
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

Proceedings of the N.Z. Society of Animal Production, 41: 53-60 (1981)

THE MAGNESIUM STATUS OF GRAZING DAIRY COWS

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SUMMARY

Factors which influence the blood magnesium status of cattle are reviewed briefly. Results from a monozygous twin herd illustrate the effects of nutritional and other factors on blood magnesium concentrations and associated changes in milk production and health.

INTRODUCTION

The objective of this paper is to review some of the results from experiments carried out on the Dairy Research and Development Unit at Massey University which relate to the blood magnesium (Mg) status of dairy cows and associated changes in productivity and health.

The Mg status of cattle is normally assessed by measuring the concentration of Mg in serum or plasma with values between 20 and 28 mg/litre (0.8 to 1.2 m mols/litre) generally being considered "normal". Cows with lower values than this are said to be suffering from hypomagnesaemia. While hypomagnesaemia often appears completely harmless, it may also be associated with low milk production and is occasionally the forerunner to clinical tetany (grass staggers) which if untreated, usually results in death.

CAUSES OF VARIATIONS IN BLOOD MAGNESIUM

Mean blood Mg values vary considerably between herds and within a herd over the season (Young *et al.,* 1979), with the lowest values generally occuring during the early spring in the first 1-3 months of lactation. At this time there is also commonly a very wide "between animal" variation in blood Mg concentrations, indicating different individual cow reactions to identical environmental conditions. As an example, 40 mature cows were sampled on two occasions a few days apart during August 1980. The mean values were 10.6 and 12.4 mg Mg/litre with standard deviations of 6.4 and 7.2 respectively.

Plasma Mg concentration for an individual cow also varies diurnally in response to feeding and this variability is exaggerated when supplementary Mg is provided at milking time which normally precedes a period of feeding (Fig. 2e).

The main factors which contribute to Mg balance in lactating cattle and are therefore likely to affect blood Mg concentrations, are shown in Fig. 1.

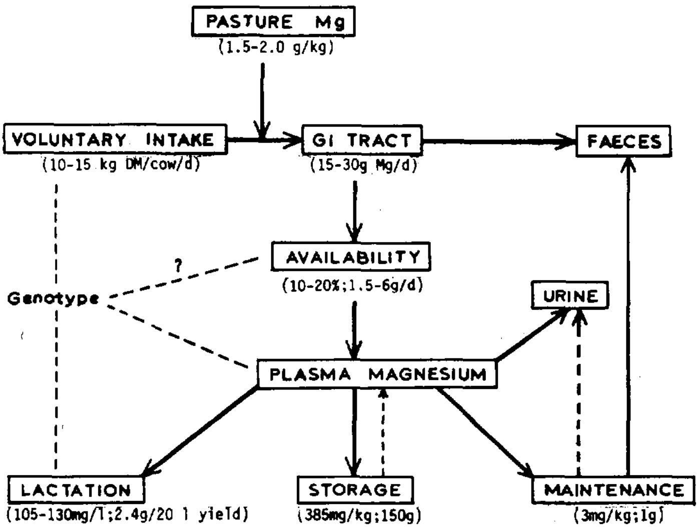

FIG 1: *Factors contributing to magnesium balance.*

Quantitative data on the amounts of Mg required per day (ARC 1965) and common variations in the amount of Mg provided and "available" to the cow, are also given and they highlight the vulnerability of cows to a Mg imbalance. At least 3.4 g Mg/d is the net requirement for a 400 kg cow producing 20 litres of milk and this quantity may not be absorbed if pasture Mg concentration, voluntary intake or "availability" are at their minimal values.

Experiments relating to many of the factors shown in Fig. 1 have been undertaken at Massey University.

GENETIC FACTORS

In a recent experiment 12 pairs of monozygous twin cows grazed as a single group were blood sampled and Mg concentrations measured on two days during a single week in August. An analysis of variance indicated that 12% of the total variance was associated with "day effects". For the animal effects the "between pair"

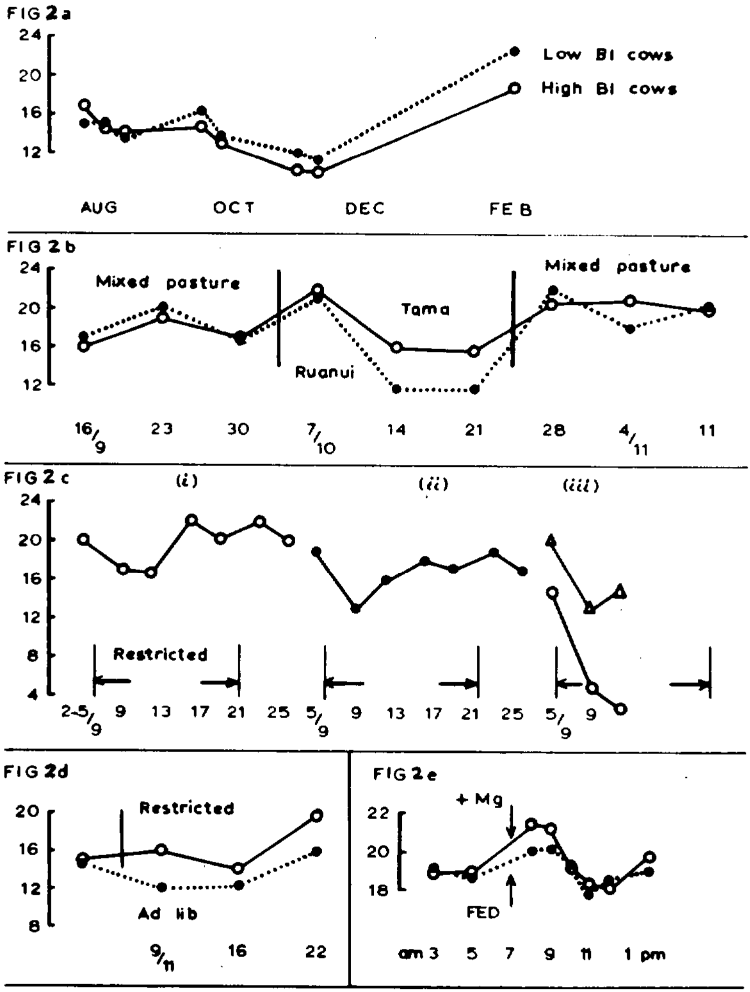

FIG. 1: *Variations in plasma Mg concentration (mg/litre) (a) due to season for cows of high or low breeding index; (b) for a pair of monozygous twins; (c) following a restriction in feed intake for 3 first calvers (i) 3 mature cows (ii) and individual mature cows whose twin mates had tetany (iii) (d) during a prolonged period of restricted feeding; (e) over the day, due to feeding and treatment with 10 g Mg as $MgCl_2$ $6H_2O$.*

variance was large (61%) and the "cows within twin pair" variance small (2%). These results suggest that a considerable portion of the variation in blood Mg concentration is of genetic origin.

The large "genotype by environment" interaction which often occurs in individual cow blood Mg concentrations from week to week add considerably to the difficulty of conducting experimental work on hypomagnesaemia (and especially grass tetany). However, the use of monozygous twins assists greatly in reducing this problem. Fig. 2b illustrates the extent to which twin pairs react similarly over time which in turn means that relatively small differences can be detected by their use in our experiments.

The genetic effect however, does not appear to be strongly associated with genotype for production. Ten Friesian cows of average (102) Breeding Index (BI) were shown to have similar blood-Mg values to 10 cows of high BI (128), immediately prior to calving and early in lactation (Fig. 2a). The low BI cows however, had significantly higher ($P<0.05$) Mg values by February, presumably because the milk production difference between the groups had become larger and level of milk production has a major influence on Mg requirements.

Pasture Magnesium

The feeding values of a large number of new species and varieties of pastures developed by Grasslands Division, D.S.I.R. have been examined on the Dairy Unit. Whenever the pastures being compared varied widely in Mg content, the blood Mg concentration of groups of 6 to 10 cows grazing them have been measured (Table 1). With the exception of the apparently anomalous result for 'Grasslands Huia' white clover, a good relationship between pasture and blood Mg concentrations is evident.

Voluntary Intake

The effects of a sudden reduction in intake, achieved by offering cows half their "normal" grazing area are shown in Fig. 2c. The data for the 8 animals have been divided into 3 parts. The mean figures for 3 first calvers are followed by those for 3 mature cows. Individual cow data for a further 2 mature cows are shown separately as they were removed from the experiment after only 6 days. This was because their twin pair mates which were also being underfed, developed clinical tetany following the feeding of an emulsified tallow supplement (200 ml/milking). It is clear from

TABLE 1: RELATIONSHIP BETWEEN PASTURE AND BLOOD MG CONCENTRATIONS

Date	*Pasture type*	*Blood Mg (mg/litre)*	*Pasture Mg (g/kgDM)*	*Reference*
Oct 1965	'Grasslands Ruanui' ryegrass	13	1.3	Butler & Metson 1967
	'Grasslands Tama' ryegrass	17	1.4	
	'Grasslands Paroa' ryegrass	20	1.6	
	Mixed pasture	21	1.9	
Sept/Oct 1969	'Grasslands Ruanui' ryegrass	20	1.9	Grace & Wilson 1972
	'Grasslands Huia' white clover	18	2.7	
Sept/Oct 1974	'Grasslands Matua' prairie grass	18	1.1	Wilson & Grace 1978
	'Grasslands Tama' ryegrass	18	1.3	
	Mixed pasture	23	1.7	

these data that underfeeding in the short term lowers blood Mg for a period of 3 to 6 days and that the extent of the depression varies between young and mature cows. Following this period blood Mg concentrations tended to return to pre-treatment levels.

In contrast to the short-term effect, underfeeding (70% *ad lib*) over a period of one month during November in a recent indoor feeding experiment resulted in higher plasma Mg values than those for cows which were fully fed (Fig. 2d). Here there was a significant relationship (r = 0.62**) between the size of the reduction in milk yield of the individual cows following the restriction and the increase in plasma Mg concentration.

Availability of Ingested Magnesium

A reduced availability of Mg due to interference from other minerals or organic matter constituents is considered by many as the most important reason for hypomagnesaemia. Low availability (5-10%) of Mg is normally associated with the consumption of immature grasses with a high nitrogen content (Kemp *et al.*, 1961; Rook and Campling, 1962). Such grasses often contain high levels of potassium, which has been shown to reduce the availability of Mg (Suttle and Field, 1969; Fontenot *et al.*, 1973).

In 1966 Kemp *et al.* reported a significant negative relationship between forage Mg availability and the higher fatty acid (HFA) level in the ration of lactating cows. It was postulated that the effect was mediated through the formation of water insoluble Mg and Ca soaps in the rumen, which would not be efficiently absorbed. This suggestion was subsequently supported by the results (Table 2) of an experiment undertaken at Massey in which blood plasma Mg concentrations in dairy cows grazing 'Ruanui' ryegrass were depressed following supplementation with 50-70% additional HFA (440 ml/d) as peanut oil. The inclusion of a starch supplemented group (900 g/d) as an "iso-caloric control" unexpectedly resulted in a significant increase in plasma Mg concentration and suggests that the soluble carbohydrate content of pastures as well as the HFA concentration may be involved in the aetiology of hypomagnesaemia.

TABLE 2: EFFECT OF PEANUT OIL AND STARCH SUPPLEMENTS ON PLASMA MG (MG/LITRE) (WILSON *ET AL*, 1969)

Date	*Starch (S)*	*Control (C)*	*Oil (O)*	*Sig. diffs.*
Sept	18.8	15.3	12.1	$S > O^{**}$, $S > C^{*}$, $C > O^{*}$
Nov	21.8	22.2	19.3	$S > O^{*}$, $C > O^{*}$

The possible role of other minerals (e.g. Na and Al), organic acids and other organic matter constituents in influencing Mg availability have been reviewed recently by Mayland and Grunes, (1979).

BLOOD MAGNESIUM AND MILKFAT PRODUCTION

Our first realisation that variations in blood Mg may be associated with changes in milkfat production came in a 1974 experiment when cows grazing 'Grasslands Matua' prairie grass containing only 1 g Mg/kgDM produced milk with a lower ($P < 0.01$) milkfat content (Wilson and Grace, 1978). The effect developed progressively over a 14 day period and by the end of the experiment the fat content of the milk was 3.8% compared with a value of 4.4% for the pre-treatment period. In several subsequent experiments (Wilson and Grace, 1978; and unpublished) no significant production responses were obtained following oral Mg supplementation (10 g Mg/d) of cows with near normal blood Mg concentrations. However, the individual animals within the experiments which were initially hypomagnesaemic showed correlated changes in milkfat concentration and plasma Mg. These results are in agreement with those of Young and Rys (1977) and Young *et al.,* (1979), who found that the magnitude of milkfat responses to oral magnesium supplements depend on the extent and severity of hypomagnesaemia.

We then considered it important to determine whether hypomagnesaemia itself causes lower production, or a Mg deficient diet causes concomitant changes in plasma Mg and production. This was investigated in 1979 by measuring the milk production of hypomagnesaemic cows given supplementary Mg either, orally, by rectal infusion, or by subcutaneous injection (Wilson, 1980). Plasma Mg concentrations were increased to a similar and significant extent ($P < 0.01$) by all treatments but a significant increase in milk and fat production occurred only in the orally treated cows. Because we have also demonstrated that supplementary Mg may improve the digestibility of some forages, both *in vitro* and *in vivo,* I now believe we have reasonable grounds for concluding that dietary Mg may alter the energy available from some rations as well as providing Mg. These two effects acting together probably account for the bulk of the relationship between blood Mg and milk production.

The finding that an optimum dietary Mg concentration is required to maximise digestion of forages in the rumen and that this may affect production raises several new questions. Perhaps Mg supplements should be provided several times a day rather than once a day? Would slow release capsules containing Mg lead to a more effective and efficient production response to Mg? What other minerals have similar intra-ruminal effects which affect production?

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