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THE INFLUENCE OF MAGNESIUM SULPHATE ON THE ABSORPTION, EXCRETION AND RETENTION OF CALCIUM AND PHOSPHORUS BY SHEEP FED ON PHOSPHATE SUPPLEMENTED RATIONS

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Abstract

S. J. MYBURGH & J. DE V. DU TOIT. The influence of magnesium sulphate on the absorption, excretion and retention of calcium and phosphorus by sheep fed on phosphate supplemented rations. *Onderstepoort J. vet. Res.* 37 (1), 1–6 (1970).

Evidence is put forward showing that continuous excessive intakes of magnesium sulphate by sheep, for example in drinking water, may result in losses of calcium from the body. However, when the intakes of both these minerals are greater than requirements the depressive effect on calcium may be overcome.

Since there is a close relationship between calcium and phosphorus metabolism any factor having a depressive effect on calcium may eventually affect phosphorus utilization.

Introduction

It is known that a sheep weighing 31.8 kg requires a minimum daily intake of 1.02 g phosphorus. However, studies by Du Toit, Louw & Malan (1940) and Louw & Reinach (1953) on the mineral content of natural pastures in South Africa showed that a widespread seasonal phosphorus deficiency occurs. During winter the daily intake of phosphorus may be only 0.5 g, though it may rise to 1.3 g in summer. Protein, and sometimes sodium, deficiencies also occur in these pastures but adequate amounts of other essential minerals, including calcium, are present.

In order to overcome this phosphorus deficiency it has become general practice in these areas to feed phosphatic supplements, preferably continuously (Du Toit, Malan, Van der Merwe & Louw, 1940; Beeson, Johnson, Bolin & Hickman, 1944; Bisschop, 1964).

Theiler (1932) noted that the value of such supplements depends on the intake of appropriate quantities of other essential nutrients. Earlier Palmer, Eckles & Schutte (1928) studied the part played by magnesium sulphate in the mineral deficiency problem. It is well-known that there is an antagonism between magnesium and calcium and, furthermore, that there is a close relationship between calcium and phosphorus metabolism. These workers found that intakes of magnesium sulphate at the concentrations sometimes found in natural water supplies may be detrimental to young cattle, since they cause continuous and serious losses of calcium from the body when at the same time the phosphorus content of the rations is low.

In some of our pastoral areas of the north-west Cape Province borehole water, which is usually the only drinking water available for stock, frequently contains exceptionally high concentrations of magnesium sulphate, *ca.* 4000 ppm (unpublished data). In view of the findings of Palmer *et al.*, (1928) it might be anticipated that excessive intakes of magnesium sulphate in such water could counteract the advantages of supplementary feeding with phosphates and, in addition, have a deleterious effect on calcium metabolism. Since no reference was made to this problem by Du Toit, Louw & Malan (1940) the present study was undertaken.

Materials and Methods

Twenty-five 2-tooth Merino wethers weighing approximately 25 to 30 kg were divided into five groups and fed as follows:

Group 1: Basal ration only.
Group 2: Basal ration + dicalcium phosphate (2.8 g).
Group 3: Basal ration + dicalcium phosphate (2.8 g) + calcium carbonate (5.0 g).
Group 4: Basal ration + dicalcium phosphate (2.8 g) + calcium carbonate (5.0 g) + magnesium sulphate (10.0 g).
Group 5: Basal ration + dicalcium phosphate (2.8 g) + magnesium sulphate (10.0 g).

The basal ration is the conventional one used in many of our studies on mineral metabolism in sheep (Reinach, Louw & Groenewald, 1952). It is essentially phosphorus deficient, and low in calcium, but contains adequate amounts of carbohydrate and protein. The daily ration per animal included 400 g veld hay, 300 g ground maize (samp), 50 g blood meal, 3 g sodium chloride, and 100 g fresh green oats. The hay, which may be regarded as a substitute for natural winter-type grazing, was low in phosphorus, carbohydrate and protein. The maize and blood meal supplied the necessary elements for body maintenance and moderate growth respectively. Of the mineral supplements, the dicalcium phosphate ($CaHPO_4$) ensured an adequate daily intake of phosphorus plus some calcium. The calcium carbonate ($CaCO_3$) provided excess calcium in Groups 3 and 4, while the magnesium sulphate ($MgSO_4.7H_2O$) supplied excess magnesium in Groups 4 and 5.

The chemical composition of the individual rations is shown in Table 1.

TABLE 1 *Chemical composition of feeds**

Feed	Protein	P	Ca	Mg	Crude Fibre
	Experiment 1				
Grass hay	4.3	0.085	0.32	0.26	36.4
Maize (Samp)	8.4	0.04	0.02	0.12	0.2
Blood meal	83.6	0.19	0.12	0.05	—
Green oats	4.8	0.06	0.04	0.09	7.08
Supplements:					
$CaHPO_4$	—	18.5	24.5	—	—
$CaCO_3$	—	—	40.0	—	—
$MgSO_4.7H_2O$	—	—	—	10.0	—
	Experiment 2				
Grass hay	4.6	0.09	0.30	0.25	36.0
Maize (Samp)	8.6	0.05	0.02	0.12	0.2
Blood meal	83.6	0.20	0.12	0.05	—
Green oats	4.8	0.06	0.05	0.10	7.10
Supplements:					
$CaHPO_4$	—	18.8	24.5	—	—
$CaCO_3$	—	—	40.0	—	—
$MgSO_4.7H_2O$	—	—	—	10.0	—

*Percentage dry weight

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The experimental animals, which were kept separately in sheltered pens, were handfed at the same time each morning and supplied with fresh water. They were exercised in an adjacent camp with a cement floor. Records of their weight were kept and they were bled fortnightly for analyses of the phosphorus, calcium and magnesium contents of their blood.

The 9-month study period was divided into two consecutive stages, the first lasting 2 months (Experiment 1) and the second 7 months (Experiment 2). A metabolism balance trial was carried out during the final month of each stage, i.e. during the second and ninth months of the study period.

Results

Details of the experimental metabolism data are shown in Tables 2 and 3. They give the total protein intake, together with the intake and output (in faeces and urine) and balances (reflecting positive or negative utilization) for phosphorus, calcium and magnesium.

Table 2 *Metabolism data*

Exp. 1	Sheep No.	Protein Intake (Nx6.25)	P Intake	P Output	P Balance	Ca Intake	Ca Output	Ca Balance	Mg Intake	Mg Output	Mg Balance
		g	g	g	g	g	g	g	g	g	g
Group 1 .	1	80.5	0.53	0.65	—0.12	1.10	1.14	—0.04	1.16	0.71	+0.46
	2	84.8	0.61	0.67	—0.06	1.42	1.21	+0.21	1.42	0.74	+0.68
	3	85.2	0.62	0.70	—0.08	1.44	1.39	+0.07	1.45	0.97	+0.48
	4	80.3	0.52	0.52	0	1.07	1.05	+0.02	1.15	0.73	+0.42
	5	81.8	0.55	0.75	—0.20	1.19	1.09	+0.10	1.24	0.72	+0.52
Group 2 .	6	84.3	1.12	0.86	+0.26	2.07	1.88	+0.19	1.40	1.11	+0.29
	7	82.3	1.08	1.05	+0.03	1.91	1.85	+0.06	1.27	1.04	+0.23
	8	81.4	1.06	0.91	+0.15	1.85	1.57	+0.28	1.22	0.75	+0.47
	10	82.3	1.08	1.04	+0.04	1.92	1.81	+0.11	1.28	0.92	+0.36
Group 3 .	11	85.2	1.14	1.14	0	4.13	3.83	+0.30	1.44	1.16	+0.28
	12	85.2	1.14	1.05	+0.09	4.13	4.07	+0.06	1.44	1.12	+0.32
	13	85.2	1.14	0.86	+0.28	4.13	3.76	+0.37	1.44	1.32	+0.12
	14	85.2	1.14	0.90	+0.24	4.13	3.37	+0.40	1.44	1.29	+0.15
	15	85.2	1.14	0.95	+0.19	4.13	3.70	+0.43	1.44	1.32	+0.12
Group 4 .	16	85.2	1.14	0.98	+0.16	4.13	3.81	+0.52	2.44	1.56	+0.88
	17	85.2	1.14	0.75	+0.39	4.13	3.89	+0.24	2.44	1.60	+0.84
	18	85.2	1.14	0.99	+0.15	4.13	3.85	+0.28	2.44	1.71	+0.73
	19	85.2	1.14	0.71	+0.43	4.13	3.68	+0.45	2.44	1.61	+0.83
	20	85.2	1.14	0.75	+0.39	4.13	3.40	+0.73	2.44	1.55	+0.89
Group 5 .	21	85.2	1.20	0.84	+0.36	2.13	1.90	+0.23	2.44	1.83	+0.61
	22	85.2	1.20	0.73	+0.47	2.13	1.91	+0.22	2.44	2.04	+0.40
	23	85.2	1.20	0.84	+0.36	2.13	2.06	+0.07	2.44	1.67	+0.77
	24	85.2	1.20	0.93	+0.27	2.13	1.97	+0.16	2.44	1.60	+0.84
	25	85.2	1.20	0.99	+0.21	2.13	2.04	+0.09	2.44	1.97	+0.47

Table 3 *Metabolism data*

Exp. 2	Sheep No.	Protein Intake (Nx6.25)	P Intake	P Output	P Balance	Ca Intake	Ca Output	Ca Balance	Mg Intake	Mg Output	Mg Balance
		g	g	g	g	g	g	g	g	g	g
Group 1 .	1	81.3	0.56	0.64	—0.08	1.00	0.96	+0.04	1.10	0.59	+0.51
	2	86.6	0.67	0.76	—0.09	1.37	1.23	+0.14	1.41	0.70	+0.71
	3	84.3	0.64	0.73	—0.09	1.26	1.18	+0.08	1.32	0.93	+0.39
	4	83.1	0.61	0.66	—0.05	1.19	1.19	0	1.24	0.86	+0.38
	5	84.8	0.63	0.71	—0.08	1.22	1.22	+0.03	1.29	0.65	+0.64
Group 2 .	6	87	1.196	1.05	+0.15	2.05	1.89	+0.16	1.44	0.73	+0.71
	7	87	1.196	0.90	+0.29	2.05	1.88	+0.17	1.44	0.58	+0.86
	8	87	1.196	1.11	+0.08	2.05	1.83	+0.22	1.44	0.79	+0.65
	9	87	1.196	1.07	+0.13	2.05	1.51	+0.54	1.44	0.82	+0.62
	10	87	1.196	1.14	+0.06	2.05	1.65	+0.40	1.44	0.83	+0.61
Group 3 .	11	87	1.196	1.13	+0.07	4.06	3.40	+0.66	1.44	1.21	+0.23
	12	87	1.196	1.12	+0.08	4.06	3.82	+0.14	1.44	1.13	+0.31
	13	87	1.196	1.14	+0.06	4.06	3.58	+0.48	1.44	1.08	+0.36
	14	87	1.196	1.13	+0.07	4.06	3.38	+0.68	1.44	1.07	+0.37
	15	87	1.196	1.13	+0.07	4.06	3.81	+0.25	1.44	1.02	+0.42
Group 4 .	16	87	1.196	1.11	+0.09	4.06	3.49	+0.57	2.44	1.36	+1.08
	17	87	1.196	1.11	+0.09	4.06	3.51	+0.55	2.44	1.78	+0.66
	18	87	1.196	1.04	+0.16	4.06	3.99	+0.07	2.44	1.66	+0.78
	19	87	1.196	1.17	+0.03	4.06	3.82	+0.24	2.44	1.50	+0.94
	20	87	1.196	1.11	+0.09	4.06	3.99	+0.07	2.44	1.40	+1.04
Group 5 .	21	87	1.196	1.14	+0.06	2.05	2.11	—0.06	2.44	1.35	+1.09
	22	87	1.196	1.20	0	2.05	2.30	—0.25	2.44	1.53	+0.91
	23	87	1.196	1.13	+0.07	2.05	2.11	—0.06	2.44	1.54	+0.90
	24	87	1.196	1.12	+0.08	2.05	2.06	—0.01	2.44	1.57	+0.87
	25	87	1.196	1.11	+0.09	2.05	2.13	—0.08	2.44	1.65	+0.79

The total effect of the excessive intake of magnesium sulphate is shown in Table 4. The average retention of minerals and their relation to the average blood mineral content is given.

The absorbed mineral content is the difference between the intake of minerals and their output in the faeces. It is expressed as the percentage mineral utilization of the absorbed mineral and is shown in Table 5.

The extent to which the various minerals are excreted, in either the faeces or urine, is shown in Table 6. The mineral excretion is expressed as a percentage of the total excretion.

The average body weight gains of the sheep during the experimental period are shown in Table 7. These gains showed that the carbohydrate and protein contents of the rations were adequate for growth.

TABLE 4 *The effect of Mg on the blood inorganic P, Ca and Mg in relation to P, Ca and Mg balances*

Exp. 1	10-Day Balances			*Average Blood content mg/100 ml*			Exp. 2	10-Day balances			*Average blood centent mg/100 ml*		
	P	Ca	Mg	P	Ca	Mg		P	Ca	Mg	P	Ca	Mg
Group 1	g —0.09	g +0.07	g +0.51	3.46	8.92	3.14	*Group 1*	g —0.08	g +0.06	g +0.52	2.6	9.1	3.0
Group 2	+0.12	+0.16	+0.34	5.60	8.84	3.28	*Group 2*	+0.14	+0.30	+0.69	5.8	9.0	3.3
Group 3	+0.16	+0.31	+0.20	5.82	9.58	3.20	*Group 3*	+0.07	+0.44	+0.34	5.8	9.3	3.2
Group 4	+0.30	+0.44	+0.83	5.92	8.74	3.34	*Group 4*	+0.09	+0.29	+0.90	5.9	9.0	3.4
Group 5	+0.33	+0.16	+0.62	5.92	9.08	3.42	*Group 5*	+0.06	—0.09	+0.91	5.9	9.0	3.4

TABLE 5 *Comparison of absorption and retention of P, Ca and Mg*

Exp. 1	Intake	Apparent absorption (Intake - faecal)	Retention	% Utilization of absorbed mineral	Exp. 2	Intake	Apparent absorption (Intake - faecal)	Retention	% Utilization of absorbed mineral
Group 1 . . .	g P 0.57 Ca 1.25 Mg 1.28	g 0 0.44 0.74	0 0.07 0.51	Deficient 16 68	Group 1 . . .	g P 0.62 Ca 1.21 Mg 1.27	g 0 0.14 0.86	0 0.06 0.52	Deficient 43 61
Group 2 . . .	P 1.09 Ca 1.94 Mg 1.29	0.14 0.34 0.50	0.12 0.16 0.34	86 47 68	Group 2 . . .	P 1.196 Ca 2.05 Mg 1.44	0.16 0.35 0.92	0.14 0.30 0.69	87.6 86 75
Group 3 . . .	P 1.14 Ca 4.13 Mg 1.44	0.19 0.45 0.48	0.16 0.31 0.20	84 69 42	Group 3 . . .	P 1.196 Ca 4.06 Mg 1.44	0.08 0.54 0.58	0.07 0.44 0.34	87.4 83 58.8
Group 4 . . .	P 1.14 Ca 4.13 Mg 2.44	0.34 0.69 1.12	0.30 0.44 0.83	88 64 74	Group 4 . . .	P 1.196 Ca 4.06 Mg 2.44	0.092 0.32 1.03	0.092 0.29 0.90	100 90.6 87.4
Group 5 . . .	P 1.20 Ca 2.13 Mg 2.44	0.36 0.33 0.84	0.33 0.16 0.62	92 49 74	Group 5 . . .	P 1.196 Ca 2.05 Mg 2.44	0.06 0 1.05	0.06 0 0.91	100 Deficient 86.6

TABLE 6 *Comparison of excretion of P, Ca and Mg (Averaged)*

Exp. 1	Total excretion	% of Total excretion		Exp. 2	Total excretion	% of Total excretion	
		Faecal	Urinary			Faecal	Urinary
Group 1	g P 0.658 Ca 1.172 Mg 0.78	96.0 69.2 69.7	4.0 30.8 30.3	Group 1	g 0.696 1.149 0.744	99.1 93.1 54.8	0.9 6.9 45.2
Group 2	P 0.965 Ca 1.78 Mg 0.96	95.7 89.9 82.2	4.3 10.1 17.8	Group 2	1.056 1.754 0.75	98.8 96.8 70.5	1.2 3.2 29.5
Group 3	P 0.978 Ca 3.82 Mg 1.246	97.5 96.5 76.9	2.5 3.5 23.1	Group 3	1.133 3.598 1.10	98.7 97.8 78.0	1.3 2.2 22.0
Group 4	P 0.833 Ca 3.68 Mg 1.607	95.3 93.4 82.1	4.7 6.6 17.9	Group 4	1.108 3.76 1.64	99.7 99.1 91.6	0.3 0.9 8.4
Group 5	P 0.866 Ca 1.976 Mg 1.821	97.6 91.4 87.5	2.4 8.6 12.5	Group 5	1.140 2.141 1.627	99.6 98.7 91.0	0.4 1.3 9.0

TABLE 7 *Body-weight gains*

Group	Ration	Initial weights (mean)	Final weights (mean)	Weight gains (mean)
		kg	kg	kg
1	Basal	28.8	34.6	+ 5.8
2	Basal + $CaHPO_4$	25.5	36.8	+11.3
3	Basal + $CaHPO_4$ + $CaCO_3$	29.5	40.0	+10.5
4	Basal + $CaHPO_4$ + $CaCO_3$ + $MgSO_4$	29.0	39.2	+10.2
5	Basal + $CaHPO_4$ + $MgSO_4$	30.9	41.3	+10.4

DISCUSSION

The metabolism data can conveniently be discussed under the following headings: (1) phosphorus utilization; (2) calcium utilization, and (3) magnesium utilization.

(1) *Phosphorus utilization*

As expected, the basal ration (Group 1) was deficient in phosphorus and was therefore in negative balance. The analysis of the blood for inorganic phosphorus confirmed this deficiency.

However, the addition of 2.8 g dicalcium phosphate to the basal ration effectively kept the animals in Group 2 in positive balance throughout the experiment. Furthermore, the average inorganic phosphorus values of the blood were normal.

The addition of even more calcium to the above ration (Group 3) produced no change in the early stages but subsequently the phosphorus utilization was slightly depressed. However, this depression was not reflected in the blood analyses and the average inorganic phosphorus values were normal.

The addition of magnesium sulphate to the ration which was particularly high in calcium and adequate for phosphorus (Group 4) somewhat improved phosphorus utilization during the earlier stages of growth but, as in Group 3, it had a depressive effect in the final stages. Again, the average inorganic phosphorus values of the blood were normal throughout.

When excess magnesium sulphate alone was given in the phosphate-supplemented ration (Group 5) the phosphorus utilization was unaffected initially but showed some depression later. Again, the average inorganic phosphorus levels of the blood were normal.

Thus the feeding of excess calcium and/or magnesium apparently had little effect on phosphorus utilization under our experimental conditions.

(2) *Calcium utilization*

The intake of 1.25 and 1.2 g calcium in the basal ration during the two experimental stages respectively gave marginally positive calcium balances. These findings are in accordance with those of Mitchell & McClure (1937), who stated that a sheep weighing 31.8 kg requires 1.14 g calcium daily.

The addition of dicalcium phosphate at the 1.94 and 2.05 g calcium levels respectively (Group 2) produced positive balances, and the blood calcium levels were normal.

The excess calcium in the phosphate-supplemented ration (Group 3) increased the retention of this mineral. The blood calcium levels were normal.

The effect of magnesium sulphate plus excess calcium in the phosphate supplemented ration in Experiments 1 and 2 (Group 4) was an initial positive balance which became somewhat reduced in the final stages. The average calcium levels of the blood were normal.

The addition of magnesium sulphate alone to the phosphate supplemented ration in Experiments 1 and 2 (Group 5) resulted in a lower, though still positive, balance initially but this balance definitely became negative at the end of the experiment. Nevertheless the blood calcium values were, on the average, normal.

To sum up, the additional magnesium sulphate in the ration of Experiment 2 (Group 5) apparently does result in some lowering of calcium utilization when the intake of the latter is in excess of normal daily requirements, i.e. 2.05 g calcium. It only seems to take effect later. The ability of the blood system to maintain normal calcium values in the face of a negative balance is remarkable.

Marginally positive or negative balances do not necessarily reflect the true position. However, there is a suggestion of a negative calcium balance due to an excess of magnesium sulphate if the trial balances of Experiment 2 (Groups 3 and 5) are compared. Furthermore the calcium utilization, expressed as absorbed calcium, for these two groups shows a decided drop initially and an even greater drop in the final month (Table 5).

(3) *Magnesium utilization*

When the magnesium intake was in excess of requirements it was effectively used by Groups 4 and 5 to maintain positive magnesium retention levels. The blood magnesium levels were normal. However, excess calcium, at the 4.13 and 4.06 g intake levels, apparently decreases magnesium retention. This is clearly indicated by the utilization of 42 and 58.8 per cent.

The well-known antagonism between calcium and magnesium with adequate phosphorus intakes is reflected in Groups 3 and 5. There is therefore some evidence that an intake of 10 g magnesium sulphate a day, or the equivalent of 1000 mg magnesium per litre in drinking water, has a detrimental effect on calcium retention.

The degree of calcium loss in sheep is apparently not as serious as it is in young cattle (Palmer, Eckles & Schutte, 1928). Nevertheless continuous losses probably are important in young sheep as well when high levels of magnesium sulphate are ingested.

In these trials the magnesium sulphate did not have any obviously serious effect on phosphorus utilization.

SUMMARY

Evidence is given supporting the view that, when magnesium sulphate is ingested continuously, sheep may suffer calcium losses from the body, reflected by negative calcium balances. Although the amount of calcium lost, as shown by metabolism data, may not be serious the percentage utilization of absorbed calcium is substantially reduced.

However, when both magnesium and calcium intakes are greater than requirements, the depressive effect on calcium may be overcome. In many cases in which the drinking water contains large amounts of magnesium sulphate the calcium levels are also high enough to ensure that losses from the body will not occur. This may not be the case, though, when the magnesium is

far in excess of the calcium. We found that a negative calcium balance occurred when the ration of magnesium to calcium was 1.19 to 1.

The metabolism data suggest that magnesium sulphate at a rate of 1000 mg magnesium per litre of drinking water will not have any marked effect on phosphorus utilization.

In both calcium and phosphorus retentions the margins are small and even slight changes could have resulted in changes of the balance of these minerals. Since there is a close relationship between calcium and phosphorus metabolism, anything having a depressive effect on calcium would also affect phosphorus utilization in the long run.

Blood levels of phosphorus, calcium and magnesium remained normal throughout.

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