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# STUDIES ON THE MOVEMENT OF Mg, Ca, P, Na and K ACROSS THE GUT WALL OF SHEEP FED FRESH PASTURE

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## SUMMARY

Sheep fitted with rumen cannula and re-entrant cannulae in the proximal duodenum and terminal ileum were fed fresh 'Grasslands Ruanui' perennial ryegrass and 'Grasslands 4700' white clover to study the movement of Mg, Ca, P, Na and K across the gut wall.

A net secretion of Na and P into and a net absorption of K, Mg and Ca from the stomach region was observed in all sheep. A net secretion of Na, P and K occurred from the small intestine, while a small but variable net secretion of Ca and Mg was found in the small intestine. A net absorption of Mg, Ca, P, K and Na occurred in the large intestine.

Differences were observed between the perennial fed and white clover fed sheep in the rates of net absorption or net secretion of Mg, Ca, P, K and Na from comparable regions of the digestive tract.

THE established requirements for Mg, Ca, P, K and Na can be used only as guidelines in determining the nutritional adequacy of a diet for ruminants as many factors can influence the utilization and availability of these minerals, particularly Mg, Ca and P, from the digestive tract. For example, hypomagnesaemia occurs in cattle grazing pastures where levels of magnesium are adequate to meet requirements according to chemical analysis.

Studies on the movement of Mg, Ca, P, K and Na throughout the digestive tract of sheep fed various diets have been carried out (Pfeffer *et al.*, 1970; Grace and MacRae, 1972) to obtain a greater insight on the influence that diets and dietary constituents may have on the direction and sites of the movement of minerals and possibly their utilization and availability.

As part of a comprehensive study on quantitative aspects of digestion in the sheep being carried out at Applied Biochemistry Division, Palmerston North, the sites and direction of net movements of Mg, Ca, P, K and Na were investigated in sheep fed fresh pasture.

## METHODS

## HERBAGE

Two pasture species, 'Grasslands Ruanui' perennial ryegrass (R) and 'Grasslands 4700' white clover (C) were compared. Details and management of these pastures have been reported (Ulyatt and MacRae, 1971). Four experiments were carried out from the spring of 1969 to the autumn of 1971. The herbage fed was cut in the vegetative state at about a height of 12 cm.

## SHEEP

The Romney wether sheep, 1 to 2 years old, weighing 38 to 40 kg, which were used to study the flow of minerals along the digestive tract, were equipped with a rumen cannula and re-entrant cannulae at the proximal duodenum and terminal ileum (Brown *et al.*, 1968). The animals used for the concurrent digestibility and balance studies were fitted rumen cannula only.

## MANAGEMENT OF SHEEP

All sheep were placed in metabolism crates equipped to collect the faeces and urine as well as digesta from the duodenal and ileal cannulae. The sheep were fed, at 09.00 hr and 16.30 hr, fresh cut pasture and given free access to water. The pasture was cut at 08.00 hr each day, and subsampled for a rapid dry matter (DM) determination (Ulyatt and MacRae, 1971) so that the quantity of fresh herbage could be estimated to give the required DM intake for each sheep. The DM intakes ranged from 500 to 1000 g daily. A second subsample was taken to determine the true DM. At 09.00 hr half the daily ration was fed; the remaining portion was stored in a cool room and fed in the afternoon. Chromic oxide was used as a marker; 1.163 g of Cr in the form of a Cr<sub>2</sub>O<sub>3</sub> impregnated paper pellet (3 g) was administered via the rumen cannula at each feed. The sheep were fed each diet for 3 weeks before any samples were collected.

## COLLECTION AND PREPARATION OF SAMPLES

The collection of the 24 hr samples of digesta from the proximal duodenal and terminal ileal cannulae was the same as that described by MacRae and Armstrong (1969). The observed flows were then corrected to mean 24 hr flows based on 100% recovery of administered Cr<sub>2</sub>O<sub>3</sub> (MacRae and Armstrong, 1969; Grace and MacRae, 1972).

These samples together with the feed and faeces collected during a 7-day balance trial were frozen, dried and ground for analysis.

### ANALYSES

The analyses for Mg, Ca, P, K and Na were carried out on the suitably diluted HCl extracts of the samples after ashing at 500°C for 8 hours. The Mg and Ca were determined by atomic absorption spectroscopy, Na and K by flame photometry and the P colorimetrically.

### CALCULATION OF RESULTS

All data were analysed by regression analyses. The daily mineral intake was the independent variable ( $x$ ) while the corrected mean 24 hr flow (Grace and MacRae, 1972) (g/24 hr) of the mineral past the proximal duodenum and terminal ileum, and that excreted in the faeces was the dependent variable ( $y$ ) (Snedecor, 1956). An example using P is shown in Fig. 1 and each regression line is fitted by a highly significant ( $P < 0.01$ ) or in some cases a significant ( $P < 0.05$ ) regression equation.

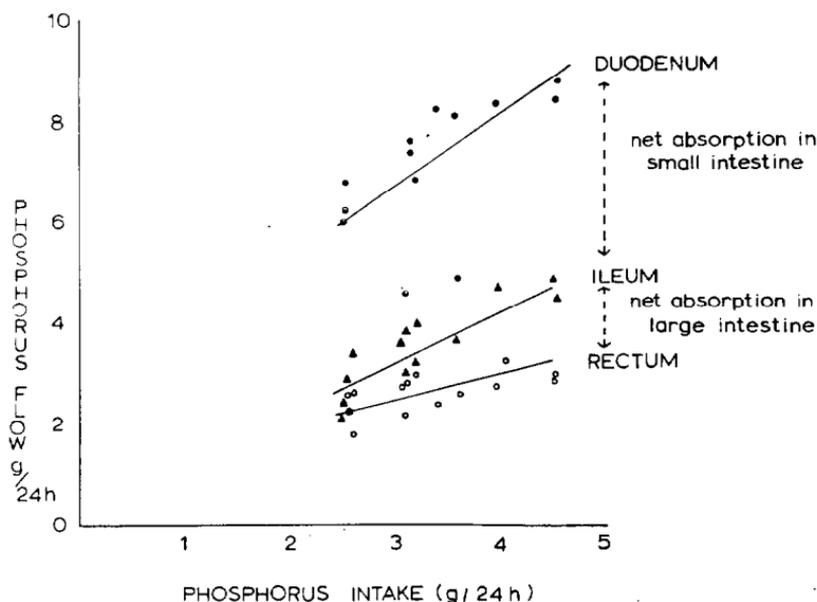


FIG. 1: Relationships between the phosphorus intake and the flow of phosphorus past the duodenum, ileum and rectum in sheep fed white clover.

A net absorption of a mineral from a region occurs if the quantities (g/24 hr) of the mineral entering that region exceeds the quantities (g/24 hr) leaving. The net absorption values obtained (g/24 hr) are therefore the algebraic sum of the movements, in both directions, of the mineral across the gut wall of the region. A net secretion occurs in the reverse situation.

In this paper, comparisons between the quantities of Mg, Ca, P, K and Na absorbed or secreted from the digestive tract of sheep fed Ruanui ryegrass or white clover were at daily intakes of 2.0 g, 7.5 g, 3.0 g, 33.0 g and 2.0 g for Mg, Ca, P, K and Na, respectively.

## RESULTS AND DISCUSSION

### HERBAGE COMPOSITION

The mineral composition of the Ruanui ryegrass and white clover fed sheep are shown in Table 1. The white clover contained a higher level of Ca and K than the Ruanui while the Mg, P and Na were similar for both species.

TABLE 1: MINERAL COMPOSITION OF RUANUI RYEGRASS AND WHITE CLOVER

		Mg	Ca	% D.M. P	K	Na
Ruanui ryegrass	....	0.22	0.79	0.45	3.1	0.25
White clover	....	0.25	1.55	0.44	4.9	0.29

### FLOWS OF MINERALS

The flows of Mg, Ca, P, K and Na along the digestive tract of sheep fed Ruanui ryegrass and white clover are shown in Table 2. These were determined from mineral concentration in the DM of the digesta and the corrected DM flows past the proximal duodenum and terminal ileum and the daily DM excreted in the faeces. For the same daily mineral intake the flow (g/24 hr) of Mg, Ca, P, Na and K past the duodenum and flow of Ca, P, K and Na past the ileum were significantly higher in the grass fed sheep compared with the clover fed sheep. The excretion of Mg, Ca, P, K and Na in the faeces was similar for all sheep. Similarly there was little difference, when comparing diets, in the apparent availabilities of Mg, Ca, P, K and Na. The apparent availabilities (average of both diets) were 29, 19, 18, 92 and 98 for Mg, Ca, P, K and Na, respectively.

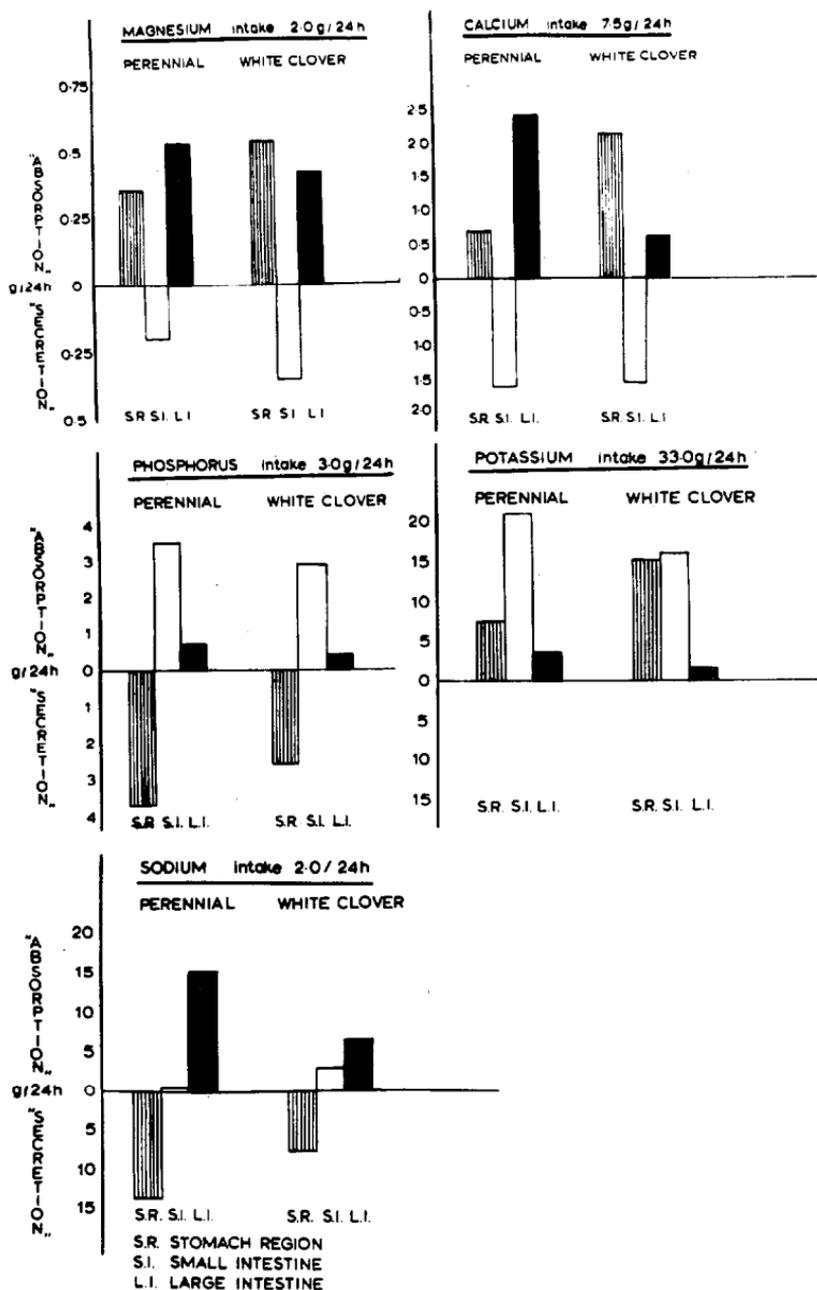


FIG. 2: Sites of net absorption and net secretion of Mg, Ca, P, K and Na from the digestive tract of sheep fed Ruanui ryegrass and white clover.

TABLE 2: DAILY QUANTITIES OF MINERALS IN THE DIET ENTERING AND LEAVING THE SMALL INTESTINE AND IN THE FAECES OF SHEEP FED RUANUI RYEGRASS AND WHITE CLOVER (Duodenal and ileal mineral flows have been corrected to 100% recovery of administered  $\text{Cr}_2\text{O}_3$ )

	<i>R</i> <sup>1</sup>	<i>C</i> <sup>2</sup>	<i>R</i>	<i>C</i>	<i>R</i>	<i>C</i>
	<i>Magnesium</i>		<i>Calcium</i>		<i>Phosphorus</i>	
In diet ....	2.00	2.00	7.50	7.50	3.0	3.0
At duodenum ....	1.53 ± 0.03	1.35 ± 0.06*	6.76 ± 0.25	5.33 ± 0.59*	6.7 ± 0.24	5.6 ± 0.31*
At ileum ....	1.83 ± 0.08	1.70 ± 0.10	8.36 ± 0.36	6.99 ± 0.44*	3.2 ± 0.11	2.7 ± 0.09*
In faeces ....	1.31 ± 0.03	1.37 ± 0.05	5.95 ± 0.12	6.23 ± 0.54	2.5 ± 0.03	2.4 ± 0.11
Apparent availability %	31	28	21	17	17	20
	<i>R</i>	<i>C</i>	<i>R</i>	<i>C</i>		
	<i>Sodium</i>		<i>Potassium</i>			
In diet ....	2.0	2.0	33.0	33.0		
At duodenum ....	15.5 ± 1.74	9.5 ± 0.37**	25.7 ± 0.88	17.8 ± 1.60**		
At ileum ....	15.3 ± 1.60	6.8 ± 0.52**	4.4 ± 0.17	1.8 ± 0.20**		
In faeces ....	0.1 ± 0.02	0.2 ± 0.03	1.0 ± 0.5	0.3 ± 0.2		
Apparent availability %	95	90	97	99		

<sup>1</sup> Ruanui ryegrass.

<sup>2</sup> White clover.

Significance \* ( $P < 0.05$ ); \*\* ( $P < 0.01$ ).

## SITES OF NET ABSORPTION AND NET SECRETION OF MINERALS

The data in Table 2 clearly show that the differences between the quantities of mineral ingested and that excreted in the faeces give no indication of the quantities of these minerals leaving the stomach region and entering the small intestine or the quantities leaving the small intestine and entering the large intestine.

However, the differences in the quantities of a mineral entering and leaving a region of the digestive tract are reflected by the extent of the observed net absorption or net secretion of the mineral which occurs from or into that region. The extent of the net absorption or net secretion of Mg, Ca, P, K and Na from the stomach region, small intestine and large intestine is shown in Fig. 2.

In all sheep a net absorption of Mg and Ca was observed from the stomach region and large intestine while a small net secretion occurred in the small intestine. The diet influenced the relative importance of the stomach region and large intestine as sites of net absorption of Mg and especially Ca. In the grass fed animals the net absorption of Mg and Ca from the large intestine was greater when compared with the stomach region while the reverse situation applied for the clover fed sheep, that is, the net absorption of Ca and Mg was greater from the stomach region.

Earlier studies concluded that the small intestine was the major site of absorption for Ca and Mg with little or no net absorption of these minerals occurring from the stomach region and large intestine. However, the findings of this study, that the stomach region and large intestine can be important as sites of absorption for Ca and Mg, confirm the observations of Pfeffer *et al.* (1970) and D. G. Armstrong (pers. comm.). These workers have observed a net absorption of Mg from the stomach region and large intestine and a net absorption of Ca from the large intestine as well as a small net absorption of Ca from the stomach region of sheep fed fresh grass.

The movement of P across the gut wall was similar for all sheep. A net secretion into the stomach region and a net absorption from the intestinal region, particularly the small intestine, occurred in all animals. Also, in the grass fed sheep, the net secretion of P into the stomach region and the subsequent net absorption from the small intestine were significantly greater compared with the clover fed sheep.

In agreement with Pfeffer *et al.* (1970) a net secretion of Na into the stomach region occurred while the major

site of net absorption for Na was the large intestine. As with P, the diet also influenced the movement of Na across the wall of the gut. There was a two-fold increase in the net secretion of Na into the stomach region and in the net absorption of Na from the large intestine in the grass fed sheep compared with the clover fed sheep. Further, since the total net absorption of Na from the digestive tract was 1.9 g and 1.8 g for the grass fed and clover fed sheep, respectively, it appears that the increase in net secretion of Na in the stomach region was compensated for by an increase in a net absorption of Na from the large intestine in the grass fed sheep. The reasons for the greater cycling of P and Na, particularly the latter, in the grass fed compared with the clover fed sheep are not known. Whether a possible increase in the salivary secretions and hence P and Na into the rumen of the grass fed sheep could account for the increase in the observed net secretion of P and Na remains to be determined.

A net absorption of K was observed from all regions of the digestive tract in all sheep. In the clover fed sheep similar quantities of K appeared to be absorbed from the stomach region and small intestine while in the grass fed sheep the net absorption of K from the small intestine was about 3 times that which occurred from the stomach region.

Finally, the dynamic nature and the dietary influence on the movement of Mg, Ca, P, K and Na across the wall of the gut of the sheep has been demonstrated in this study. Further, since the stomach region and large intestine as well as the small intestine are important sites for the net absorption of some minerals, the entire digestive tract should be considered in detailed studies on the absorption and availability of Mg, Ca, P, K and Na from the diet.

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