Studies on magnesium in ruminant nutrition

2.* The effect of abrupt changes in the nature of the diet on the urinary magnesium excretion of sheep

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The increased incidence of hypomagnesaemic tetany in dairy cows soon after the onset of grazing in the spring has led to an investigation of the effect of abrupt dietary changes on the magnesium content of body fluids (Head & Rook, 1955; Rook & Balch, 1958). In the experiments reported by Rook & Balch (1958) a change from typical winter rations to cut spring herbage produced an immediate fall in the urinary Mg excretion of dairy cows which was interpreted as evidence of a reduced intestinal absorption due to the lower content and availability of Mg in the spring herbage. These experiments did not reveal how much the reduced intake of Mg contributed to the decrease in the urinary Mg excreted.

The experiments described below were designed to investigate in more detail the influence of changes in diet on the urinary excretion of Mg. They showed that a change from hay or grass nuts to spring herbage can also produce a depression in the urinary Mg excretion of wethers even when it involves an increase in the intake of Mg, indicating that factors associated with the nature of the diets are primarily responsible for this phenomenon. A change of diet in the reverse direction was also studied and was found to have the opposite effect, which was again independent of the change in Mg intake. Calcium metabolism was also studied but the results showed no consistent trends and are therefore not presented here.

EXPERIMENTAL

Animals. Adult wethers of various ages, weights and breeds were used as experimental animals. Sheep A–D were 4-year-old North Country Cheviots, E was a 4-year-old Greyface, F a 4-year-old Suffolk and G and H were 3-year-old Blackfaces. Their weights ranged from 55 kg for the Blackfaces to 70 kg for the Suffolk. Before the beginning of the experiments all sheep were accustomed to being harnessed and crated.

Diets. Since a high incidence of hypomagnesaemic tetany in dairy cows has been associated with the grazing of fertilized leys in the spring, this type of herbage was used in these experiments. One sample (S_4) was collected from a pasture on which the disease had occurred in lactating beef cows and ewes 2 days previously, and the other

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three were from ungrazed pastures. Samples were collected during May and June 1956 and April 1957. The methods of cutting, sampling and storage were those used in a previous experiment (Field, McCallum & Butler, 1958). Details of the chemical and botanical composition, the fertilizer treatment and the age of the sward are given in Table 1.

Table 1. *Details of the diet of the sheep*

Diet	Month and year of collection	Type of sward	Fertilizer treatment*	Dominant species†	Dry matter (%)	Mg in dry matter (%)
S_1	June 1956	2nd-year ley	C	P.R.G., C., W.W.C.	20·4	0·162
S_2	May 1957	1st-year ley	C	P.R.G.	14·2	0·274
S_3	May 1957	2nd-year ley	S.A., K	P.R.G., C., W.W.C.	17·7	0·171
S_4	June 1957	1st-year ley	P	I.R.G., P.R.G., C., B.R.C.	16·0	0·108

* P, potato manure (10 % N, 10 % P_2O_5, 15 % K_2O); C, compound (8 % N, 9·5 % P_2O_5, 13 % K_2O); S.A., sulphate of ammonia; K, potassium superphosphate (15·5 % P_2O_5, 10 % K_2O).

† I.R.G., Italian rye-grass; P.R.G., perennial rye-grass; C., cocksfoot; B.R.C., broad red clover; W.W.C., wild white clover.

The hay and grass nuts used were bought from a local merchant and their origin is unknown. The protein content (13 %) and digestibility coefficient (about 45 %) of the two samples of grass nuts suggest, however, that they were not made from spring herbage. Sufficient chopped hay or grass nuts for an experiment was mixed and sampled for chemical analysis, and the requisite amounts, either 1 or $1\frac{1}{4}$ lb, were weighed out into polythene bags.

Design of experiments. Each experiment comprised two or three successive periods of varying duration (9–18 days) during which the intake and urinary excretion of Mg were measured. No attempt was made to measure the faecal excretion since after a change of diet there is a delay of 5 or 6 days before the faeces are representative of the new diet. Table 2 gives details of each experiment in terms of the sheep used, the nature and Mg content of the diet in each feeding period and the length of the period. Since in Expt 1 the change in diet from grass nuts (GN_1) to spring herbage (S_1) involved a reduction in Mg intake of 0·5 g/day, it was arranged that in Expt 2 the dietary change from hay (H_1) to spring herbage (S_2) involved an increase in Mg intake of 0·66 g/day. Expt 3 was a repetition of Expt 2 with different sheep and diets and in addition was designed to investigate the reverse change in diet. Expt 4 represented an unsuccessful attempt to produce hypomagnesaemia in two wethers by an abrupt change from hay (H_1) to a spring herbage (S_4) collected from a pasture on which hypomagnesaemic tetany had occurred 2 days previously in lactating beef cows and ewes, and which had a very low Mg content supplying only 0·94 g/day. After S_4 had been given for 18 days, the diet was changed back to the original hay. The differences between the figures given in Table 2 for the Mg intake when the same hay was given are due to variation between bales and to sampling and analytical errors. A ration similar in nature to the one used in the first period was given to each sheep for at least a month before the beginning of an experiment to allow time for the animal's metabolism to become adapted to the diet.

The contents of one food bag were given at 10 a.m. and of the other at 4 p.m. and were eaten completely. Distilled water was always available in plastic containers during the experiments. On the day before the ration was changed to spring herbage, each sheep was passively immunized against pulpy-kidney disease.

Daily quantitative collections of urine were made for the last 6 days of the first period and were continued to the end of each experiment. The methods of collection, sampling, storage and Mg estimation were those previously used (Field *et al.* 1958).

At intervals throughout the experiments blood samples were taken from the jugular vein for the estimation of serum Mg levels by the method of Hawk, Oser & Summerson (1947).

Table 2. *Design of experiments*

		Feeding period								
		1			2			3		
Expt no.	Sheep used	Length of period (days)	Diet*	Mg intake (g/day)	Length of period (days)	Diet*	Mg intake (g/day)	Length of period (days)	Diet*	Mg intake (g/day)
1	A, B	9	GN_1	2·28	9	S_1	1·78	—	—	—
2	A, C	9	H_1	1·46	9	S_2	2·12	—	—	—
3	E, F, G, H	9	GN_2	1·10	9	S_3	1·65	9	GN_2	1·10
4	A, D	9	H_1	1·30	18	S_4	0·94	9	H_1	1·30

* GN, grass nuts; H, hay; S, spring herbage.

RESULTS

Clinical condition of the sheep. No clinical abnormalities were observed in the sheep at any time during the experiments.

Serum Mg levels. Throughout the experiments the concentration of Mg in the serum remained within the generally accepted normal range (2–4 mg/100 ml), although herbage (S_4) from a field on which tetany occurred was given to sheep A and D for 18 days. Further, none of the dietary changes studied produced any marked change in the serum Mg level within this normal range. For these reasons the values obtained are not recorded here.

Urinary Mg excretion. In the first experiment, the change in diet from grass nuts (GN_1) to spring herbage (S_1) was followed immediately by a fall in urinary Mg excretion with minimal values occurring on the 1st day in sheep A and on the 2nd day in sheep B. Thereafter Mg excretion of both sheep rose; that of sheep A was still rising, though less rapidly, at the end of the observation period of 9 days, but that of sheep B reached a constant value on the 4th day after the dietary change (Fig. 1). These rises which occurred when the Mg intake remained constant suggested that the reduction in intake associated with the dietary change was not the sole cause of the initial fall in urinary excretion.

The dietary change from hay (H_1) to spring herbage (S_2) in Expt 2 was followed immediately by a fall in the urinary Mg excretion of both sheep; minimal values occurred on the 2nd day after the change for sheep A and on the 1st day for sheep C

(Fig. 2). Thereafter the excretion of sheep A rose until the 5th day when it reached a constant value, which was similar to that when diet H_1 was given. Thus, by the end of the observational period, the urinary Mg excretion had not reflected the increased Mg intake. With sheep C, the initial fall was followed by a marked increase to values much higher than those obtained with diet H_1, but thereafter the excretion again fell sharply.

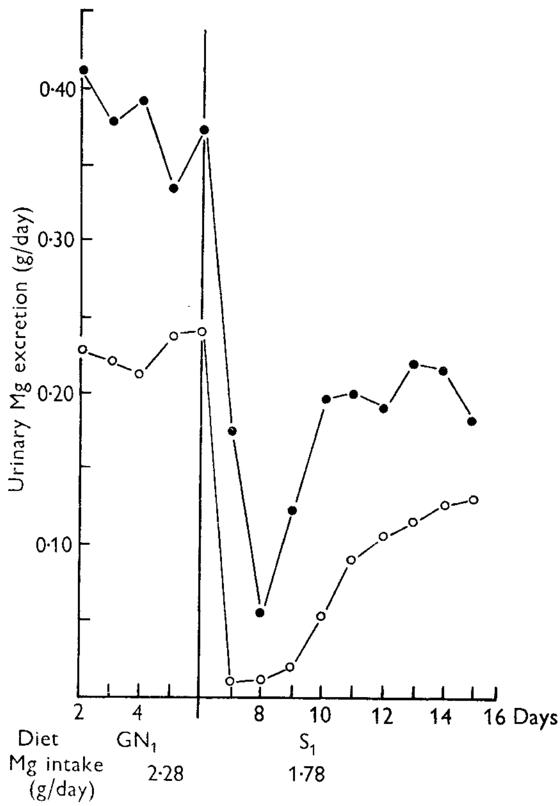

Fig. 1. Effect of a dietary change from grass nuts (GN_1) to spring herbage (S_1) on the urinary magnesium excretion of two sheep. o, sheep A; ●, sheep B.

After the dietary change from grass nuts (GN_2) to herbage (S_3) in Expt 3, three of the four sheep used, F, G and H, showed a similar picture to that obtained with sheep A in Expt 2, namely an initial fall in urinary Mg excretion followed by an increase to values similar to those obtained when the previous diet containing less Mg was given (Fig. 3). The other sheep (E) showed no initial fall and the excretion increased to higher values than those obtained during the first period. The reverse change of diet from S_3 to GN_2 produced an initial increase in excretion in all sheep despite the fall in Mg intake. Thereafter the excretion fell to values similar to those obtained previously when diet GN_2 was given.

After the change to S_4 in Expt 4 the urinary Mg excretion at first fell sharply and then remained relatively constant at a low level until the diet was changed back to H_1, when a marked increase followed by a rapid fall to very low values (6 and 13 mg/day for sheep A and D, respectively) occurred (Fig. 4). The maximum values during this third period, 120 and 144 mg/day for sheep A and D, respectively, were higher than those obtained in the first period on this diet and occurred for sheep A on the 3rd day and for sheep D on the 2nd day after the diet had been changed. This result was similar to that obtained in Expt 3, but the peak in the excretion curve was more exaggerated, possibly owing to the longer feeding of spring herbage and to the increase in Mg intake associated with this dietary change.

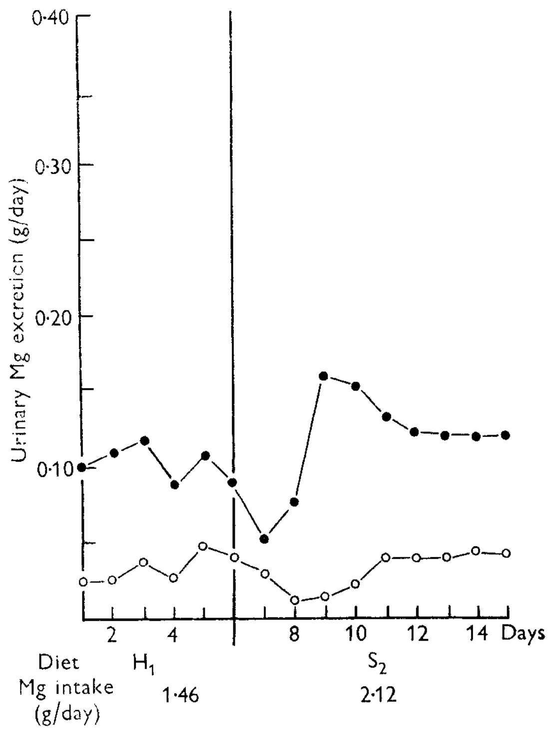

Fig. 2. Effect of a dietary change from hay (H_1) to spring herbage (S_2) on the urinary magnesium excretion of two sheep. ○, sheep A; ●, sheep C.

Volume of urine. The time course of changes in the mean volume of urine excreted by all the sheep whose diet was changed from hay or grass nuts to spring herbage is plotted in Fig. 5. The pattern was similar for all sheep, except that the largest volume was voided on the 2nd day after the diet had been changed by some sheep and on the 3rd day by the remainder. At these times the values for urinary Mg excretion were at their lowest. There were no gross differences in urine volume from sheep to sheep on the same experiment.

DISCUSSION

Rook & Balch (1958) investigated the effect on the urinary Mg excretion of dairy cows of a change from typical winter rations to spring herbage which was cut daily from the same pasture at two stages of growth and provided much less Mg than the winter rations. After the change to the less mature herbage, they found an immediate fall in urinary Mg and interpreted it as evidence of reduced intestinal absorption due to the lower content and availability of the Mg in the herbage. With the more mature spring herbage they observed a rise in urinary Mg after an initial fall and tentatively attributed it to increased Mg intake consequent upon a higher dry-matter consumption after the first 2 days. However, the results of my investigation show clearly that a change in diet from hay or grass nuts to spring herbage can produce a marked fall in the

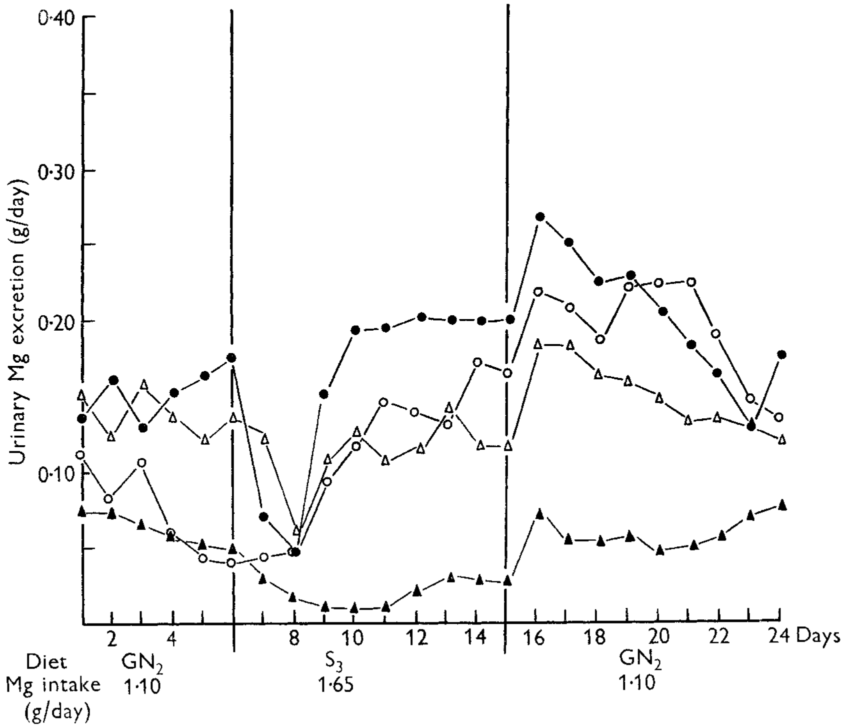

Fig. 3. Effect of dietary changes from grass nuts (GN_2) to spring herbage (S_3) and back to grass nuts (GN_2) on the urinary magnesium excretion of four sheep. ○, sheep E; ●, sheep F; △, sheep G; ▲, sheep H.

urinary Mg excretion of sheep even when the change in diet involves an increase in Mg intake, and that the fall is followed by a progressive increase in urinary Mg even though the intake remains constant. The complexity of the changes in Mg metabolism associated with a change in the nature of the diet is further illustrated by the fact that the reverse dietary change to the original hay or grass nuts produced the opposite effect on the urinary Mg, namely, an immediate increase followed by a fall. The increase occurred when the dietary change involved a decreased Mg intake and the highest urinary value was greater than those found when the hay or grass nuts were given originally. These effects were thus largely independent of the change in the Mg intake and it is conceivable that both types of effect are mediated by similar factors associated with the nature of the diets.

Since the Mg absorbed in excess of the body's requirements is excreted by the kidney, changes in urinary Mg excretion may be secondary to changes in intestinal absorption, or to changes in excretion by routes other than the kidney. They may also result from impaired renal function due to a changed rate of glomerular filtration or tubular reabsorption.

Thus it is possible that the depression in urinary Mg excretion produced by a dietary change from dry feed to spring herbage was caused by a temporary but severe inhibition

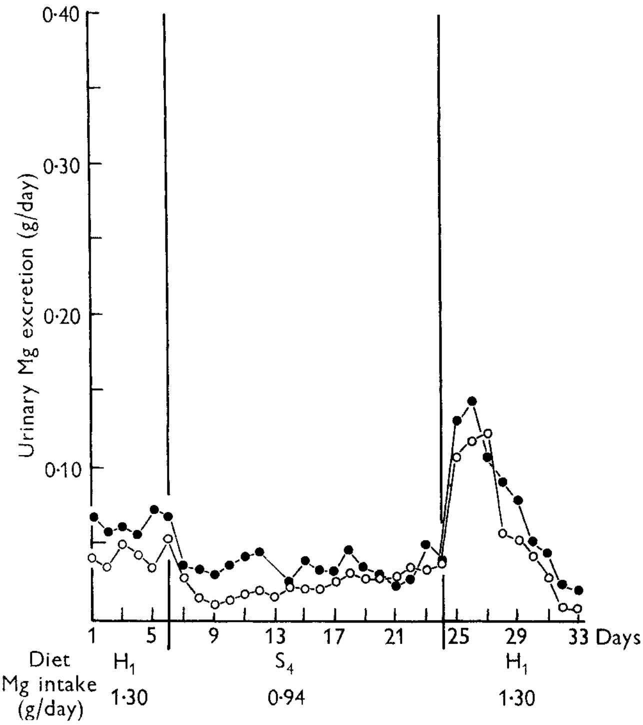

Fig. 4. Effect of dietary changes from hay (H_1) to spring herbage (S_4) and back to hay (H_1) on the urinary magnesium excretion of two sheep. ○, sheep A; ●, sheep D.

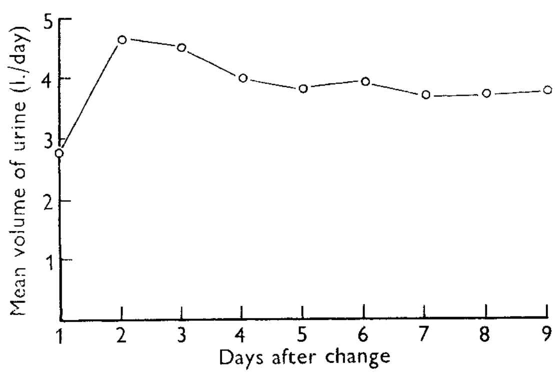

Fig. 5. The time course of changes in the mean volume of urine excreted by all sheep whose diet was changed from hay or grass nuts to spring herbage.

of Mg absorption. Similarly, the increase in urinary Mg excretion that occurred when the diet was changed from spring herbage to hay could be interpreted as an indication of a temporary enhancement of absorption.

Although we are a long way from understanding these phenomena, they are not isolated ones, since Annison, Lewis & Lindsay (1959*a*, *b*) have described a wide range of metabolic disturbances occurring in the period immediately after a dietary change. These findings also emphasize the need to make the change-over from winter rations to spring herbage on the farm as gradual as possible.

There are other possible theoretical explanations of the changes in urinary Mg excretion associated with changes in diet. The most obvious is that changes in the endogenous faecal excretion occur and that they influence the urinary excretion. These changes could arise from altered reabsorption of the Mg secreted into the gut, or to increased secretion possibly due to changes in the acid–base balance (Annison *et al.* 1959*b*).

A feature of the results is the individual variation in the effect of dietary changes in the urinary Mg excretion. It was demonstrated clearly in the second experiment, in which the urinary Mg excretion of sheep A was still depressed at the end of the period of observation, whereas for sheep C the depression only lasted for 2 days. Further, in the third experiment, one of the four sheep failed to show a fall in urinary Mg excretion after the dietary change. Thus any explanation of the changes in Mg metabolism associated with dietary change must also explain why certain animals are relatively unaffected.

SUMMARY

1. A study was made of the effect of dietary changes involving hay, grass nuts and spring herbage on the urinary magnesium excretion and the concentration of Mg in the serum of adult wethers of various breeds. The samples of spring herbage were obtained from fertilized leys, on one of which hypomagnesaemic tetany in cows and ewes had recently occurred.

2. No dietary change produced any marked alteration in the serum Mg levels and the values remained within the normal range, even when the tetany herbage was given for 18 days.

3. An immediate fall in urinary Mg excretion usually occurred after a dietary change from hay or grass nuts to spring herbage, even when the change led to increased Mg intake. Lowest values, which occurred within 1–2 days of the dietary change, were followed by an increase although the Mg intake remained constant. In some instances the excretion at the end of the period of observation reflected the difference in the Mg content of the two rations.

4. The reverse dietary change produced the opposite effect on urinary Mg, namely an immediate increase followed by a fall. The increase occurred when the dietary change led to a decreased intake, and maximal values were observed within 1–3 days of the change.

5. The volume of urine excreted was highest 2 or 3 days after the diet had been changed from hay or grass nuts to spring herbage.

6. It is not known whether these changes in urinary Mg excretion are caused by changes in absorption or in endogenous faecal Mg excretion.

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