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Within herd variability in the mineral status of grazing dairy cows in early lactation

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ABSTRACT

Two groups of 10 mature, crossbred cows received either a single daily dose of 10 g Mg or no supplemental Mg for two 5 day periods. Blood was sampled twice daily and urine once daily. On 3 days blood and urine were sampled four times. Serum Mg levels of 3 unsupplemented animals fell from 0.74 ± 0.034 to 0.25 ± 0.020 mmol/l within 5 days while other animals within this group maintained serum Mg levels despite the absence of Mg supplementation. At any given sampling time serum Mg levels of individuals within the unsupplemented group varied from 0.22 to 0.88 mmol/l and those of supplemented animals from 0.41 to 0.83 mmol/l. Mean serum Mg, Ca, Na and K concentrations did not differ between the groups. Unsupplemented animals had significantly ($P < 0.001$) lower urinary fractional clearance ratios of Mg and Ca.

The within and between animal variation in serum Mg levels was high for both Mg supplemented and unsupplemented animals. The fractional clearance of Mg in urine indicated a likely benefit from Mg supplementation for 100 % of the unsupplemented animals while serum Mg concentrations only identified 40 % of these animals. Fractional clearance of Mg in urine has potential as an indicator of animal Mg status.

Keywords: magnesium; calcium; minerals; dairy cattle; urine; serum; fractional clearance ratios.

INTRODUCTION

Metabolic disorders are of increasing concern to the New Zealand dairy farmer. Towers (1984) reported an estimated loss to the dairy industry of \$28 million dollars annually in reduced milkfat production and cow deaths as a result of hypomagnesaemia. While hypomagnesaemia is probably the primary metabolic disease involving the major minerals, hypocalcaemia (milk fever) can be a serious problem in late pregnancy and early lactation, especially in older cows.

Observations indicate that under New Zealand grazing conditions there exists considerable variation in magnesium status between individual cows within a herd, and also between neighbouring herds, but the extent of this variation in serum Mg has not been quantified. Field & Suttle (unpublished; cited in Field, 1970) observed a fourfold difference in urinary Mg excretion between sets of identical twins. This is in contrast to the small variation, namely 5%, in the excretion of Mg within twin sets (Field, 1970).

It is common practice to measure Mg in serum for clinical Mg diagnosis. However, such measurements only assess a small part (1%) of the total body Mg content. As there appears to be no mechanism within the animal to regulate absorption of Mg from the gut, renal Mg reabsorption plays a vital role in the maintenance of total body Mg. A renal threshold of 0.7-0.8 mmol Mg/l plasma (ARC, 1980) exists below which Mg excretion is sharply reduced. Towers (1982) concluded that urinary Mg has promise as an indicator of Mg status in reflecting Mg intake. However, a greater understanding of the factors influencing urinary Mg concentration is required before this potential can be realised.

This paper reports the extent of the variation in Mg, Ca, Na and K status of grazing dairy cattle with and without Mg supplementation.

MATERIALS AND METHODS

Two groups of 10 Friesian x Jersey cross cattle in early lactation and aged 3 to 11 years were balanced for age, previous production, bloat susceptibility, history of metabolic disorders and an average calving date of 25/7/92. Prior to the beginning of experimentation blood samples were collected by coccygeal venipuncture from all animals on three occasions during 10 days (days -13, -7, -3) to establish baseline serum Mg levels for individual cows while receiving 10 g Mg per day (as MgC_{12}) as a single dose at the morning milking.

Four days before sampling commenced all animals were fitted with an indwelling jugular catheter. On the first day of sample collection CIDRs were inserted to prevent oestrus behaviour during the experimental period.

The experiment comprised two 5 day periods (days 1 to 5 and 8 to 12) during which animals in Group 1 received 10 g supplemental Mg while those in Group 2 did not. The two 5 day treatment periods were split by two days on which all animals received the standard Mg dose at both morning milkings. Animals were grazed as a single mob throughout the experiment and were offered pasture to appetite.

Blood was sampled at 0700 and 1400 h, prior to milkings and to drenching at the morning milking. Blood tubes were incubated in a water bath at 37°C for 1 hour, centrifuged at 2500 rpm for 15 minutes and the serum removed for subsequent analysis.

Urine was sampled at 1400 h using the technique of perineal stimulation. Samples were acidified to pH 2-3 with 1M HCl.

Milk weights from individual animals were recorded at each milking and a sub-sample taken for subsequent Mg, protein, fat and lactose analysis.

On days 3, 8 and 12 urine and blood samples were collected four times per day at:- 0700, 1100, 1400 and 1900 h to assess the diurnal variation in mineral status.

Analysis

Serum Mg, Ca and creatinine were determined using the Hitachi System 717, serum and urine Na and K by Ion Selective Electrode and urinary Mg and Ca by atomic absorption spectrophotometry. Protein, lactose and fat in milk were determined by Milkoscan. The Mg concentration in milk was determined by atomic absorption spectrophotometry following a 1:100 dilution with 0.789 % Na₂EDTA.

Calculations

In the absence of total urine collection differences in mineral concentration as a result of variation in urine volume between animals can bias results. The fractional clearance ratio (FCR) is the electrolyte clearance expressed as a percentage of creatinine clearance. Corrected urinary Mg (CUM) is urinary Mg concentration corrected for urinary creatinine concentration :

$$FCR_x = (U_x/S_x) * (S_{Cr}/U_{Cr}) * 100$$

$$CUM = U_x/U_{Cr}$$

where U_x = urinary concentration of X (mmol/l)

S_x = serum concentration of X (mmol/l)

U_{Cr} = urinary concentration of creatinine (mmol/l)

S_{Cr} = serum concentration of creatinine (mmol/l).

Statistical Analysis

Treatment means were analysed using "t" tests and analysis of covariance. Means \pm standard errors are presented.

RESULTS

Serum Minerals

Individual serum Mg prior to experimentation ranged from 0.5 to 0.9 mmol/l with up to 20 % variation within an animal between days. The response to the removal of Mg supplementation was varied. Concentrations in 3 unsupplemented animals fell from 0.74 ± 0.03 to 0.25 ± 0.02 mmol/d within 5 days while other cattle in this group maintained concentrations. Values ranged from 0.22 to 0.88 mmol/l and 0.41 to 0.83 mmol/l in unsupplemented and supplemented groups, respectively. Between individual variation in both groups prevented significant differences in diurnal or day to day mean serum Mg levels being detected (Figures 1 & 2). Supplementation with 10 g Mg/d for 2 days elevated serum Mg (Figure 2) in the unsupplemented group.

Treatment groups did not differ in serum Ca, K or Na concentrations. There was significant variation in serum Ca, Na and K concentrations between days. While Ca (range 2.22 to 2.5 mmol/l) and K (range 4.34 to 5.07 mmol/l) values showed no obvious trends serum Na concentration increased (4.5 ± 0.42 mmol/l) from 139 ± 0.85 mmol/l on day one to 143 ± 0.70 mmol/l on day 12.

Urinary mineral excretion

Unsupplemented cows had lower urinary concentration (2.9 ± 0.36 and 1.1 ± 0.20 mmol/l for Mg supplemented and unsupplemented animals, respectively) and lower fractional Mg clearance (Table 1). The average FCR of Ca and Na was also

FIGURE 1: Diurnal variation in mean serum Mg concentration of grazing dairy cattle either supplemented or unsupplemented with Mg in early lactation.

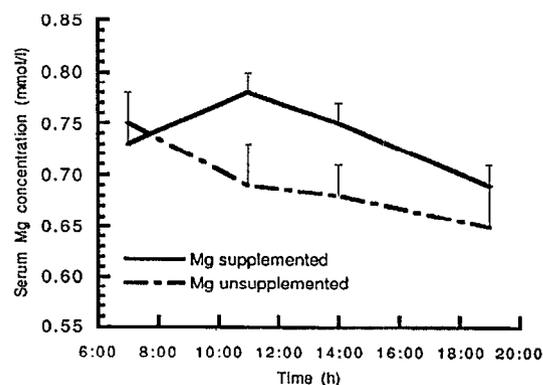
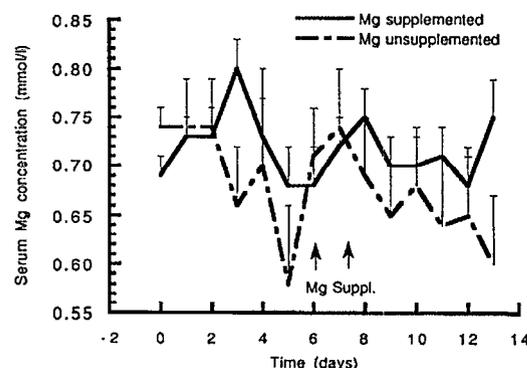


FIGURE 2: Day to day variation in mean serum Mg concentration of grazing dairy cattle either supplemented or unsupplemented with Mg in early lactation.



significantly lower in unsupplemented animals (Table 1). Fractional excretion of Mg was elevated during the 2 days of Mg supplementation mid trial but did not reach the levels of the Mg supplemented group (Figure 3). Average corrected urinary Mg (CUM) values for Mg supplemented and unsupplemented animals were 1.47 ± 0.085 and 0.39 ± 0.036 mmol/l, respectively. Supplementing Group 2 animals with Mg for 2 days mid trial elevated CUM to 1.07 ± 0.019 mmol/l.

TABLE 1: Fractional clearance ratios (5%) of magnesium, calcium, sodium and potassium in urine of magnesium supplemented and unsupplemented cows.

	Supplemented mean	Unsupplemented mean*	SED
Mg	15.5	4.2	2.04
Ca	40.2	8.1	10.31
Na	2.2	1.5	0.32
K	214.0	235.0	14.68

*means calculated using results of urine samples collected at 2pm on days 1-5 and 8-13 only.

The FCR of K at 1400 and 1900 h was 48 ± 7.8 percentage units (PU) greater than at 0700 and 1100h. Urinary Na excretion increased by 1.7 ± 0.5 PU between 0700 and 1100 h and declined to intermediate levels by 1900 h while Ca excretion declined by 19 ± 4.5 PU from 0700 to

1900h. Diurnal variations in FCR for K, Na and Ca were similar for both groups but that of Mg excretion differed between treatments. In Mg supplemented animals the FCR of Mg peaked at 1100h and subsequently declined (Figure 4). This diurnal variation was not present in unsupplemented animals (Figure 4). For all minerals there were significant differences between days in the FCR.

FIGURE 3: Day to day variation in the mean fractional clearance ratio of Mg in urine of grazing dairy cattle either supplemented or unsupplemented with Mg in early lactation.

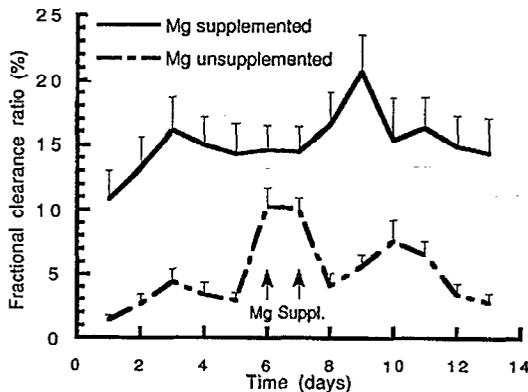
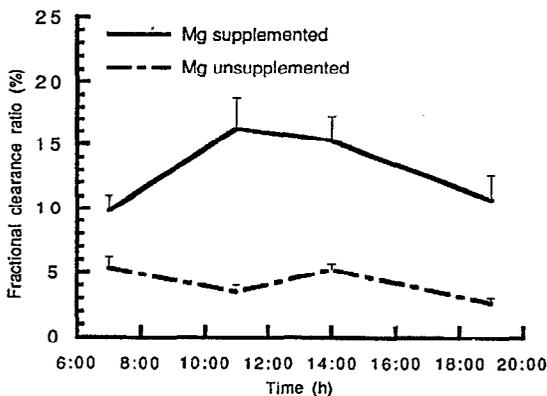


FIGURE 4: Diurnal variation in the mean fractional clearance ratio of Mg in urine of grazing dairy cattle either supplemented or unsupplemented with Mg in early lactation.



Milk

Yields of milk, fat, protein and lactose did not differ between supplemented and unsupplemented groups. Milk yields averaged 17.7 ± 0.94 and 18.5 ± 1.12 litres, respectively. The Mg concentration in milk from unsupplemented animals was higher than that of Mg supplemented cows, 11.00 ± 0.23 and 10.42 ± 0.16 mg /100ml, respectively and significantly more Mg was excreted in the milk from unsupplemented cows

DISCUSSION

Results indicated that even in animals receiving Mg supplementation there was considerable variation in serum Mg levels between individual animals and within animals on a day to day basis. In the absence of Mg supplementation the variation between animals increased. If serum Mg concentra-

tions were the only method of assessing the Mg status of the unsupplemented herd in the current experiment then only 40% of the animals would have been diagnosed as hypomagnesaemic and in need of Mg supplementation. In contrast 100 % of the unsupplemented animals had FCR less than 10 % indicating a likely response to Mg supplementation (Sutherland *et al.*, 1986). If urinary Mg excretion is to be used as an indicator of Mg status it is important that attention be paid to sample quality as faeces contain ten times more Mg than urine (Ellison, 1991). This technique requires further field evaluation before it can be recommended as a routine procedure.

Considerable variation in serum mineral concentration, up to 300 %, and FCR, up to 100%, were observed within and between animals on a diurnal and day to day basis. Such variations have implications in scientific experiments and in monitoring dairy herds for metabolic disease by blood or urine profiles. Sampling the same group of animals at all collections would be advantageous. Initial selection of animals should ensure adequate representation of age and production within the herd. Older cows (greater than 5 years old) have lower Mg concentrations than young animals (Morris, 1994). With the Mg concentration in milk between animals being relatively constant the demand for Mg by high producing animals is greater than that of lower producers. Samples should be collected at the same time each day to minimise diurnal variation. While variation from day to day will still occur due to such factors as diet, feeding level and the weather this can be quantified in scientific work but not in a practical context.

Withdrawal of Mg supplementation significantly decreased both urinary Mg concentration and the fractional clearance ratio. Towers (1982) reported that urinary Mg levels are largely dependent on Mg intake and are rapidly influenced by changes in diet, time of feeding and administration of supplements. Mature ruminants lack a readily available mobilisable pool of Mg for use during dietary deficiency. As a consequence renal Mg reabsorption plays a vital role in the maintenance of total body Mg. A threshold of 0.7-0.8 mmol/l plasma (Sykes & Russel, 1991) exists below which Mg excretion is sharply reduced through renal reabsorption of filtered Mg. Within a day of removing Mg supplementation in the current experiment the FCR of Mg was significantly less ($P < 0.001$) than that of supplemented animals, supporting the conclusions of Towers (1982). Serum Mg concentration in supplemented animals was elevated within three hours of drenching and offering fresh feed. Feeding did not elevate serum Mg levels in unsupplemented cows.

Sutherland *et al.* (1986) suggested that animals with a FCR less than 10 % would benefit from Mg supplementation. Mean fractional clearance of Mg in unsupplemented animals ranged from 1 to 8 % (overall mean 4.2%, Table 1) while the FCR for supplemented animals exceeded 10 % at three of the four sampling times during the day (Figure 4). When Mg was given to the unsupplemented cows for two days the FCR increased to 10.31 %.

In the absence of simultaneous blood and urine samples a corrected urinary Mg (CUM) value can be calculated by dividing urinary Mg concentration (mmol/l) by urinary creatinine (mmol/l). Sutherland *et al.* (1986) reported likely

benefits to Mg supplementation when CUM levels fall below 1 mmol/l. In the absence of Mg supplementation in the current experiment CUM values less than 1 mmol/l were observed. These levels were elevated to 1.1 ± 0.02 mmol/l when Mg was administered for two days mid trial.

The fractional clearance ratios for K and Mg were similar but values for Na and Ca excretion were higher than those observed by Fleming *et al.* (1991). Removing Mg supplementation significantly decreased the FCR of Ca. Fleming *et al.* (1991) concluded that fractional excretion of electrolytes on single, simultaneously obtained blood and urine samples in cattle provided a reasonable indication of electrolyte clearance by the kidneys, but suggested that further studies were required to determine normal ranges of FCR for cattle at various stages of gestation and lactation and various dietary intakes to make this a useful test for the identification of electrolyte and metabolic disorders.

Young *et al.* (1979) reported milkfat production responses of 10-15 % in herds supplemented with Mg during the first 3 months of lactation. Removal of Mg supplementation in the current experiment had no significant effect on production. A longer treatment period may be required to assess milk production responses.

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