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The importance of an accurate estimate of net endogenous loss of magnesium in ruminants

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ABSTRACT

Attempts to scale up to dairy cattle from a model of magnesium (Mg) metabolism in sheep has shown more rapid reduction in plasma Mg concentration than has been observed in practice when rates of Mg absorption are reduced. Nutrient requirement tables of agriculture research council (1980) provide an estimate for endogenous loss of 3 mg/kg LW/d and, because of the paucity of data, apply this value to sheep and cattle. Such a value represents over 40-50% of the daily requirement for Mg of a typical New Zealand dairy cow even in early lactation. Moreover, the estimate is represented as a constant function of body weight. Net absorption of Mg in ruminants occurs largely in the rumen, but there is recent evidence suggests significant absorption occurs in the large intestine. Therefore, endogenous secretions into the gastrointestinal tract will be available for re-absorption in the large intestine. Under these circumstances it is important for modelling purposes to have an understanding of the true secretion of Mg from which net endogenous Mg losses and, therefore, maintenance needs can be predicted with accuracy. This paper argues from evidence in the literature that net endogenous losses of Mg are unlikely to be a constant. True secretion could be up to 15 times the net endogenous loss because of potentially large exchanges of Mg in different regions of the alimentary tract, which are probably a function of plasma Mg concentration. The case is made a new approach to estimation of maintenance requirement of Mg.

Keywords: magnesium; ruminant; net endogenous loss; absorption; secretion.

INTRODUCTION

A recent attempt to scale a sheep model of Mg metabolism (Robson *et al*., 1997) for use with dairy cattle predicted more rapid changes plasma Mg concentration than observed in independent experimental data after scaling for animal size and differences in production between sheep and cattle. The constant endogenous faecal loss (EFL) of 3 mg/kg body weight (BW)/day (Agriculture Research Council (ARC), 1980) used in the model represented a significant proportion of the net Mg requirements. As can be seen in Table 1, net EFL represents between 30 and 100% of the theoretical net requirement of a ruminant for Mg, depending on metabolic status and productivity. Furthermore, experimental estimates of net EFL from the literature vary over a ten-fold range.

This review considers the processes of true absorption and true secretion of Mg, which determine net EFL. It reveals a large exchange of Mg in the small and large intestine, which will be important to consider in modelling whole body Mg metabolism and requirement.

TABLE 1: Net requirement and endogenous faecal loss (EFL) of Mg, for different animals with different physiological status based on estimates of requirement of ARC (1980).

Animal	Body weight (kg)	Milk production (kg/d)	Net requirement (g/d)	Net EFL (g/d)	% EFL of net dietary requirement
Cow Friesian	500	10	2.5	1.5	60
Cow Friesian	500	20	3.5	1.5	43
Cow Friesian	500	30	4.5	1.5	30
Sheep lactating	75	3	0.65	0.2	29
Sheep maintenance	60		0.2	0.2	100

TABLE 2: Summary of values for net endogenous faecal loss (EFL) obtained by different techniques in different species and different physiological status (adapted from ARC (1980)).

Animal	EFL (mg/kg BW/day)	Method
Calf	0.63-2.46	Low-Mg diet.
Calf	3.5	Isotope dilution.
Dry Cow	2.01	Low-Mg diet.
Lactating Cow	3.0-6.0	Low-Mg diet.
Lactating Cow	1.5	Isotope dilution.
Sheep	3.35	Extrapolation of rectilinear regression of urinary Mg on Dietary Mg.
Sheep	3.4	Comparative balance with ^{28}Mg.
Sheep	0.7-5.04	Isotope dilution.
Sheep	2.7	Low-Mg diet.
Sheep	0.44-1.69	Values for faecal excretion at dietary Mg intake sufficient for maintenance.
Sheep	2.8	Based on low-Mg diet with varying levels of intravenous Mg, regression of EFL on serum Mg concentration.
Sheep	3.2	^{28}Mg.

ASSESSING NET ENDOGENOUS FAECAL LOSS OF MAGNESIUM

A review of the experimental data, on which estimates of net EFL of Mg are based, reveals a range of values between 0.5-5.0 Mg mg/kg BW/day for several techniques in both cattle and sheep (ARC, 1980), Table 2.

In balance trial experiments, estimates of EFL are calculated by rectilinear regression of faecal Mg output vs. intake and extrapolation to zero intake. The large range of values observed has been attributed to experimental errors introduced below the range of actual data (Field, 1962) by the assumption of linearity of the relationship at Mg intake, this assumption has recently been questioned in Mg-deficient animals (Bell *et al*., 2001).

In experiments in which sheep were given intravenous Mg infusions (Allsop and Rook, 1979), relationships between plasma Mg concentration and total faecal Mg output were observed with artificial diets low in Mg, and with natural diets. Differences in the magnitude of response between the diets led the authors to speculate only that apparent availability of Mg may decrease at high plasma Mg concentrations. However, This could also be explained by dependence on plasma Mg concentration of either reduction in the true absorption or increased true endogenous loss.

NET ENDOGENOUS FAECAL LOSS: A BALANCE BETWEEN TRUE SECRETION AND TRUE ABSORPTION

Net EFL is the balance between two processes, true secretion and true absorption of Mg secreted along the gastrointestinal tract. Estimates of true absorption and secretion are difficult to obtain and, usually, experimental data have only provided evidence of the net Mg transport in a localised region. Grace (1983) summarised net Mg transport along the digestive tract from a number of experiments with cannulated animals. These consistently showed a net absorption in the stomach area, net secretion in the small intestine and net absorption in the hindgut (Table 3).

The estimates for the net secretion into the small intestine vary widely, from near 0 mg/kg BW/day on a dried-pasture diet (Grace and MacRae, 1972) to 11 mg/kg BW/day on concentrates (Ben-Ghedalia *et al*., 1975). Intermediate values of 6-8 mg/kg BW/day have been observed on ryegrass diets (Grace *et al*., 1974). Estimates of net secretion of Mg in the small intestine of sheep by Ben-Ghedalia *et al*. (1975) are larger than the highest estimates of total net endogenous Mg loss reported in the literature, consistent with the view that Mg secreted in the small intestine can be reabsorbed lower down of digestive tract. Experiments using indigestible markers and slaughter consistently show a large net secretion of Mg into the small intestine (Sklan & Hurwitz, 1985; Perry *et al*., 1967; Field, 1961). For example, Perry *et al*. (1967) showed that the quantities of these secretions in calves were up to three times (1.1-7.8 g) the amount of Mg in the daily ration (figure 1).

ESTIMATES OF TRUE SECRETION OF MAGNESIUM

Evidence for the true rate of true secretion of Mg into the gastrointestinal tract can be derived from the few studies with radioisotopic tracers that describe the movement and net exchange of minerals. Field (1961) demonstrated a large secretion of Mg into the proximal small intestine of sheep by observing changes in the specific activity following a) intravenous injection and b) oral administration of ^{28}Mg. The specific activity of digesta in the duodenum was observed to increase following intravenous injection and to decrease following oral administration. By observing subsequent changes in specific activity along the digestive tract, it was calculated that 75% of the Mg secreted in the proximal small intestine had been reabsorbed within the distal small intestine.

There is considerable evidence for high rate of true secretion of Mg beyond the rumen, one of the accepted major sites of absorption (Tomas & Potter, 1976). However, since neither hyper- nor hypomagnesaemia appear to change

TABLE 3: The movement of Mg (g/d) in the digestive tract of ruminants (from Grace, 1983).

Diet	In diet	Entering duodenum	Net absorption from the	Leaving ileum	Net secretion from small intestine	In faeces	Net absorption from hindgut	References
Sheep								
Grasslands Ruanui, perennial ryegrass,	1.76	1.44±0.26	0.32	1.76±0.079	0.32	1.23±0.038	0.53	Grace *et al., 1974*
Grasslands Manawa, short- rotation ryegrass	1.84	1.38±0.059	0.46	1.61±0.068	0.23	1.34±0.038	0.27	Grace *et al., 1974*
Grasslands 4700, white clover	2.04	1.42±0.07	0.62	1.79±0.118	0.37	1.44±0.059	0.35	Grace *et al., 1974*
Grassland Huia white clover	1.85	1.44±0.055	0.41	1.41±0.022	0.03 (absorbed)	1.30±0.055	0.11	Grace & Body*, 1979*
Dried pasture	1.67	1.09±0.03	0.58	1.17±0.09	0.08	1.04±0.02	0.13	Grace & MacRae*, 1972*
Concentrate:vetch (*Vicia sativa L.*)	4.69	3.57	1.12	4.33	0.76	3.28	1.05	Ben-Ghedalia *et al., 1975*
Hay:barley (6:3)	1.49	1.18	0.31	1.41	0.23	1.27	0.14	Pfeffer *et al., 1970*
Hay	1.22	1.03	0.19	1.28	0.25	0.97	0.31	Pfeffer *et al., 1970*
Cattle								
Hay, grass concentrates	18.3	14.75	3.55	15.45	0.7	14.9	0.55	Rogers & van't Klooster*, 1969*

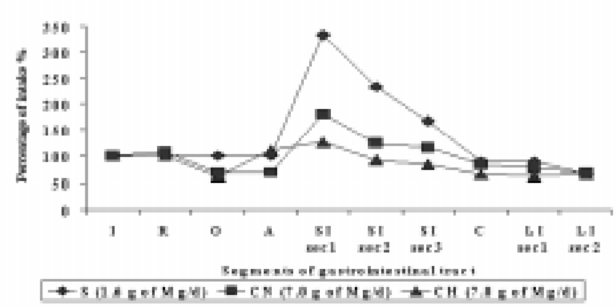

FIGURE 1: Net movement of Mg along the gastrointestinal tract of calves fed different types of) expressed as percentage of Mg intake (adapted from Perry *et al*., 1967). **Symbols**: I, intake; R, rumen; O, omasum; A, abomasum; SM, small intestine; C, caecum; LI, large intestine, S, Semipurified; CN, Concentrate and CH, concentrate plus hay.

net absorption from this site in sheep (Martens & Stössel, 1988), there must be major absorption of Mg at the distal small intestine and large intestine. These latter sites could be the place of adaptation (homeostasis) of the gastrointestinal tract to Mg imbalance (Allsop & Rook, 1979; Schweigel & Martens, 2000).

EVIDENCE FOR EFFECT OF MAGNESIUM STATUS ON ENDOGENOUS MAGNESIUM SECRETION

Evidence that true secretion of Mg along the intestinal tract is Mg-status dependant is available in the reduction in Mg concentration in bile in hypomagnesaemic animals (Allsop & Rook, 1979). Additionally, Grace *et al*. (1985) reported that Mg concentration in saliva was positively related to Mg concentration in lucerne and ryegrass. This suggests that net EFL is likely to be directly related to blood Mg concentration, because the quantities of true secretion of Mg into the gastrointestinal tract are related with animal Mg status. Very recently a linear relationship has, in fact, been observed between plasma Mg concentration and the net secretion along the small intestine (Schweigel & Martens, 2000).

OPPORTUNITIES FOR REABSORPTION OF ENDOGENOUS SECRETION OF MAGNESIUM

Acceptance that there are large secretions of Mg into the gastrointestinal tract, yet use of a single low value for net EFL by ARC (1980), implies that those secretions are normally efficiently reabsorbed in distal region of this tract. Evidence for this comes empirically from observations that, despite large variation in apparent availability of Mg in ruminants, rate of apparent Mg absorption increases almost linearly with increase in Mg intake (Adediji & Suttle, 1999; Schweigel & Martens, 2000). In addition, in balance studies, the apparent absorption of Mg in the intestine of lambs was increased when they were fed a supplementary source of Mg (Mg-Mica) that increased Mg concentration in the intestine (Hurley *et al*., 1990). Furthermore, Care & van't Klooster (1965) reported an increase of Mg absorption in the ileum when concentrations of Mg in the small intestine increased. The consequence of such a positive relationship would be to reduce effects of variation in net EFL as a consequence of variation in true EFL.

CONCLUSION

Endogenous faecal loss is an important component of the net requirement for Mg in ruminants. Adaptation of a simple value for net EFL disguises the true movement of Mg along the alimentary tract and may provide misleading estimates of requirement. Modelling Mg metabolism will be more soundly based if the fluxes of Mg and the role of the hindgut in Mg absorption and homeostasis can be better quantified.

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