CONFERENCE ON HYPOMAGNESAEMIA
Proceedings of the British Veterinary Association
November 23rd and 24th, 1960 - Victoria Halls, London, W.C.1.

BASIC SOURCE OF MAGNESIUM METABOLISM

III. Intake and Utilization of Magnesium from Herbage by Lactating Cows

A. KEMP, W. B. DEIJS, O. J. HEMKES
A. J. H. VAN ES
Institute for Biological and Chemical Research on Field Crops and Herbage, Wageningen
Laboratory of Animal Physiology, Agricultural University, Wageningen

AS LONG AS 30 years ago Sjollema (1931) found in his investigations that a fall in the magnesium concentrations in blood-serum was always attendant on the incidence of hypomagnesaemic tetany in milking cows. According to these results clinical symptoms of hypomagnesaemic tetany occurred only when the serum magnesium levels fell below 1·0 mg./100 ml or lower.

By approaching the problem from this point of view hypomagnesaemic tetany does not occur when the serum magnesium levels remain within the normal range. Therefore, the magnesium concentration of the blood-serum is generally chosen as the starting point of experiments. This is now clearer because later experiments have shown that if, for instance, 2 cows of 1 herd are suffering from hypomagnesaemic tetany the serum magnesium concentrations of nearly all the other cows of the herd are low or very low. This means that in periods during which the frequency of hypomagnesaemic tetany is high, the number of animals with hypomagnesaemia is considerably higher. An investigation carried out on 23 farms in the Netherlands showed that the serum magnesium levels of 90 milking cows grazing the same pastures on which hypomagnesaemic tetany occurred the day before had been reduced in nearly every case and that these levels sometimes were very low. Of these 90 cows, only 1 had a level higher than 2·0 mg./100 ml, 38 cows showed levels between 1·1 mg./100 ml and 2·0 mg./100 ml while 51 cows, that is almost 60 per cent, had very severe hypomagnesaemia with serum magnesium levels lower than 1·1 mg./100 ml (Kemp, 1958).

Recently, results of grazing experiments with lactating cows in different countries have shown that fertilizer treatment of pasture may have a striking effect on the serum magnesium levels (Bartlett *et al*, 1954; Kemp, 1958; Smyth, Conway and Walsh, 1958 and Hvidsten *et al*, 1959). In all these experiments hypomagnesaemic tetany could be induced. These data indicate that dietary factors play an important part in the origin of hypomagnesaemia.

In literature no common opinion can be found as to the possible influence of the magnesium content of the ration on the incidence of hypomagnesaemia. It is commonly held that hypomagnesaemia occurs as well on pastures with high magnesium contents in the herbage as on pastures low in magnesium, although there have been only few systematic investigations in this field. That hypomagnesaemia is not wholly independent of the intake of magnesium is, however, clear. Firstly, several experiments have shown that an oral administration of magnesium considerably reduces the incidence of hypomagnesaemic tetany in cattle (see, for example, Allcroft, R, 1954 and Bartlett *et al*, 1954). Moreover, it has been possible to maintain the serum magnesium levels within the normal range by high applications of magnesium on pasture (Bartlett *et al*, 1954; Parr and Allcroft, 1957; Smyth *et al*, 1958).

In the light of these observations, some results of our grazing experiments and balance trials will be discussed.

GRAZING EXPERIMENTS

In 1956 and 1957 grazing experiments with milking cows were carried out on the 'Droevendaal' experimental farm at Wageningen (Kemp, 1958).

It was found that a heavy potash dressing of the experimental pastures is associated with lower serum magnesium levels in the cows both on plots with high and on plots with low nitrogen. Also lower serum magnesium concentrations were found on the plots which were heavily dressed with nitrogen as well on the plots with high potassium as on the plots with low potassium. The greatest differences in serum magnesium levels occurred between 2 groups of cows, 1 of which grazed on plots on which a light potassium and nitrogen dressing was given and the other on plots with high applications of potassium and nitrogen. Throughout the experimental grazing season the mean difference between these 2 groups of cows was 0·82 mg./100 ml and in spring and autumn even more than 1·20 mg./100 ml. Serum magnesium values of 0·2 mg./100 ml were found and 6 cows showed clinical symptoms of hypomagnesaemic tetany, 4 of them seriously.

In these experiments in both years samples of blood and herbage were taken once or twice a week throughout the grazing season. In this way it was possible to study the relation between the magnesium in herbage and the magnesium concentrations in blood-serum. A detailed paper dealing with the response of magnesium in blood-serum to alterations in the composition of herbage resulting from potash and nitrogen dressing on pasture has already been published (Kemp, 1960).

A statistical treatment of these data showed a highly significant positive correlation between the magnesium content of the herbage and the serum magnesium concentrations.

Fig. 1 shows that low and very low serum magnesium levels do not occur when the magnesium content of herbage is higher than about 0·20 per cent Mg. When magnesium in herbage, however, is lower than 0·20 per cent Mg very low as well as normal serum magnesium levels may occur. In these experiments the lowest magnesium contents of herbage have been found in early spring and late autumn and the highest values in summer. According to the findings of Dijkshoorn and 't Hart (1957), this seasonal effect is associated with the influence of temperature on the uptake of minerals in herbage. In this connection it is remarkable that the highest frequency of hypomagnesaemic tetany in our country occurs in spring and in autumn.

As in the Netherlands herbage magnesium is mostly lower than 0·20 per cent Mg in early spring and late autumn, it is important to find an explanation for the considerable variations in serum magnesium levels when herbage magnesium is lower than 0·20 per cent Mg (Fig. 1). A statistical treatment of the data of this figure showed that the variations in serum magnesium are associated with the potassium and nitrogen contents of herbage. There is a highly significant negative correlation between the potassium contents in herbage and the serum magnesium levels as well as between the crude protein in herbage and the serum magnesium values. Consequently, when the magnesium contents of the herbage are for example 0·15 per cent Mg either an increase in potassium or an increase of crude protein, or an increase of both potassium and crude protein in the herbage is correlated with a decrease in serum magnesium levels.

It does not seem likely that the variation in serum magnesium levels is to be explained by differences in milk yield between the cows, because in these experiments no correlation has been found between daily milk yield and the magnesium contents of blood-serum. Perhaps this variation might be explained by differences in the magnesium intake by the animals or by differences in utilization of the magnesium ingested.

In order to get more information about this we started by carrying out balance trials with lactating cows.

BALANCE TRIALS

In 1958 and 1959 8 balance trials have been carried out with lactating cows which were fed indoors on a winter ration in Exp. 1 and on freshly cut herbage in the other 7 experiments. In every trial there were 4 Friesian cows, consequently data on 32 cows are available in total. The major details of the experimental plan are given in table 1 and the main results of the experiments in table 2. Data on the experimental routine and on the analytical methods will be described elsewhere.

As to the accuracy of the determination of magnesium, from the magnesium contents in 2 separately treated samples of herbage and faeces we estimated the coefficients of variation of the figures of the magnesium

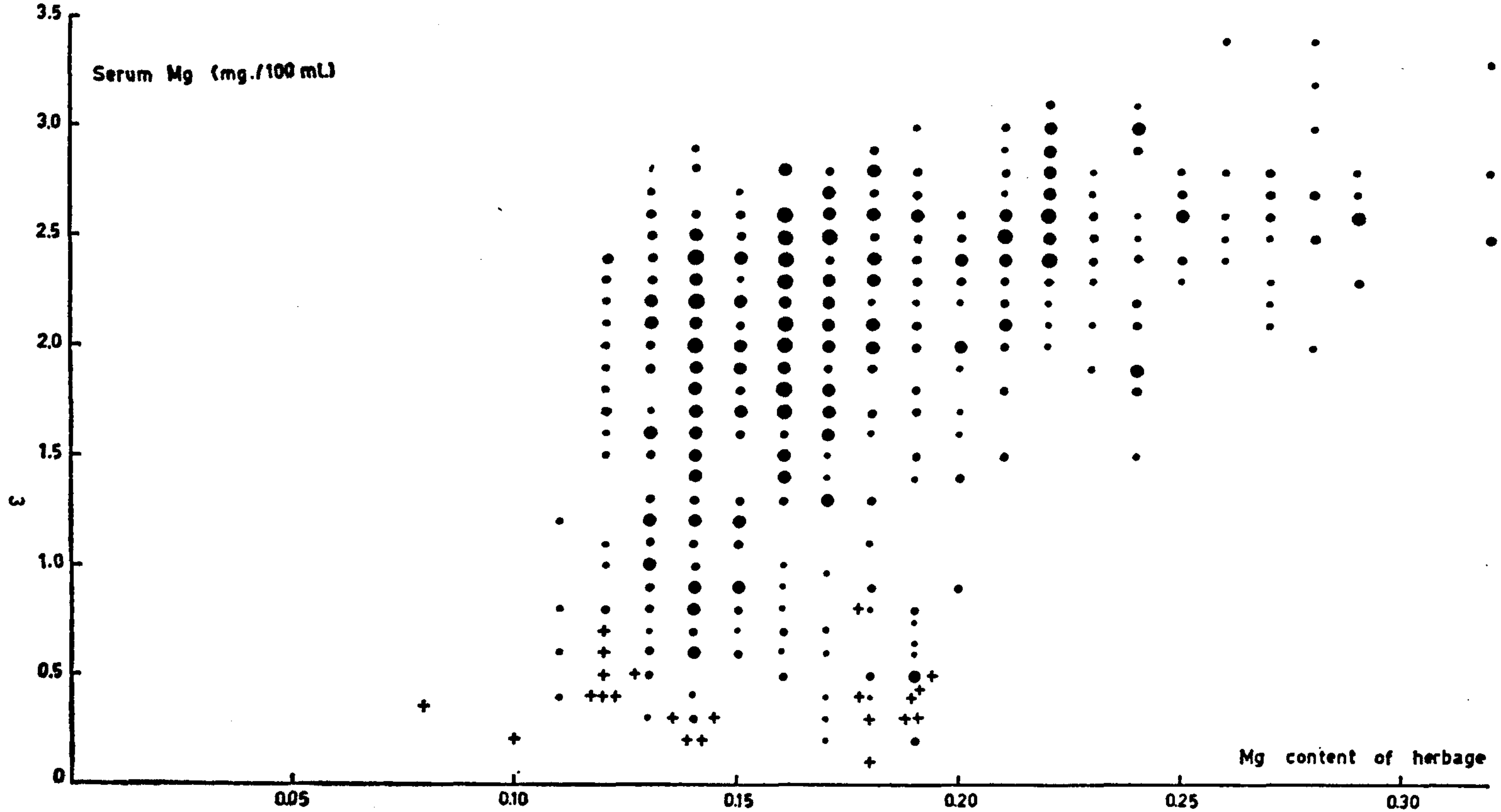

Fig. 1. Correlation between the magnesium content of herbage on a dry matter basis and the serum magnesium concentrations in 822 milking cows from which 23 showed clinical symptoms of hypomagnesaemic tetany.
+ = with clinical symptoms of hypomagnesaemic tetany.
.. •, and ●, = 1, 4, and 16, observations respectively.
SI

intake and the magnesium in faeces at about 2 per cent. Those of the figures of magnesium in milk or in urine were much lower. Therefore we assumed that the standard deviations of the figures for 'availability' and for retention were about 3 units and 1 gram Mg respectively.

In the present experiments not only the magnesium balances were established but also data on other constituents were collected. However, this first paper is mainly dealing with magnesium.

RESULTS

The results of the metabolism experiments carried out with the 8 groups of 4 lactating cows each are given in table 2. The values reported are daily means of the experimental periods.

With the 28 cows receiving only cut herbage, the intake of magnesium ranged from 10·3 g./day to 22·4 g./day, with the 4 cows receiving winter rations these values were 31·8 g./day to 34·1 g./day. A higher intake of magnesium in winter rations has been reported by Brouwer and Brandsma (1953) and by Rook (1958).

As to the magnesium contents in the herbage offered in our trials, these values ranged from 0·108 per cent to 0·210 per cent in the dry matter which are very normal concentrations in our country. The herbage fed in Exp. 2, 3, 4, and 6, shows the reducing influence of heavy potassium applications on pasture on the magnesium contents of herbage.

The greater part of the ingested magnesium is excreted in the faeces, namely, 83 per cent as the mean of all values within a range of 67 per cent to 93 per cent. Rook (1958) found in his metabolism experiments with herbage, a range of these values from 72·6 per cent to 94·7 per cent and mean values of 82·3, 83 and 82·4, in 3 experiments respectively. There is a striking conformity between these results. According to the results of Rook (1958) as well as our own data, there is a considerable variation in the proportions of the feed magnesium excreted in the faeces and, therefore, also in 'availability' which is the percentage of ingested magnesium not excreted in the faeces. In the 1 experiment with a winter ration this 'availability' was not found to be significantly higher than in rations consisting of freshly cut herbage. The mean 'availability' of magnesium in all the individual cows was 17 per cent within a range of 7 per cent to 26 per cent with 1 exception of 33 per cent. The proportion of the feed magnesium not excreted in faeces is not related with the amount of magnesium ingested.

Compared to the excretion of magnesium in faeces, the excretion of magnesium in urine is much lower. The excretion of magnesium in the urine was lower according to the magnesium concentration in the blood-serum being lower. Sjollema (1932) already reported very low levels of urinary magnesium in cattle at pasture which were suffering from hypomagnesaemic tetany. In our trials the mean excretion of magnesium in urine was 2·00 g./day within a range of 0·45 g./day to 4·24 g./day. There is one exception, namely the excretion of magnesium of cow 3 in Exp. 1. It is possible that this high value, *viz* 5·39 g.Mg/day, is due to the contamination of urine with faeces or an incorrect determination of magnesium.

The fluctuations in the excretion of magnesium in urine were mainly caused by variations in the concentration of magnesium in the urine. However, the urine production may also play a part. For instance, the daily urine production may become half as much again if the amount of feed potassium is increased considerably.

The amount of magnesium secreted in the milk, on the contrary, is mainly dependent on the daily quantity of milk produced because the concentrations of magnesium in the milk of individual cows were within a relatively small range. The daily secretion of magnesium for all 32 cows was 1·80 g./day on an average while the lowest and the highest values were 0·62 g./day and 2·59 g./day respectively. The lowest secretions of magnesium have been found in Exp. 7 and 8. The cows used in these experiments were at the

TABLE I
Details of the Experiments

Experiment	Cow nr.	Cow Name	Duration of the periods: Prel. period	Duration of the periods: Exp. period	Ration	% crude protein	% K	Intake of dry matter kg./day	Mean daily milk yield kg.
					Winter ration				
1 (1958)	1	Klaske 12	14 days	7 days	hay			14·16	18·44
	2	Rika 25	20. IV to 3. V	3. V to 10 V	silage			14·91	24·71
	3	Janke 113			fodder beets			15·79	17·85
	4	Joh. Wipkje			concentrates			15·38	18·48
					Herbage				
2 (1958)	1		—	10	(1)K	22	3·7	10·49	14·97
	2	the same		10. V to 20. V	k	22	2·2	12·30	20·68
	3	as in Exp. 1			k	22	2·2	12·54	16·97
	4				K	22	3·7	12·08	16·93
3 (1958)	1		—	8	k	20	2·0	10·85	14·83
Same pasture as	2	the same		20. V to 28. V	K	20	3·7	10·71	17·86
in Exp. 2	3	as in Exp. 1			K	20	3·7	12·19	16·45
	4				k	20	2·0	11·86	16·39
4 (1959)	1	Ijbeltje 14	2	6	K	17	2·6	12·13	17·55
	2	Dientje J.M.	22. IV to 24. IV	24. IV to 30. IV	k	17	1·8	10·90	14·44
	3	Uret. Joh. 19			k	17	1·8	11·90	17·66
	4	Johanna 4			K	17	2·6	9·30	12·81
5 (1959)	1		2	6		17	3·3	13·27	17·85
	2	the same	30. IV to 2. V	2. V to 8. V		17	3·3	11·73	14·55
	3	as in Exp. 4				17	3·3	12·77	18·79
	4					17	3·3	11·37	14·39
6 (1959)	1		2	6	k	22	2·0	12·81	15·81
Same pasture as	2	the same	8. V to 10. V	10. V to 16. V	K	22	3·2	11·22	14·32
in Exp. 4	3	as in Exp. 4			K	22	3·2	12·24	17·72
	4				k	22	2·0	10·23	15·15
7 (1959)	1	Klaske 12	7	10	(2)N	18	1·6	9·65	9·48
	2	Uret. Joh. 19	14. IX to 21. IX	21. IX to 1. X	n	12	1·7	10·10	11·03
	3	Janna 3			n	12	1·7	8·00	6·20
	4	Uret. Joh. 17			N	18	1·6	9·08	6·98
8 (1959)	1	Benedictus	7	10	(3)KCl	13	1·6	10·46	9·76
	2	Dientje J.M.	5. X to 12. X	12. X to 22. X	KCl	13	1·6	9·38	5·07
	3	Janke 113				13	1·6	9·31	6·83
	4	Ymkje 10				13	1·6	11·52	8·99

(1) K heavily dressed with potassium; k slightly dressed with potassium;
(2) N „ „ „ nitrogen; n „ „ „ nitrogen
(3) Cow 1 and 2, KCl, 400 g./day in the form of pellets.

latter half of their lactation and the daily milk yield was lower than the yield of the cows in the other experiments.

The body retentions of magnesium in the individual cows fluctuated from —1·4 g./day to +1·5 g./day with a mean of —0·41 g./day. The lowest retention was associated with the lowest magnesium intake and the lowest 'availability' of the magnesium ingested. In the 4 cases in which cows showed low serum magnesium levels the magnesium balances were negative, although all negative magnesium balances were not associated with hypomagnesaemia. The data suggest a positive correlation between the calcium and nitrogen retentions and the magnesium balances. This would be in agreement with the finding of Rook (1958).

TABLE II

THE INTAKE, THE EXCRETION IN THE FAECES AND URINE, THE SECRETION IN THE MILK AND THE RETENTION OF MAGNESIUM IN LACTATING COWS FED INDOORS ON WINTER RATIONS OR FRESHLY CUT HERBAGE

Experiment number	Animal	Magnesium intake g./day[1] A	Magnesium in dry matter %	Magnesium in faeces g./day B	Magnesium in urine g./day	Magnesium in milk g./day D	Total excretion g./day	Retention g./day	"Availability" of Mg (Percentage of ingested Mg not excreted in faeces)	"Available" Mg above the quantity secreted in milk g./day A-B-D	Mean serum magnesium values mg./100 ml.
Winter ration 1	1	31·81	0·212	25·83	3·14	1·88	30·85	0·96	19%	4·10	2·15
	2	32·78		26·77	2·22	2·59	31·58	1·20	18	3·42	2·45
	3	34·13		27·86	5·39	1·82	35·07	—0·94	18	4·45	2·20
	4	33·59		25·88	4·24	1·99	32·11	1·48	23	5·72	2·35
Herbage 2	1 K	14·30	0·135	12·68	0·85	1·80	15·33	—1·03	11	—0·18	1·05
	2 k	20·52	0·162	16·62	1·34	2·58	20·54	—0·02	19	1·32	2·20
	3 k	20·58	0·162	16·57	2·00	2·05	20·62	—0·04	19	1·96	2·60
	4 K	16·66	0·135	14·12	1·42	2·13	17·67	—1·01	15	0·41	2·20
3	1 k	17·70	0·164	15·49	0·45	1·83	17·77	—0·07	12	0·38	1·35
	2 K	15·03	0·139	12·90	1·19	2·18	16·27	—1·24	14	—0·05	0·60[2]
	3 K	16·90	0·139	13·80	1·57	2·14	17·51	—0·61	18	0·96	2·20
	4 k	19·57	0·164	15·15	2·10	2·27	19·52	0·05	23	2·15	2·10
4	1 K	13·33	0·108	11·55	1·01	2·13	14·69	—1·36	13	—0·35	2·35
	2 k	13·81	0·123	11·96	0·54	2·06	14·56	—0·75	13	—0·21	2·25
	3 k	14·99	0·123	11·86	2·00	2·21	16·07	—1·08	21	0·92	2·40
	4 K	10·33	0·108	8·79	0·64	2·04	11·47	—1·14	15	—0·50	2·00
5	1	18·06	0·136	16·63	0·52	2·12	19·27	—1·21	8	—0·69	1·80
	2	15·94	0·136	13·19	1·03	2·11	16·33	—0·39	17	0·64	2·75
	3	17·37	0·136	14·31	2·01	2·39	18·71	—1·34	18	0·67	2·65
	4	15·44	0·136	13·78	0·53	2·17	16·48	—1·04	11	—0·51	2·30
6	1 k	17·68	0·135	16·46	0·81	1·75	19·02	—1·34	7	—0·53	1·25
	2 K	13·83	0·122	11·15	1·73	2·04	14·92	—1·09	19	0·64	2·65
	3 K	15·10	0·122	10·05	3·34	2·21	15·60	—0·50	33	2·84	2·45
	4 k	14·13	0·135	11·35	1·59	2·20	15·14	—1·01	20	0·58	2·15
7	1 N	20·48	0·210	15·90	3·17	0·93	20·00	0·48	22	3·65	2·50
	2 n	19·21	0·188	14·31	3·59	1·09	18·99	0·22	26	3·81	2·50
	3 n	15·26	0·188	12·41	2·20	0·78	15·39	—0·13	19	2·07	2·40
	4 N	19·25	0·210	15·86	1·65	0·77	18·28	0·97	18	2·62	2·20
8	1 KCl	20·39	0·192	16·64	3·15	0·95	20·74	—0·35	18	2·80	2·10
	2 KCl	18·34	0·192	15·80	2·26	0·62	18·68	—0·34	14	1·92	2·60
	3	18·12	0·192	14·35	3·12	0·87	18·34	—0·22	21	2·90	2·40
	4	22·43	0·191	18·73	3·04	0·96	22·73	—0·30	16	2·74	2·10

[1] inclusive of magnesium in drinking water.
[2] with slight clinical symptoms.

The serum magnesium levels of the experimental cows are mainly within the normal range, however there are some exceptions. Low serum magnesium levels have been found in cow 1 in Exp. 2 and 3 (herbage) while the serum magnesium concentrations remained within the normal range in Exp. 1 (winter ration). Cow 2 in Exp. 3 showed low serum magnesium values and slight symptoms of hypomagnesaemic tetany (herbage rich in potassium); however, this cow showed normal serum magnesium values in Exp. 1 and 2 in which winter ration and herbage low in potassium was given respectively. The serum magnesium concentrations in cow 1 were low during Exp. 6.

According to the aforementioned there is a wide variation in urinary excretion of magnesium and especially transitions to another ration may change these values a good deal. The lowest amounts of magnesium excreted in the urine are associated with lower serum magnesium levels.

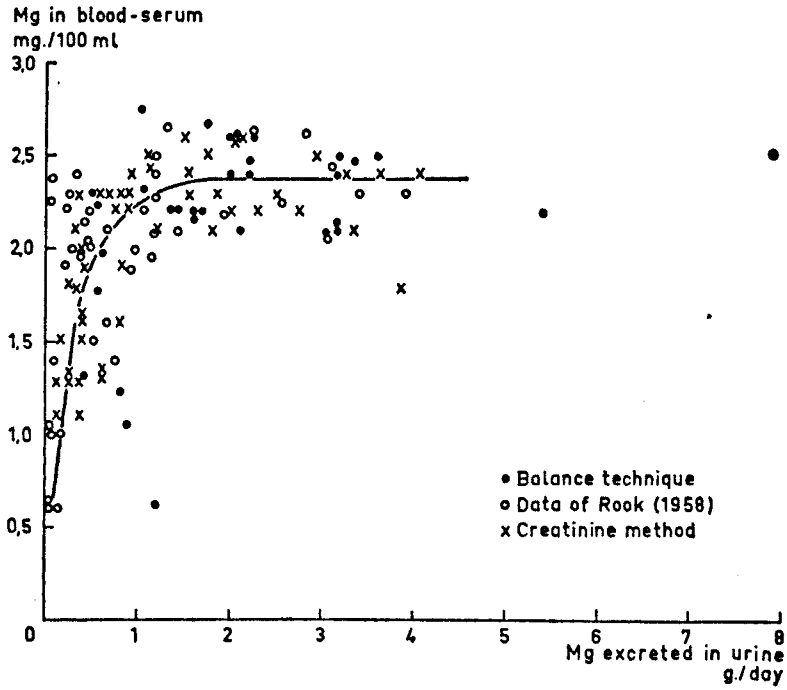

FIG. 2. Correlation between the daily amount of magnesium excreted in urine and the magnesium concentration in blood-serum.

Fig. 2 shows this relationship very clearly. This figure has been composed with data of 3 sources. Firstly, we used the data on the metabolism experiments reported in table 2 and, secondly, the data of Rook (1958). Data were also obtained from an experiment in which samples of blood and urine have been collected from a number of lactating cows of the 'Droevendaal' experimental farm at Wageningen.

One week before the cows were put to a pasture heavily dressed with liquid manure, a sample of blood and urine was taken from each cow; samples were also collected from the same cows a week after this date. These samples were analysed for magnesium. Also, in those of the urine the concentration of creatinine was determined. Since the daily amount of creatinine excreted in urine is fairly constant the daily excretion of magnesium could be computed approximately by means of the concentration of magnesium in the urine.

Firstly, it is notable that the data of the different experiments are about localised within the same range; accordingly, there are no significant differences between these 3 groups of data. Low serum magnesium levels occur only when the excretion of magnesium in urine is below 1 g./day. In this respect it must be considered that a slight contamination of the urine with faeces containing per kg. about 10 times as much magnesium as urine may play a part in some of the values of magnesium in urine. For instance, the lowest serum magnesium level in this figure, 0·6 mg./100 ml, is associated with an unreliably high magnesium excretion in the urine in consequence of heavy contamination with faeces. Some of the other values may also be slightly too high, therefore the rate of 1 g./day mentioned above may be lower. With excretions of magnesium in the urine higher than 1 g./day all serum magnesium levels are within the normal range.

DISCUSSION

That part of the magnesium ingested which enters the blood may be used for maintenance, for production of milk, and for retention.

The retention of magnesium, however, appears to be limited, high retentions do not occur, but high excretions in urine do. Obviously, any 'available' magnesium in excess of the amount necessary for maintenance, secretion of milk and retention is mainly excreted in the urine approximately giving a linear relation between 'available' magnesium above the quantity secreted in milk and the urinary excretion of magnesium (Fig. 3).

Also, in the case of negative retentions, the relation between 'available' magnesium above the quantity secreted in milk and the amount of magnesium excreted in urine seems to be linear. The retention is zero when the former amount of magnesium is about 2·5 g./day. Obviously this amount is equal to the amount of magnesium required for maintenance and milk diminished by the amount of magnesium secreted in milk. The accuracy of this figure, of course, is low in view of its standard deviation of 1 g. mentioned above and of possible unknown systematic errors.

In fig. 3 magnesium ingested—magnesium in faeces—magnesium in milk in g./day is plotted against the excretion of magnesium in urine in g./day. A regression analysis of magnesium excreted in urine on the amount of 'available' magnesium above the quantity secreted in milk for the experiments reported here gave the following relationship:

$$\text{Mg in urine (g.)} = 0{\cdot}59 \times (\text{Mg in food—Mg in faeces—Mg in milk}) + 1{\cdot}02$$

The error attached to the regression coefficient was $0{\cdot}59 \pm 0{\cdot}04$.

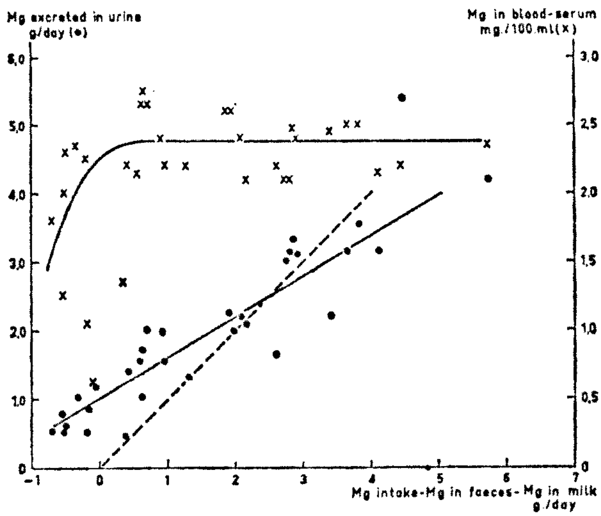

FIG. 3. Relationship between the 'available' magnesium above the quantity secreted in milk (g./day) and the magnesium excreted in urine (g./day) and the serum magnesium concentrations (mg./100 ml).

If it is assumed that the amount of magnesium required for maintenance and milk, diminished by the amount of magnesium secreted in milk, is mainly excreted by the kidney, then the amounts of magnesium excreted in urine lower than about 2·5 g./day might be explained by an increased reabsorption in the kidney from the urine or by a more efficient utilization of magnesium for maintenance. This would be in agreement with the fact that the serum magnesium levels begin to fall when the retention of magnesium is lower than about —1 g./day which also may be deduced from the data of fig. 3. Therefore, the level of the daily excretion of magnesium in urine appears to be an even better measure for the magnesium status of the animal than the magnesium concentrations in blood-serum. However, in this respect it must be considered that according to fig. 3, the excretion of magnesium in urine may be lower than 1 g./day, while at the same time hypomagnesaemia as well as normal serum magnesium levels may occur. This suggests individual differences concerning the influence of stored magnesium in the body on the magnesium concentrations of blood-serum.

According to the aforementioned our experiments about the origin of hypomagnesaemia suggest that hypomagnesaemia in cattle arises as a result of a shortage of magnesium due to the reduction in the dietary supply of 'available' magnesium. This emphasizes the importance of a sufficient supply of feed magnesium. This result is entirely in agreement with the findings of Rook (1958).

The present data give no conclusive evidence about the influence of fertiliser treatment of pasture on the 'availability' of the magnesium ingested. The average 'availability' of magnesium was 16·1 per cent in 11 animals fed on a ration high in potassium or nitrogen and the same was 19·7 per cent in the 10 cows with a ration low in potassium or nitrogen. The exceptions mentioned before, i.e. cow 1 in Exp. 3, cow 1 in Exp. 6, and cow 3 in Exp. 6, have not been included in these averages. This difference might be seen as an indication that high contents of potassium and/or nitrogen of the herbage are associated with a lower percentage of the magnesium ingested which is not excreted in the faeces. v.d. Horst and Hendriks (1958) found a considerably unfavourable influence of potassium dressings on pasture on the 'availability' of magnesium.

Our experiments also suggest the existence of individual differences in utilization of feed magnesium. It is remarkable that all cows with serum magnesium levels ranging from 0·50 mg./100 ml to 1·80 mg./100 ml showed very low percentages of magnesium not excreted in the faeces (7 per cent to 14 per cent), while the other cows of the experiments receiving the same herbage showed normal serum magnesium concentrations ranging from 2·10 mg./100 ml to 2·75 mg./100 ml and higher percentages of magnesium not excreted in faeces (11 per cent to 23 per cent). This is in agreement with the fact that in practice it is a common opinion that some cows are more susceptible to hypomagnesaemia than other cows, although differences in mganesium intake may play a part here. In this respect it must be observed that a high yielding cow is not necessarily more susceptible to hypomagnesaemia than a cow with a low milk yield because a higher production in general will lead to a considerably higher intake of herbage.

The factors responsible for the considerable differences in 'availability' of feed magnesium are so far unknown. Hence for the time being, the variations of serum magnesium levels for a same magnesium content of herbage (Fig. 1) related with variations in potassium and crude protein contents of the herbage may be explained by both differences of magnesium intake, due to variation of dry matter intake, by individual differences in the absorption of magnesium from the digestive tract and possibly by a depressing effect of high potassium and nitrogen contents or other factors of the herbage on the magnesium digestion.

SUMMARY

1. Grazing experiments showed a significant positive correlation between the magnesium content of herbage and the magnesium concentration in blood-serum in lactating cows. Low serum magnesium levels did not occur when the magnesium in herbage was higher than 0·20 per cent Mg in dry matter. However, when the magnesium in herbage is lower than 0·20 per cent Mg both normal and low serum magnesium levels may occur. The latter variation was associated with a variation in potassium and crude protein contents of the herbage. This might be explained by differences in magnesium intake and utilization of herbage magnesium ingested by the animals.

2. For a better understanding balance experiments have been carried out with lactating cows fed indoors on a winter ration or freshly cut herbage. The daily magnesium intake of the cows on winter ration ranged from 31·8 g./day to 34·1 g./day, while the daily magnesium intake on herbage ration ranged from 10·3 g./day

to 22·4 g./day. 83 per cent of the magnesium ingested was excreted in the faeces within a range of 67 per cent to 93 per cent. The secretion of magnesium in milk was about 0·12 g. per kg. of milk. The urinary excretion of magnesium was related with the magnesium retention. It was found that the excretion of magnesium in urine is a better measure of the magnesium status of the animal than the magnesium concentration in the blood-serum, since a decrease of magnesium excretion in urine preceded a fall in the serum magnesium level.

3. It was concluded that the magnesium supply of cows was determined by the magnesium intake and the 'availability' of the magnesium ingested. In this respect the milk yield was thought to be of minor importance. Probably, there exist individual differences between the cows in the utilization of feed magnesium and there seems to be also a relation between the chemical composition of the herbage and the 'availability' of herbage magnesium. In the supply of 'available' magnesium in lactating cows fertilizer treatments of grassland with nitrogen or with potassium or both, play an important part because they may influence the magnesium intake as well as the 'availability' of the magnesium ingested.

ACKNOWLEDGMENTS

We are indebted to J. Wind for stimulating this investigation and for his advice. Our thanks go to Prof. Dr. E. Brouwer who was so kind as to place at our disposal his digestion stall for carrying out the first experiments and for his helpful suggestions and criticisms.

The investigation was partly sponsored by the National Council for Agricultural Research of the Organization for Applied Scientific Research (T.N.O.).

REFERENCES

ALLCROFT, R. (1954). *Proc. XVth Int. Vet. Congr., Stockholm*, **1**, 573.

BARTLETT, S., BROWN, B. B., FOOT, A. S., ROWLAND, S. J., ALLCROFT, R., and PARR, W. H. (1954). *Brit. Vet. J.*, **110**, 3.

—— HEAD, M. J., LINE, C., ROOK, J. A. F., ROWLAND, S. J., and ZUNDEL, G. (1957). *J. Agric. Sci.*, **49**, 291.

BROUWER, E. en BRANDSMA, S. (1953). *Meded. v.d. Landb. hogeschool, Wageningen*, **53**, 31.

DIJKSHOORN, W., and 't HART, M. L. (1957). *Neth. J. Agric. Sci.*, **5**, 24.

HORST, C. J. G. v.d., HENDRIKS, H. (1958). *Tijdschr. Diergeneesk*, **83**, 1162.

HVIDSTEN, H., ODELIEN, M., BAERUG, R., TOLLERSRUD, S. (1959). *Acta Agric. Scand.*, **1**, 261.

KEMP, A. (1958). *Neth. J. Agric. Sci.*, **5**, 4.

—— (1960). *Neth. J. Agric. Sci.* (in press).

PARR, W. H., ALLCROFT, R. (1957). *Vet. Rec.*, **69**, 1041.

ROOK, J. A. F., BALCH, C. C., LINE, C. (1958). *J Agric. Sci.*, **51**, 189.

—— (1958). *J. Agric. Sci.*, **51**, 199.

SJOLLEMA, B. (1931). *Landb. Tijdschr.* 43.

—— (1933). *Acta vet. Neerl.* 1.

SMYTH, P. J., CONWAY, A., WALSH, M. J. (1958). *Vet. Rec.*, **70**, 846.