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Changes in plasma, milk and urinary magnesium concentrations in pasture-fed dairy cows in early lactation

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ABSTRACT

Estimates of magnesium (Mg) balances and plasma Mg concentrations of 51 dairy cows were obtained at 2-weekly intervals from calving during the first 3 months of lactation (late August to early December). During that period estimated 24h Mg excretion increased from 1.1 to 3.2g Mg/d ($P<0.001$) and varied with age. Plasma magnesium concentrations in 10% of samples were below the threshold (0.6 mM) at which productivity is considered to be impaired. Within cow repeatability for plasma Mg was 0.70 ± 0.048. Individual cows showed unique patterns in the relationship between plasma Mg and estimated urinary Mg output. Mean milk Mg concentration was 104 ± 0.54 mg/l, almost 20% lower than published values used in estimates of net requirements for Mg. Individual cow repeatability for milk Mg concentration was 0.67 ± 0.082 which, together with the plasma data, suggest an important genetic component in Mg homeostasis. This will need to be accounted for in models of Mg metabolism.

Keywords: dairy cows; magnesium; plasma; urine; milk; modelling.

INTRODUCTION

Lost production and cow losses alone due to hypomagnesaemia probably cost the dairy industry NZ$46M annually before management costs are considered, and are still a major concern of the industry. A simulation model of Mg metabolism based on the literature of physiological studies in sheep has been developed (Robson *et al*., 1997) and is in the process of being converted into a farm-side programme for dairy cattle, which, with simple analysis of accessible biological fluids such as urine, can be used to predict need for Mg supplementation.

There are few balance studies available with dairy cattle and none for New Zealand pastures from which we can develop the model. This paper describes a series of measurements of plasma, urine and milk Mg concentrations and predictions of Mg balances using milk output data, urinary Mg:creatinine concentration ratios and estimates of feed intake from milk output and bodyweight change. These were carried out during the first 3 months of lactation, the critical period for hypomagnesaemic tetany, in an age-balanced cohort.

MATERIALS AND METHODS

During the beginning of the 1998/99 season 51 cows, stratified to reflect the age distribution of the herd, were identified from 345 cows (75% Friesian, 25% Jersey-Friesian crossbred) in the Lincoln University herd. They were selected hierarchically within age class to represent the range of and mean milk production in the previous season. Two-year-old cattle were selected at random. Of the 51 cattle 9, 9, 24 and 9 were classified as 2, 3, 4-8 and 9 + years old, respectively. They were identified by leg straps and run with the main herd, on ryegrass (*Lolium perenne L.*) - white clover (*Trifolium repens*) pastures supplemented with 1 kg crushed barley/cow/day fed on the milking platform from 8 September until the end of the trial. The planned start and mid point of calving were 10 and 23 August, respectively. The trial ran from 24 August until 3 December 1998.

The Mg supplementation regimen operated by the farm manager applied to all cows. During off farm grazing from 10 July onwards pasture was dusted with Biomag (Coast Biologicals, Manukau City) containing 92% MgO at a rate of 50g/cow/d. Cows entering the colostrum and milking herds after calving were offered Mg as $MgCl_2.6\ H_2O$ dispensed in water troughs at a rate of 60g/cow/d until the end of December. In addition, Biomag was added to the barley meal supplements at the rate of 10 kg/2.5 tonne (= 2.2 g Mg/kg barley) between 28 September and 5 October and at the rate of 20 kg/2.5 tonne (= 4.4 g Mg/kg barley) between 6 October and 23 November.

During the morning milking blood and urine samples were taken and bodyweight was recorded from identified lactating cows at fortnightly intervals commencing on 24 August and finishing on 3 December. A sample of bulk milk was obtained after the morning milking. Herd tests at two consecutive milkings were carried out on 22 September and 17 November; individual milk volume was measured and a subsample retained for Mg analysis.

Herbage samples were obtained from the paddocks grazed in the 48h prior to milking for each period by walking a "W" pattern and hand-plucking herbage at grazing height every 15 paces.

Sampling, storage and analysis

Blood was taken into evacuated heparinised tubes from tail vein sampling while the cows were on the rotary platform at the morning milking. Blood was spun at 3000 g, and plasma recovered and stored at –20°C before analysis for Mg by atomic absorption spectrophotometry (AAS).

Urine was obtained into plastic containers by perineal stimulation either while the cow was on the milking platform or, subsequently, while held in a crush for weighing, by perineal stimulation. Immediately after milking duplicate 3 ml samples were transferred to plastic vials and acidified (0.1 ml 50% HCl). Mg concentration was analysed by AAS, and creatinine by the Jaffé reaction (Boehringer Mannheim GmbH 124 192).

Subsamples of herbage were oven dried at 95°C for at least 36h for dry matter (DM) determination. A further

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sample was stored at –20°C before freeze drying and subsequent analysis for Mg by AAS and for Na and K by flame emission spectrophotometry following acid digestion using the technique of Thompson and Blanchflower (1971). Metabolisable energy (ME) content was estimated by near infrared spectroscopy (NIR) using established local algorithms for this plant material.

Statistical Analysis

Least squares means for pasture analysis were obtained using the general linear model in Minitab 11 (1996). The variance of cow and time effects in bodyweight, plasma, urine and milk were estimated using REML routine in Genstat (1995), and predicted means given with standard errors based on pooled variances to allow for unbalanced data sets resulting from missing values.

RESULTS

The data were analysed according to calendar time, because no additional information or statistical differences were gained from evaluating the data (live weight, plasma Mg, urine Mg) in relation to time since calving.

There was a significant effect of time ($P<0.001$) for cow live weight but no age group interaction, since all groups showed a gradual increase in bodyweight *viz.* 44, 10, 27 and 38 kg gain in 2, 3, 4-8 and 9+ year old cows, respectively. Mean bodyweights were 380, 425, 503 and 517 kg, respectively, and with the exception of the latter two groups were significantly different ($P<0.05$). Milk volume (l/d) was 18.9 ± 1.21, 26.3 ± 1.40, 30.1 ± 0.89 and 29.8 ± 1.75 on 22 September and 18.2 ± 1.21, 20.7 ± 1.40, 26.7 ± 0.88 and 24.9 ± 1.59 on 17 November for cows in the 2, 3, 4-8 and 9+ groups, respectively.

There was gradual but consistent increase in herbage Mg concentration from 1.8 ± 0.12 g/kg DM on 24 August to 2.3 ± 0.06 g/kg DM on 16. Potassium concentration was lowest in August and September (31.7 ± 2.38 g/kg DM) and increased to 38.9 ± 1.68 g/kg DM by 5 October, subsequently falling to 34.5 ± 1.68 g/kg DM by 16 November and 24.9 ± 1.68 g/kg DM by 30 November. Sodium concentration showed more variation, but increased from 1.5 ± 0.49g/kg DM on 7 September to 3.5 ± 0.42 g/kg DM on 16 November and remained at this level for the remainder of the trial.

The mean plasma Mg concentrations for each age group are given in Fig. 1. There was a highly significant interaction between time and group due to a trend for increase with time in all groups, but particularly so in 3 and 9+ year old cows which tended to have low values after calving. The repeatability of plasma Mg concentration for individual cows across all observations was 0.70 ± 0.048.

Mean urinary Mg concentrations for each age group are given in Fig 2. Concentration increased in all groups with time ($P<0.005$). There was also a significant effect of age of cow ($P<0.01$) due to greatest concentrations in the 9+-year-old cows and lowest concentrations in 3-year-old cows. The repeatability of individual urinary Mg concentration across all observations was 0.51 ± 0.068.

Urinary creatinine concentration did not differ between groups, although the older cows (4-8 and 9+ age groups) did tend to have higher concentrations in the August and September periods and showed a decline from 430 ± 95 in late August to 390 ± 55 mg/l in early October. Repeatability within cow was low (0.13 ± 0.59).

The mean Mg concentration in bulk milk was 104 ± 0.54 mg/l and showed no consistent variation with period other than a trend for highest readings in the later periods *viz.* 105.5 and 106.6 mg/l in late November and early December. The individual herd test results for Mg were, however, significantly ($P<0.001$) lower in September than in November, being 100 ± 1.34 and 104.7 ± 1.23 mg/l, respectively. The mean values for the four age groups were 103.1 ± 2.29, 105.8 ± 2.73, 102.4 ± 1.58 and 98.1 ± 2.50 mg/l for the 2, 3, 4-8 and 9+ year old cows, respectively, but were not significantly different. Individual cow repeatability for milk Mg concentration was 0.68 ± 0.085.

FIGURE 1: Mean plasma Mg concentrations (±sem) for each age group of dairy cows.

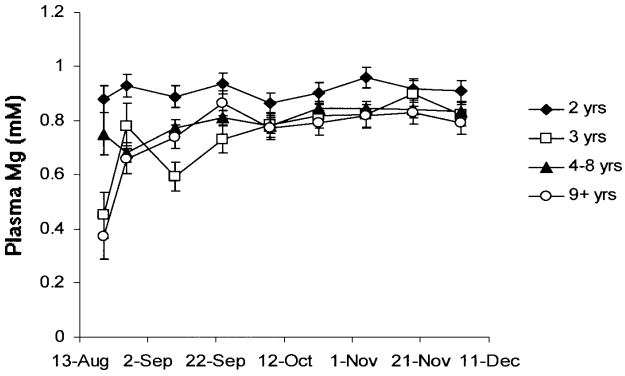


FIGURE 2: Mean urinary Mg concentrations (±sem) in dairy cows of differing ages.

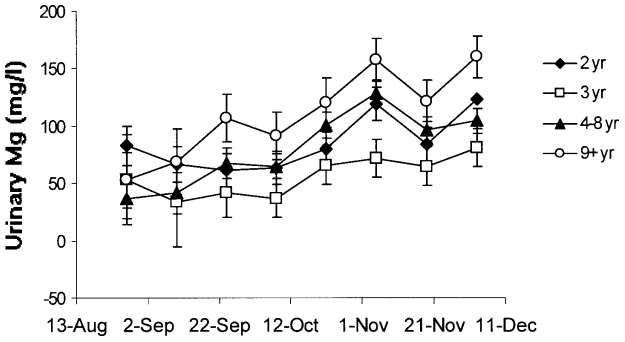
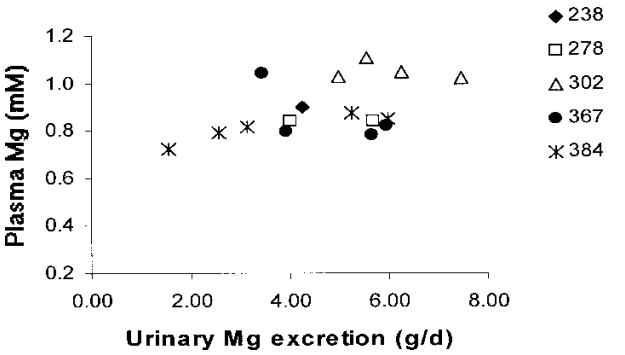


FIGURE 3: Relationship between plasma Mg concentration and total urinary Mg excretion for some 4-8 year old dairy cows. Numbers in the legend represent the identification number of each individual animal.



DISCUSSION

The average daily milk volumes recorded in the herd tests were above the average for the South Island industry (Dairy Statistics, 1998). The herbage mineral concentrations were within the range expected for New Zealand pastures in the spring. Magnesium concentrations were above the estimated minimal value of 1.9 g/kg DM to meet requirement (Grace, 1983). The trend for lowest K concentration in early spring with a subsequent increase is probably atypical and may reflect the relative maturity of herbage accumulated during the winter period. The K concentrations were, however, always greater than 25 g/kg DM above which significant impairment of Mg absorption can be anticipated (Green *et al*., 1983; Dalley *et al*., 1997). Herbage sodium concentrations were always in excess of the theoretical requirement of 1.2g/kg DM (Grace, 1983).

The mean magnesium concentration in milk of 104 ± 0.54 mg Mg/l was consistently 20% lower than the value of 120 mg Mg/l on which estimates of nutrient requirements of animals have been based (ARC, 1965; ARC, 1980). These estimates, however, were based on data sets from literature that showed a very wide range from 30-310 mg Mg/l. Even if the extreme values are omitted concentrations still ranged from 92-170 mg Mg/l. ARC (1965) and ARC (1980) adopted a mean of 126 mg Mg/l. Clearly, the present work suggest that the net Mg requirements of Friesian/Jersey cattle in New Zealand for Mg may be considerably overestimated if these ARC values are used. Other studies have suggested that milk Mg concentration may be affected by plasma Mg concentration (Wiener *et al*., 1980). However, although individual plasma Mg concentrations ranged from 0.45 to 1.1 mM at the time of the milk sampling, no such relationship could be established in the present studies.

Magnesium balances of the cattle were estimated at the times of herd testing. Urinary Mg output was estimated from Mg:creatinine ratios in urine and from estimated urinary creatinine 24h output (g/d) using the formula from Windisch *et al*. (1995) where: Urinary Creatinine (g/d) = 1.43 + 0.0021W, and W = live weight (kg). The metabolisable energy (ME) required for the milk production and maintenance was calculated from actual milk production, live weight and live weight change since the previous weighing, using values of ARC (1980). ME content of herbage was then used to derive DM intake. This allowed calculation of Mg intake from current herbage Mg concentration. The value of 3 mg Mg/kg LW/d for endogenous loss of Mg was assumed (ARC, 1980). Accretion or resorption from the body have been ignored as these are negligible compounds to the fluxes accounted for (Robson, 1991). The data for 4-8 year old animals are given in Table 1. Availability estimates of all animals range between 13 and 17%. These calculations suggest that in both September and November animals were absorbing only 15% of total Mg intake. This corresponds precisely with the absorption coefficient calculated by Adediji and Suttle (1999) from data in the literature for cattle consuming grasses containing 30-40g K/kg DM.

One of the aims of the experiment was to define relationships between urinary Mg concentration, urinary Mg:creatinine ratio or calculated urinary Mg output and plasma Mg concentration, and the extent of their co-variances. The ultimate objective is to predict from a simulation model of magnesium metabolism the magnesium status of the herd and therefore the risk of clinical cases of hypomagnesaemic tetany in individual cows. A surprising feature of the data was that, although a general trend for increase in plasma Mg concentration with increases in estimated urinary Mg output could be discerned, individual cows appeared to establish unique patterns in this relationship. An example of this is given in Fig. 3 for a sample of 4-8 year old cows. This clearly shows that at the same estimated rate of urinary Mg excretion differences of 0.2 mM in plasma Mg concentration existed which could not be explained by milk yield. It is recognised that genetic variation exists in the ability to absorb Mg (Field & Suttle, 1979). The present work suggests there may be between cow variation in plasma Mg concentration that is independent of Mg absorption and Mg availability to tissues. This is perhaps supported by the very high repeatability of plasma Mg concentration observed (0.7±0.048). Whether animals, which maintain lower than average plasma Mg concentrations independent of Mg throughput, are more or less susceptible to hypomagnesaemic tetany is a matter that requires further investigation. It was surprising, in the context of substantial Mg supplementation *viz*. >10g Mg/d employed in this study, that in significant numbers of plasma samples (~ 10%) Mg concentrations were below 0.6 mM, the threshold below which production is considered to be impaired (Sutherland *et al*., 1986). This occurred predominantly, but not exclusively, in the first 6 weeks of lactation and despite the fact that they appeared to be utilizing only 70% (September) and 55% (November) of Mg apparently absorbed, i.e., (milk Mg + endogenous Mg)÷(milk Mg + endogenous Mg + urinary Mg) (Table 1).

Clearly, a better understanding of the variation in individual cow plasma Mg concentration and the factors which influence this are needed for the construction of a model which predicts need for Mg supplementation.

TABLE 1: Estimated magnesium balances (g/d) of 4-8 year old cows on herd test days in September and November. These estimates include only animals with a complete set of results for these two days.

Time	No. of animals	Mg intake (g/d)		Mg output (g/d)			Availability %
		Herbage	Suppl	Milk	Endog-enous	Urine	
Sep	8	33.1	7.2	3.1	1.5	1.8	16
Nov	15	42.8	11.6	2.8	1.6	3.9	15

REFERENCES

Adediji, O.; Suttle, N.F. 1999: Influence of diet type, potassium and animal species on the absorption of magnesium by ruminants. *Proceedings of the Nutrition Society 58:* 31A.

Agricultural Research Council 1965: The nutrient requirements of farm livestock. No. 2 Ruminants. London HMSO.

Agricultural Research Council 1980: The nutrient requirements of ruminant livestock. CAB Farnham Royal, Slough, England.

Dalley, D.E.; Isherwood, P.; Sykes, A.R.; Robson, A.B. 1997: Effect of intraruminal infusion of potassium on the site of magnesium absorption within the digestive tract in sheep. *Journal of agricultural science, Cambridge 129:* 99-105.

Dairy Statistics 1998. Livestock Improvement Corporation, New Zealand Dairy Board.

Field, A.C.; Suttle, N.F. 1979: Effect of high potassium and low magnesium intakes on the mineral metabolism of monozygotic twin cows. *Journal of comparative pathology 89*: 431-439.

Genstat 5 Reference Manual 1995: Lawes Agricultural Trust, Rothamstead Experimental, Harpenden, Clarendon Press Oxford.

Grace, N.D. 1983: The mineral requirements of grazing livestock. Occasional Publication 9. New Zealand Society of Animal Production.

Green, L.W.; Fontenot, J.P.; Webb, K.E. 1983: Effect of dietary potassium on absorption of magnesium and other macro-elements in sheep fed different levels of magnesium. *Journal of animal science 56:* 1208-1212.

Minitab 11 1996: Minitab Reference Manual, Release 11. Pennsylvania State College, USA.

Robson, A.B. 1991: Modelling of magnesium metabolism in ruminants. PhD Thesis. Lincoln University.

Robson, A.B.; Field, A.C.; Sykes, A.R.; McKinnon, A.E. 1997: A model of magnesium metabolism in young sheep. Magnesium absorption and excretion. *British journal of nutrition 78:* 975-992.

Sutherland, R.J.; Bell, K.C.; McSporran, K.D.; Carthew, G.W. 1986: A comparative study of diagnostic tests for assessment of herd magnesium status in cattle. *New Zealand veterinary journal 34:* 133-135.

Thompson, R.H.; Blanchflower, W.J. 1971: Wet-ashing apparatus to prepare biological materials for atomic absorption spectroscopy. *Laboratory practice 20:* 889-861.

Towers. N.R. 1982: Urinary magnesium - an indicator of magnesium status/ intake? *Proceedings of the New Zealand Society of Animal Production 42*: 167-168.

Wiener, G.; Russell, W.S.; Field, A.C. 1980: Factors influencing the concentration of minerals and metabolites in the plasma of cattle. *Journal of agricultural science, Cambridge 94:* 369-376.

Windisch, W.; Kirchgessner, M.; Eder, K. 1995: 3-methyl histidine and creatinine in the urine of lactating cows during and after protein and energy deficiency. *Journal of animal physiology and animal nutrition 74:* 274-280.