

4135

### Magnesium Sulfate as a Factor in Retention of Calcium and Phosphorus in Cattle.\*

L. S. PALMER, C. H. ECKLES AND D. J. SCHUTTE.†  
(With the technical assistance of W. M. Neal and T. W. Gullickson.)

*From the Divisions of Agricultural Biochemistry and Dairy Husbandry,  
University of Minnesota, St. Paul.*

We<sup>1</sup> reported in connection with a study of a P deficiency in the rations of cattle in parts of Minnesota that the drinking water in the affected regions contains an unusually large amount of magnesium sulfate. This was suspected of being a factor in the mineral deficiency problem because of the well-known antagonism between Mg and Ca, and indirectly because of the close relationship between Ca and P in metabolism. It was shown that aphosphorosis could be produced experimentally in dairy cattle during liberal feeding of prairie hay and oats grown in the affected regions. The diseased condition could be both prevented and allayed by a P supplement in the form of  $\text{Ca}_3(\text{PO}_4)_2$ , bonemeal or  $\text{NaH}_2\text{PO}_4$ ; under the latter conditions the feeding of Epsom salt in large (85 gm.) daily doses for an entire year seemed to exert no ill effect. Haag and Palmer,<sup>2</sup> using rats, found that a high Mg diet hindered Ca retention when both Ca and P were low, but that this result was less frequent if either Ca or P were high, and was not apparent when both Ca and P were high. The effects of high Mg on P retention were similar, but not so uniformly depressing when both Ca and P were low, as was the case with Ca retention. High Ca or P, or both, tended to counteract the effects of high Mg. Recently Kramer<sup>3</sup> and co-workers, and also Shipley and Holt<sup>4</sup> have shown that Mg in low concentration can inhibit *in vitro* calcification of rachitic bones. The former workers found that suitable increments of inorganic phosphates overcome the inhibitory action of Mg.

---

\* Published with the approval of the Director, as Paper No. 784, Journal Series, Minnesota Agricultural Experiment Station.

† The results here presented are taken from the thesis of Diederick Joh. Schutte for the degree of Master of Science, University of Minnesota, 1928.

<sup>1</sup> Eckles, C. H., Becker, R. B., and Palmer, L. S., *Minnesota Agricultural Experiment Station Bulletin* No. 229, 1926.

<sup>2</sup> Haag, J. R., and Palmer, L. S., *J. Biol. Chem.*, 1928, lxxvi, 367.

<sup>3</sup> Kramer, B., Shelling, B. A., and Orent, E. R., *Johns Hopkins Hosp. Bull.*, 1927, xli, 426.

<sup>4</sup> Shipley, P. G., and Holt, L. E., *Johns Hopkins Hosp. Bull.*, 1927, xli, 437.

It was evident that it had not yet been determined whether  $MgSO_4$  is a factor in cattle nutrition under the natural conditions of P deficiency prevailing in Minnesota. Further experimental evidence also seemed advisable with cattle relative to the apparent counter-acting effect of phosphates when fed with Mg salts.

The animals used comprised 2 mature cows, E-92 and E-74, which became dry shortly before their first balance period on the basal ration, and 2 heifers, Nos. 392 and 387. E-92 and 392 served as check animals, but the latter, which was pregnant, aborted after the first balance period, and E-92 was used as check animal for No. 387. The average inorganic P content per 100 cc. of blood plasma<sup>5</sup> of the 4 animals at the beginning of the experiment was as follows: E-92, 2.67 mg.; E-74, 3.59 mg.; No. 387, 4.75 mg.; No. 392, 4.05 mg. E-74 and No. 387 were selected for Mg feeding because their blood showed a higher inorganic phosphate content than the corresponding animal of the same age, indicating a superior state of P nutrition. It seemed desirable to give the Mg-fed animals this advantage rather than the check animals. The ration used for all trials was designed to furnish organic nutrients 10 to 20% in excess of the Morrison<sup>6</sup> standard for maintenance, with sufficient P and Ca to maintain an approximate metabolic balance. The ration consisted of prairie hay, grown in the phosphorus-deficient region of Minnesota, ground oats, gluten meal, and cane molasses in varying proportions to meet the individual requirements of the animals. The daily amount of Epsom salt fed amounted to 155-165 gm. This was based upon an average of 0.5%  $SO_4$  content of the well water in the affected regions, and upon an average daily water consumption of 45 lbs. per animal during the winter months. The Mg salt was fed mixed with the molasses, which was poured over the hay.

The feces and urine were collected together. Two adjoining metabolism stalls made possible the conduct of the balance experiments in pairs, in each case an experimental and the check animal. The construction of the stalls was patterned after similar equipment designed by members of the staff of the Pennsylvania Institute of Animal Nutrition.<sup>7</sup> The animals were confined in these stalls for several days before the collection of excreta began. The excreta were weighed and sampled daily, and samples stored in sealed jars

<sup>5</sup> Determined by the method of Briggs, *J. Biol. Chem.*, 1924, lix, 255, on 3 consecutive days, using jugular venous blood.

<sup>6</sup> Henry, W. A., and Morrison, F. B., "Feeds and Feeding," p. 746. 18th Edition, Unabridged. The Henry-Morrison Company, Madison, Wis., 1923.

<sup>7</sup> Fries, J. A., Braman, W. W., and Kriss, M., *J. Dairy Sci.*, 1924, vii, 12.



with chloroform as preservative. The daily aliquots were remixed and sampled at the end of the period.

Each portion of the feed for the entire balance trial was thoroughly mixed and sampled for analysis. Refused portions were also weighed and analyzed. The animals were fed 4 times daily and watered twice daily at regular intervals. Common salt was allowed in liberal amounts. No exercise was permitted during the balance trial but regular brushing was practiced to increase the comfort of the animals. The animals were tested for pica frequently by offering them bleached bones. Inorganic P and Ca of the blood plasma were determined on 3-day composites taken just before and just after each balance trial. Ca was estimated by a modification of the methods of Kramer and Howland,<sup>8</sup> and Kramer and Tisdall<sup>9</sup>; Mg by the method of Howland and Kramer.<sup>10</sup>

Experiment 1 consisted of 2 balance periods with each of the 2 mature cows, E-92 and E-74. Both animals had been on the basal ration for 30 days prior to the first balance period. E-74 received daily 165 gm. of Epsom salt for 35 days before and during Period 2. The results are shown in Table I.

Experiment 2 consisted of 4 balance periods with the experimental heifer No. 387, one balance period with the control heifer No. 392, and one period with the cow E-92. The first balance period was preceded by a 30-day feeding, the second by 42 days on the diets to be tested, the third by 21 days of preliminary feeding, and the fourth balance period immediately followed Period 3. The first period was a basal ration test for both animals. Period 2 was a  $MgSO_4$  period for heifer No. 387, preceded by 42 days of Epsom salt feeding, 156 gm. being fed daily. Period 3 was an identical trial run after a further interval of 21 days during which the Epsom salt was fed. In the fourth period, 100 gm. of  $NaH_2PO_4$ ,  $H_2O$  were fed daily, mixed with the grain in addition to the 156 gm. of Epsom salt. The control animal was omitted for Periods 3 and 4 in the experiment because cow E-92, which served as control, had already served in sufficient trials to establish her uniformity of metabolism. The results are shown in Table I.

The variations in the inorganic P and Ca of the blood plasma of the animals are shown in Table II. The data represent the average of the analyses made before and after each balance trial.

The data show conclusively that intakes of  $MgSO_4$ , comparable to that consumed by cattle in regions where they are forced to drink

<sup>8</sup> Kramer, B., and Howland, J., *J. Biol. Chem.*, 1926, lxxviii, 74.

<sup>9</sup> Kramer, B., and Tisdall, F. F., *J. Biol. Chem.*, 1921, xlvii, 475.

<sup>10</sup> Howland, J., and Kramer, B., *Am. J. Dis. Child.*, 1921, xxii, 105.

TABLE II.

The effect of Mg on blood Ca and P, in relation to the calcium and phosphorus balances.

Animal	Period	Ration	10-day balance		Inorganic Ca per 100 cc. plasma	Inorganic P per 100 cc. plasma
			P	Ca		
E-92	1	Basal	gm. +36.6	gm. +12.8	11.50	2.67
E-92	2	Basal	-5.1	+12.7	12.47	2.24
392	1	Basal	-13.8	+32.8	12.20	4.05
E-74	1	Basal	+19.5	-14.8	11.24	3.59
E-74	2	Basal+165 gm MgSO <sub>4</sub> , 7 H <sub>2</sub> O	-9.1	-93.4	11.66	2.35
387	1	Basal	-16.7	+75.7	12.36	4.75
387	2	Basal+156 gm. MgSO <sub>4</sub> , 7 H <sub>2</sub> O	-25.4	-95.6	10.70	4.35
387	3	Basal+156 gm. MgSO <sub>4</sub> , 7 H <sub>2</sub> O	-16.9	-59.2	10.70	4.66
387	4	Basal+156 gm. MgSO <sub>4</sub> , 7 H <sub>2</sub> O+ 100 gm. NaH <sub>2</sub> PO <sub>4</sub> , H <sub>2</sub> O	+102.1	-3.6	10.43	6.67

water containing this salt, may cause serious and continuous losses of Ca from the body tissues when the P content of the ration is low. The effect of Mg feeding on P balance is not striking, and in these experiments was evident as a detrimental factor only in the younger animal. The ability of the blood system to maintain a nearly constant level of inorganic Ca in the face of severe negative Ca balances is striking. In the case of the older animal receiving MgSO<sub>4</sub>, the negative Ca balance was accompanied by a decrease in inorganic blood P. Conclusive proof is offered in the data that inorganic P supplements completely overcome the detrimental effect of Mg feeding, both with respect to the effects on Ca and P balance and on blood P. The large relative storage of Mg in the body of cattle, shown in the data, raises very interesting questions regarding the site of storage of this element.

Some evidence which appears significant was secured with respect to the relation of Mg feeding to the incidence of pica. E-74 and No. 387 began showing evidence of pica soon after receiving Epsom salt in their ration, and the condition became progressively more pronounced as the Mg feeding continued. By the end of the third balance period, No. 387 had developed a severe pica. This decreased greatly within 5 days after the addition of phosphate to her ration and within 10 days she was entirely normal.