supplementary forage (SF) consisted of hay and/or corn silage given in addition to the main forage source. All nutrients analysed in the forage varied widely between farms with much higher levels being recorded in the MFS compared to SF. Potassium averaged 2.65% in the MFS, reaching a high of 4.53% on one farm. Potassium was lower in SF with an average of 1.18% across farms. Sodium content was generally low in all forage but did reach higher levels (0.4 – 0.6%) in some plant species. Chloride content was much higher than sulphur and contributed more to the anionic content in the forage. DCAD content varied between farms with the average for the MFS being higher than SF (+168 and +37 meq/kg DM respectively). Individual forage samples ranged from –161 to +502 meq/kg DM.

Molasses was high in chloride and sulphur (0.90% S; 2.90% Cl and –547meq/kg DM). Anionic salts were fed on ten farms to supply between –852 and –3030 meq/cow/d. Three farms provided molasses, which supplied –370 to –1326 meq/cow/d. Anionic salts provided a source of supplementary sulphur, which was fed at high levels (32-55 g/cow/d) on some farms.

Plasma metabolites, urine pH and body condition score (BCS) were summarised to present the minimum and maximum for both farms and for all cows (Table 2). Urine pH varied greatly between farms ($P<0.001$). Mean urine pH was alkaline at pH 7.71, with 83.6% of cows with urine pH greater than 7.0 (Figure1). Mean BCS was 3.47, however variation did exist between farms ($P<0.001$) with three farms falling below 3.0. ICa and total Ca were different between farms with ICa being the most variable ($p<0.001$). Sub-clinical hypocalcaemia was evident with 28.4% of all cows experiencing plasma ICa levels below a defined concentration of 1.0 mmol/l (Figure 2). The number of cows reaching clinical levels (≤0.7 mmol ICa/l) was extremely low (3.7%) with a maximum recording of 17.6% on one farm. Total Ca followed a similar pattern with 32.5% of cows reaching sub-clinical levels below 2.0 mmol/l. Phosphorus was variable for farms ($p<0.001$), with 32.1% of all cows falling outside the normal range (1.13-2.25 mmol/l). Plasma Mg, Na and BHB concentrations were variable between farms ($P<0.001$), unlike plasma K.

Table 1. Variation in dietary nutrients (dry matter basis) fed to dairy cows during the prepartum period on commercial dairies. Means are expressed on a farm basis.

Variable	Mean	Herd Size	Minimum	Maximum
Main Forage Source (Pasture/Hay/Silage)				
K%	2.65	23	1.19	4.53
Na%	0.09	23	0.04	0.32
S%	0.23	23	0.14	0.39
Cl%	1.48	23	1.06	1.92
DCAD** meq/kg DM	***+168***	***23***	***-24***	***+502***
Supplementary Forage (Hay/Corn Silage)				
K%	1.18	10	0.35	2.51
Na%	0.07	10	0.01	0.25
S%	0.15	10	0.09	0.27
Cl%	0.73	10	0.14	1.76
DCAD* meq/kg DM	+37	10	-123	+188
Supplementary Anions (Anionic Salts/Molasses)				
Meq#/cow/d	-894	23	-3030	0
Sulphur g/cow/d	14.4	23	0	54.8

* Dietary Cation-Anion Difference (DCAD) = ($Na^+ + K^+$) – ($Cl^- + S^{--}$), expressed as meq/kg DM
# Milliequivalents of ($Na^+ + K^+$) ($Cl^- + S^{--}$),

Table 2. Variation in urine pH and BCS (1-5) during the prepartum period and plasma metabolites within 24 hours post-partum . S.D. is the within farm variation.

Variable	Mean	Sample Size	S.D.	FARM Min	FARM Max	COW Min	COW Max
Urine pH	7.71	220	0.57	5.90	8.43	4.50	8.80
BCS	3.47	233	0.66	1.97	4.42	1.5	5.0
Plasma metabolites mmol/l							
ICa	1.04	271	0.14	0.80	1.15	0.39	1.30
Total Ca	2.05	268	0.29	1.67	2.29	0.86	2.62
Mg	1.04	251	0.16	0.93	1.15	0.65	1.80
P	1.74	246	0.51	1.41	2.39	0.32	3.39
K	4.55	264	0.39	4.28	4.90	3.6	6.2
Na	144.2	265	2.45	140.7	149.0	137.0	154.0
BHB	0.53	246	0.22	0.30	1.17	0.2	1.90

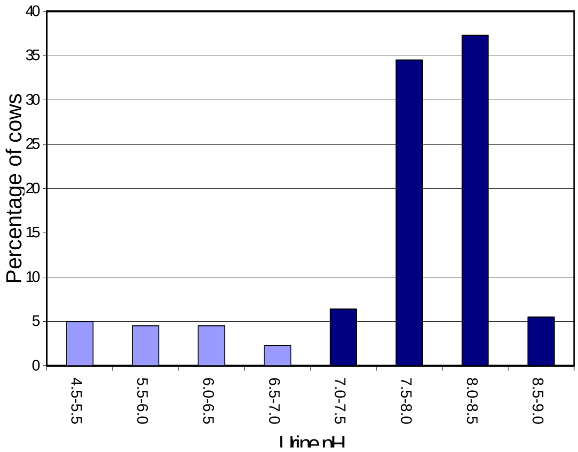

Figure 1. Variation in urine pH measured in cows during the prepartum period (N=220). Urine pH above recommended levels is represented by dark shading.

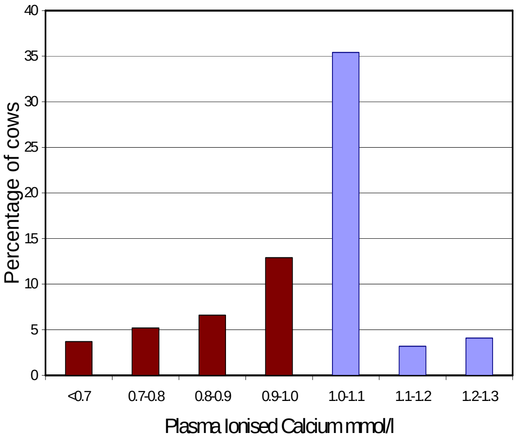

Figure 2. Variation in Plasma Ionised Calcium measured within 24 hours post-calving (N=271). ICa below recommended level is represented by dark shading.

DISCUSSION

The survey indicated that only a small percentage of cows grazing sub-tropical pastures (3.7%) reached critically low levels of plasma ICa (≤0.7 mmol/l) even though the main forage source contained 2.65% K. This result is in contrast to international feeding systems where Goff and Horst (1997a) recorded a 50% incidence in clinical hypocalcaemia for cows fed 2.1% K diets, prepartum. Lerclerc and Block (1989) noted that 47% of cows experienced clinical hypocalcaemia when fed a diet high in DCAD (+331 meq/kg DM). Our results are different, possibly because of the higher levels of chloride found in sub-tropical pastures. Despite the low level of clinical cases, sub-clinical hypocalcaemia (ICa<1.0 mmol/l) was detected in 28.4% of cows recorded in the survey and is reason for concern. It is still possible that the diet DCAD fed to cows during the prepartum period needs to be lowered further to reduce sub-clinical hypocalcaemia.

Urine pH is a good indication of the acid base status in blood pH. Urine pH in this study averaged 7.71 across farms with 83.6% of cows measuring pH levels greater than 7.0. For successful control of hypocalcaemia the average pH of the urine (Holstein-Friesian) should be between 6.0 and 6.5 (Goff and Horst 1997b). The urine data suggests that the DCAD of the diet was not low enough to cause a metabolic acidosis, hence calcium mobilisation may not be adequate prior to calving.

Normal ranges for plasma P, Mg, K and Na are (P: 1.13-2.25; Mg: 0.7-2.25; K: 3.9-5.8; Na: 132-152). In this survey, plasma Mg, K and Na concentrations fell within the normal range following parturition, although variation existed between farms. According to Oetzel *et al*. (1988) these blood metabolites are unaffected by the feeding of anionic salts pre-calving. Phosphorus was extremely variable between farms with 14.2% of cows experiencing deficient levels. Goff and Horst (1997a) found that plasma P concentration decreased at calving to 1.23 mmol/l, however the values were still within the normal range.

High levels of sulfates were fed as anionic salts in the prepartum period and this is of concern since some studies have reported a polioencephalomalacia-like syndrome (non-responsive to thiamine) when dietary sulfate is raised above 0.4% (equates to 40g S in a 10 kg DM intake). Some farms are supplementing with 32-55g S in one feeding in addition to forage S. It is also important to note that sulfate salts are not as effective in acidifying the blood as are chloride salts (Goff and Horst 1997b). Replacing some of the sulfates with chloride salts would reduce any chance of toxicity and improve the acidifying effects of the anionic salts.

Dietary nutrients are possibly not in balance during the prepartum period on some farms as indicated by the variation in both BHB and BCS across farms. BHB is related to fat mobilisation, and high levels can be an indication that the cow is in an extreme negative energy balance. Sub-clinical hypocalcaemia can lead to reduced nutrient intake postpartum and consequently an increase in fat mobilisation. Some herds were over conditioned with BCS greater than 4.0. Excessively fat cows tend to eat less postpartum and mobilise more body tissues than thin cows (Treacher *et al.* 1986).

This survey has demonstrated that large differences exist between farms in nutrients fed during the prepartum period to dairy cows. The existence of sub-clinical hypocalcaemia and low plasma P in some herds suggests that the prepartum diet needs modification.

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