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INDIVIDUAL VARIATION IN BLOOD MAGNESIUM AND SUSCEPTIBILITY TO HYPOMAGNESAEMIA IN COWS

By
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The fact that hypomagnesaemic tetany usually affects only a limited number of individuals within a herd of uniformly treated cattle was emphasized by *Seekles* (1955). The measurements by *Kemp et al.* (1960) reveal very large differences in serum magnesium between animals on magnesium-poor, hypomagnesaemia-producing pastures. Other variables must be of importance in addition to the nutritional factors in the aetiology of hypomagnesaemic tetany since *Blaxter & McGill* (1956) found that the disease was 15 times more frequent among sixth calvers than among cows calving for the first time.

The range usually accepted as normal for magnesium in the blood serum of cows is quite wide, 1.85—3.17 mg/100 ml according to *Allcroft & Green* (1934). The extent to which variations within this range under ordinary farm conditions can reveal differences in the susceptibility to hypomagnesaemia may not have been thoroughly investigated.

The question of the prognostic value of serum magnesium measurements has been mentioned briefly in a congress report (*Halse* 1961). In the present paper the observations referred to previously are reported in greater detail together with material accumulated in the meantime. The literature has been discussed rather extensively in an attempt to correlate knowledge about variations in blood magnesium, magnesium metabolism and susceptibility to disease.

ANIMALS

Five herds of cows were studied. They consisted of Norwegian Red cattle or Red Polls or of crosses between these two breeds.

Herd no. 1 in the Vestfold area with about 100 animals had cases of tetany or paresis during the pasture season for several years during the 1950's in addition to a high frequency of milk fever in direct connection with calving at all seasons.

Blood samples from this herd were analyzed on several occasions in the course of 3 years. The nature of the tetany disease was demonstrated by serum Mg values as low as 0.3 mg/100 ml, as a rule accompanied by varying degrees of hypocalcaemia.

Three series of observations are of interest in the present context.

1. In the first year "mineral crisis" with hypocalcaemia and varying degrees of hypomagnesaemia was produced in two cows by subjecting them to two days of fasting. This happened in September. One of the cows had tetany one month before (*Halse* 1961).

2. In the following winter serum magnesium was determined five times between Dec. 17th and March 4th in 19 cows (Tables 1—2). The animals were strongly selected with respect to recent disease histories, with nine cases of milk fever and two of tetany in the same year.

3. In the spring of the third year another group of 19 animals was sampled before and after let-out to pasture (Fig. 1 and Tables 3 and 4). The group contained several cows believed to be specially susceptible to tetany because of age, high yield or previous disease. Actually three cases of tetany or paresis were recorded in this group after 1—3 weeks of grazing, while there were four among the remaining 80 cows in the herd.

Winter rations appeared adequate for 27—30 kg of milk per day, consisting of hay, roots, potatoes, silage, Beckman-treated straw, and concentrates with 20—30 g of Mg/day. Dolomite supplements were tried, but did not influence the serum Mg level in the winter (12 g of Mg/day).

Herds nos. 2—5 in the agricultural area around Oslo had better health records than no. 1. Single cases of grass tetany may have occurred in previous years in herd no. 3.

Herd no. 2 with 29 cattle belonging to the Veterinary College was tested repeatedly in the pasture season of 1965 and again in March 1966 (Tables 5—7).

The remaining three herds (Table 8 and Fig. 2) with alltogether about 150 heads of cattle were tested immediately before and 3—4 days after let-out to spring pasture in May 1967. Between samplings they grazed on an average about 6 hrs. per day and received supplementary indoor feeding. Herd no. 4 was tested again on the 10th day on grass when the supplementary feeding had been stopped.

Large amounts of silage were given in herd no. 4 before letout. Otherwise the winter rations in all herds were of the same composite type as in no. 1. Feeding standards appeared to be somewhat higher in nos. 4 and 5 than in no. 3.

METHODS

Serum (herd no. 1) or heparin plasma (other herds) was prepared from jugular vein blood within 24 hrs. after drawing and stored at 5°C until analyzed, usually within a week's time.

In samples from herd no. 1 magnesium was determined by phosphate precipitation according to a modification of the method of *Briggs* (1922), using a Beckman DU spectrophotometer. Calculations were based on readings from known Mg standards analyzed each week exactly in the same way as the sera.

In 1965—66 Mg and Ca were analyzed by complexometric titration. EDTA with Eriochrome black T (*Bowden & Patston* 1963) gave the sum of both elements, and Ca alone was measured with EGTA according to a micromodification (*Halse* unpublished) of the method of *Ringbom et al.* (1958). The Ca values were within 0.1 mg/100 ml of figures obtained with conventional murexide titration. As instruments were used an EEL titrator (Evans Electro Selenium) and a Dosimat digital-reading micro burette (Metrohm).

Finally, in 1967 the opportunity of performing analyses on a large scale with a Technicon Autoanalyzer was made use of. Magnesium was determined according to a modification of the method of *Gitelman et al.* (1966), and calcium by an adaptation to photometry (*Halse* 1968) of the indicator principles of *Ringbom et al.* Parallel analyses of all samples were performed routinely. The reproducibility of means of two parallels appears from the following standard deviations: (1) phosphate precipitation and (2) complexometry ±0.06, (3) autoanalyzer ±0.01—±0.04 mg Mg/100 ml. The autoanalyzer results were on an average 0.1 mg/100 ml higher than those obtained by titration. The phosphate method was not compared to the others.

It should be made clear that the three magnesium methods were used in different years, (1) in Tables 1—4 and Fig. 1, (2) in Tables 5 and 6, and (3) in Table 8 and Fig. 2. This means that all major conclusions in the following are drawn from variations seen within series of blood samples analyzed by the same method.

RESULTS

Reproducibility of a normal range for plasma- or serum-magnesium. Attention is drawn to the constancy of the minimum obtained in groups of cows under feeding conditions to which they were adapted. In this respect there was no difference between the grass tetany herd on winter rations (Table 1 and Fig. 1) and herd no. 2 without tetany (summer and winter, Table 5). One exceptional cow brought the minimum down to about 1.30 mg/100 ml in herd no. 3 before pasture (Table 8 and Fig. 2). In

Table 1. Reproducibility of differences in serum magnesium between groups of cows in herd no. 1. Classification according to levels on January 11th of observations made Dec. 17th, Jan. 28th, Feb. 18th and March 4th.

Significance test, *differences between individuals* in Table 2.

Group	Number of cows: total	previous diseases: milk fever	previous diseases: tetany	Calving dates	Milk yield in February, averages kg/day	Serum Mg, mg/100 ml: January 11th: range	January 11th: mean	Dec. 17th - March 4th, 4 samples per animal: range	Dec. 17th - March 4th: mean ± s
I	4	2	1	Aug. 14th -Dec. 26th	17.3	1.55—1.85	1.68	1.60—2.30	1.88±0.22
II	6	5	0	Aug. 15th -Dec. 19th	16.8	1.95—2.15	2.06	1.65—2.45	2.11±0.22
III	5	1	1	Aug. 15th -Dec. 12th	17.6	2.20—2.25	2.24	1.72—2.55	2.20±0.18
IV	4	1	0	July 26th -Dec. 29th	15.2	2.30—2.55	2.35	2.10—2.70	2.36±0.18

Table 2. Variance analysis. Same material as in Table 1. Significance of differences in serum magnesium between individuals.

Source of variation	Degrees of freedom	Sum of squares	Mean square
Between animals	18	3.947	0.2193
Within animals	76	2.378	0.0313
Total	94	6.325	

Variance ratio: $\frac{0.2193}{0.0313} = 7.00 \quad P < 0.001$

the rest of the material ranges were limited downwards by figures between 1.55 and 2.04 mg/100 ml under ordinary conditions of feeding (different methods of analysis not corrected for).

The upper limits of the ranges on different occasions showed greater irregularities and tended to be related to variations in the total herd average, as seen in Table 5.

Differences between individuals. The maintenance of differences between groups of cows within the same herds in successive series of samplings in the course of about 2½ months is demonstrated in Tables 1 and 5, respectively under indoor and pasture conditions. Differences between individuals were shown to be statistically significant by variance analysis, with $P < 0.001$ both in Table 2 and Table 5.

Indications that individual differences can persist for much longer intervals of time are found in Table 3. In Table 5 indi-

Table 3. Serum magnesium of animals included in Table 1 and tested again in May in the same or the following year.

Group no. in Table 1	Animal, code number	Mg, mg/100 ml: same year: Jan. - March means of 4 observations	Mg, mg/100 ml: same year: May 27th early pasture	Mg, mg/100 ml: one year later: May 2nd before pasture
I	156 K	1.68	1.65	1.75
I	11 R	1.93	1.30	
II	8 S	2.05	1.70	
II	207 K	2.09		2.10
III	148 H	2.12	1.90	
II	24 O	2.18		2.15
IV	82 O	2.35		2.05
IV	67 R	2.55		2.25

Table 4. Comparison of serum Mg levels of the same animals while indoor fed and after varying intervals of pasture feeding. Ten cows from Fig. 1 sampled again June 13th. Differences between animals not accounted for by stage in lactation cycle or milk yield.

Animals	Age, years	Date of calving	Milk before pasture kg/day	Serum Mg, mg/100 ml: May 2nd, 2 weeks before pasture	May 23rd, 1 week on pasture	June 13th, 4 weeks on pasture	Clinical
77 T	7	April 27th	23	1.70	0.75	0.95	Treated for tetany May 24th
156 K	12	Jan. 4th	26	1.75	1.45	1.45	Treated for tetany June 5th, serum Mg: 0.25 mg/100 ml
2 cows, identical Mg-levels May 2nd	4—7	Febr.-March, 13th	24—26	1.90	1.0—1.10	1.85—1.90	Healthy
103 S	5	Oct. 31st	17	2.05	1.55	2.35	Treated for paresis May 24th
220 K	5	Febr. 14th	23	2.15	1.45	1.00	Borderline, not in need of treatment
4 cows, identical Mg-levels May 2nd	5—10	Febr.-April 11th	22—27	2.25	1.75—2.35	2.25—2.65	Healthy

vidual values obtained with a time distance of 9 months were significantly correlated, with $P < 0.01$, but the correlation was better between values obtained on different dates in the same pasture period.

Individuals during let-out to pasture. In herd no. 1 a significant correlation was observed between the degree of hypomagnesaemia after one week on a tetany-producing pasture and individual levels within the normal range before let-out ($P < 0.01$ in Fig. 1). Table 4 shows that the original before-pasture ranking order was partly maintained even among 10 cows which were sampled again after 4 weeks on grass. Magnesium levels on successive dates were significantly correlated, but not observations on the first and last day because of the belated development of hypomagnesaemia in one of the cows.

Attention is drawn to the fact that three serious cases of tetany or paresis occurred among cows which had serum magne-

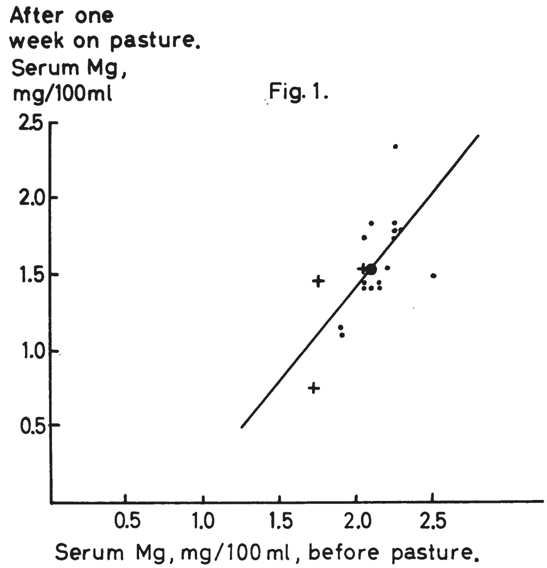

Figure 1. Correlation between serum magnesium values of 19 cows two weeks before and one week after let-out on a hypomagnesaemia-producing pasture. Three cows which got tetany (+) were initially in the lower half of the range. $r = +0.67$, $P < 0.01$. Ranges: before, 1.70—2.50 mg Mg/100 ml; after, 0.75—2.35 mg Mg/100 ml. Comparison to a third series of blood analyses in Table 4. Herd no. 1.

sium values within the lower half of the normal range before pasture in Fig. 1 and Table 4.

In contrast to the low-normal animals the cows initially above the group average in serum magnesium remained healthy with the exception of the doubtful case of the cow with late hypomagnesaemia in Table 4. Because of signs of discomfort it was suspected for some time that she might get tetany. For this reason she is placed among the clinical cases in Table 9 in spite of the fact that she came through without serious illness and without treatment.

The familiar moderate decrease in blood magnesium during let-out to pasture was seen in two of the herds without grass tetany in Table 8 and Fig. 2. The important point in the present context is the fact that groups of animals which were at the lower end of the before-pasture range marked themselves out by low values also after let-out ($P < 0.001$ within herds in the combined material). A counterpart was not seen at the opposite end of the range. As appears from the graph, no difference was pre-

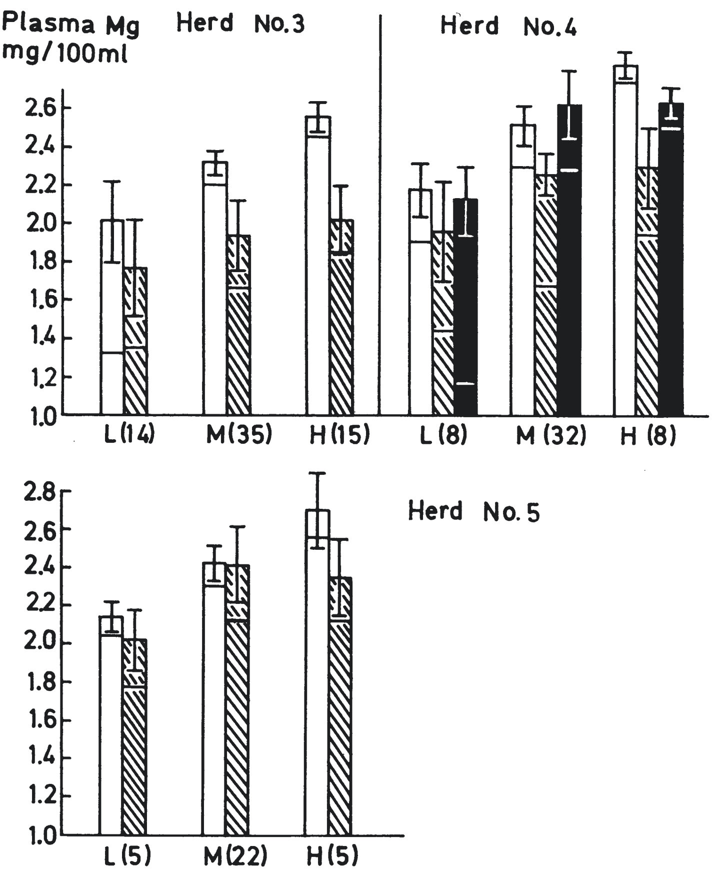

Figure 2. Reproducibility of differences in plasma magnesium between groups of cows within three herds during let-out to pasture. Animals classified according to range before let-out into low (L), medium (M) or high (H) magnesium groups. Numbers of animals in brackets. Means (height of columns), standard deviations and group minima on day before pasture (white), after 3—4 days (hatched) and 10 days (black) on pasture.
Significance test of observations after let-out: variance quotients within herds, L against M, 47.2; L against H, 24.7. Both tests $P < 0.001$. One cow with moderate hypomagnesaemia on 10th day in the L group in herd no. 4. Total ranges and averages in Table 8.

sent at subsequent samplings between groups of cows initially classified as medium and high in plasma magnesium.

Calcium in blood plasma. Table 6 demonstrates the complete absence of differences in plasma calcium between cows with below- and above-average magnesium levels in the complete ma-

Table 5. Reproducibility of differences in blood plasma Mg between groups of cows in herd no. 2. Classification according to Mg range on June 14th. Observations from the pasture season and after half a year on indoor rations. Plasma Ca values in Table 6. Age, stage of lactation and milk yield, see Table 7.

Ranges in mg of Mg/100 ml serum:

Low: 1.65—2.20
Medium: 2.30—2.55 } June 14th
High: 2.60—2.90

Date	mg of Mg/100 ml						
	low group		medium group		high group		total range
	n	mean ± s	n	mean ± s	n	mean ± s	
June 14th	9	2.00±0.19	10	2.41±0.08	9	2.73±0.11	1.65—2.90
Aug. 6th	6	1.95±0.30	5	2.25±0.21	7	2.46±0.26	1.60—2.90
Aug. 29th	6	1.93±0.25			5	2.55±0.33	1.55—3.05
March 9th	7	1.96±0.32	8	2.09±0.23	8	2.30±0.16	1.60—2.45

n = number of animals.
Significance of differences *between individuals on pasture:* $P < 0.001$ by variance analysis.
Correlation coefficient between values on June 14th and March 9th: $r = +0.58$, $n = 23$, $P < 0.01$.

terial of observations from herd no. 2. The two blood components were found to be unrelated also in herds nos. 3—5 before pasture.

It is of interest that the low-magnesium group in herd no. 3 showed a statistically significant increment in plasma calcium after let-out ($P < 0.01$). This resulted in practically identical

Table 6. Plasma Ca corresponding to two different ranges for plasma Mg in herd no. 2. Same material as in Table 5, pasture period and March 9th, but grouped according to actual Mg levels.

Magnesium category	Number of samples	Concentrations in meq./l			
		plasma Mg		plasma Ca	Ca + Mg
		range	mean ± s	mean ± s	sum of means
Low	44	1.30—1.83	1.58±0.17	5.12±0.26	6.70
High	50	1.87—2.50	2.05±0.14	5.09±0.21	7.14

The difference in calcium between the two groups of observations is not statistically significant.

Table 7. Animals in Tables 5 and 6, herd no. 2. Age, stage of lactation and milk yields on June 14th corresponding to the different plasma Mg ranges in Table 5.

Magnesium range	Number of animals	Age, years		Days post partum		Milk production, kg		
						per day		per year
		range	mean	range	mean	range	mean	mean
Low	9	5.2—7.3	6.7	48—360	188	12.7—26.3	18.3	4770
Medium	10	3.4—7.3	4.4	72—258	179	9.8—28	16.8	4650
High	9	3.3—6.1	4.4	36—227	146	7.5—24.5	17.8	4560

values for the sum of calcium and magnesium in meq. units in all the magnesium categories in this herd on pasture (calcium difference between low- and high-magnesium animals about 0.7 mg/100 ml). This phenomenon was not seen in herds nos. 4 and 5.

Age, date of calving, milk yield. Some relationship between magnesium level and age is indicated both in Table 4 and Table 7. There is no systematic trend in the other variables mentioned. In herds nos. 3—5 (not tabulated) no age-relationship could be detected. The yield- and days post partum-figures overlapped extensively as in Table 7. But there was some unevenness in the distribution of cows at different stages of lactation among the different magnesium categories. This could account for slightly higher daily milk averages (10—15 %) among low-magnesium

Table 8. Plasma Mg in three herds before and after let-out to pasture. Reproducibility of differences between groups of cows demonstrated in Fig. 2.

Days before or after let-out	Mg in mg/100 ml								
	herd no. 3			herd no. 4			herd no. 5		
	n	range	mean ± s	n	range	mean ± s	n	range	mean ± s
Before, 1—2	64	1.32—2.69	2.31 ±0.22	48	1.91—2.95	2.52 ±0.22	32	2.04—3.05	2.42 ±0.20
After, 3—4	64	1.35—2.23	1.91 ±0.21	48	1.44—2.64	2.22 ±0.23	32	1.77—2.50	2.34 ±0.24
After, 10				47	1.17—3.00	2.55 ±0.29			

n = number of animals.

cows than in the rest of the material. Generally yields were as in Table 7 in herd no. 3 and 3—4 kg higher per day in herds nos. 4 and 5.

DISCUSSION

Reproducibility of differences between individuals in blood magnesium. Findings similar to those in the present investigation were made by *Allcroft & Green* (1938). They studied seasonal hypomagnesaemia without clinical symptoms in cows on winter pastures in England. Under equal conditions serum magnesium averages were constantly lower than for the entire herd in a group of cows which had suffered from hypomagnesaemia previously. This was seen at bimonthly samplings from June to February, even when the animals became hypomagnesaemic again.

A significant positive correlation between before-pasture levels and those obtained after 1 week on a hypomagnesaemia-producing pasture was mentioned by *Bartlett et al.* (1957). But they emphasized that the correlation was not significant between initial levels and the minima in serum magnesium observed on grass. The explanation was offered that moderate extra body reserves of magnesium in certain animals could prevent the onset of hypomagnesaemia for a few days.

The persistence of differences in serum magnesium between cows for entire seasons was mentioned briefly by *Kemp* (1958).

Of special interest are the experiments of *Rook & Balch* (1958) in which hypomagnesaemia was produced in cows by shifting them abruptly from winter rations to the indoor-feeding of fresh young grass (Table 9). In spite of the fact that all cows had normal-range serum magnesium values initially, they differed widely in the severity of the hypomagnesaemia produced. A statistical treatment of observations taken from the original publication gave a significant positive correlation between individual levels before (normal range) and after 4 days of grass feeding (some cows as low as 0.5 mg of Mg/100 ml serum): $n = 12$, $r = 0.64$, $P < 0.05$. The correspondence with the material from the grass tetany herd in Fig. 1 is evident ($r = +0.67$).

The effects of turning cows out to pasture were studied in a large number of herds by *Butler* (1963). Serum magnesium averages for 10 cows per herd showed a significant correlation between values before and after 5—14 days on grass. But the behaviour of individuals was not mentioned by this author.

The normal serum magnesium range and renal regulation. Correspondence between the lower limit of the normal serum range and the renal magnesium threshold has been referred to repeatedly as evidence of the importance of the kidneys in magnesium homeostasis (*Wilson* 1960; *Averill & Heaton* 1966).

When observations from the spring pasture period are excluded, also the range minima in the present investigation (1.55—2.04 mg/100 ml, see Results) are in quite good agreement with estimates of the renal threshold level. Thus, steeply increasing urinary excretion figures were obtained in cows by *Ender et al.* (1957) when the serum level rose above 1.5—2.0 mg of Mg/100 ml. The corresponding value was about 2.0 mg/100 ml in the cows of *Kemp et al.* (1960). Magnesium-poor urines at serum levels below 1.8 mg/100 ml were observed by *Rook & Balch.* A threshold value of 2.15—2.2 mg/100 ml arrived at more indirectly (*Rook et al.* 1958) might be too high, according to the authors.

In other species maximum renal tubular reabsorption rates corresponding to respectively 2 and 1.5—1.7 mg of Mg/100 ml in blood serum were found in sheep (*Wilson*) and rats (*Averill & Heaton*).

Quantitative aspects. The occurrence of minima in blood magnesium close to the renal threshold level may mean that in all herds studied in the present investigation there were animals which subsisted on quite narrow margins of the element in their metabolism. Assuming identically functioning kidneys, individuals with higher levels within the normal range might be considerably better off. Averages calculated from *Ender et al.*'s measurements show for instance a urinary excretion of 0.35 g of magnesium per day in the serum range 1.5—1.75 mg/100 ml. At 2.25—2.5 mg/100 ml the surplus excreted was as large as 2.9 g per day.

Variations in renal handling of magnesium. Quite large variations in urinary magnesium unrelated to the serum level are evident both in *Ender et al.*'s and *Kemp et al.*'s cows. This inaccuracy of serum magnesium as an indicator of excretory quantities is natural since the blood level at which a given surplus of the element is eliminated must vary with the renal filtration rate and the tubular capacity for magnesium reabsorption (discussed by *Wilson*).

Renal calcium-magnesium interrelation. According to recent studies in this department (*Halse,* unpublished), the renal excretion of magnesium is influenced by variations in the blood calcium level. The urine of cows made moderately hypocalcaemic by a short period of fasting became practically magnesium-free at blood magnesium levels well above the ordinary threshold range. Similarly, hypocalcaemic parturient cows showed significant increments in blood magnesium without increasing the rate of urinary magnesium excretion. Interaction at the level of the kidney is indicated also in rats by the findings of *Richardson & Welt* (1965). Other explanations were offered by the authors. But the fact remains that serum magnesium was decreased while urinary magnesium remained unaltered in rats made hypercalcaemic with vitamin D.

In most of the present material plasma calcium was the same in cows with different magnesium levels (Table 6). However, in herd no. 3 after let-out to pasture some causal relationship between calcium increments and low levels of magnesium in the plasma cannot be excluded. It should be noted that this was the herd with the greatest let-out effects on plasma magnesium in Table 8 and Fig. 2.

"Availability" of feed magnesium as a source of individual variations. The balance experiments by *Rook & Balch* and *Rook et al.* and by *Kemp et al.* show that the ability of cows to utilize feed magnesium varies widely with the type of diet and tends to be low on fresh young grass.

Of special importance for the present discussion is the fact that great individual variations were seen in magnesium "availability". In single cows it could be more than 50 % below the average for a group of animals on a given diet. Both groups of authors suggested that *such variations could be the reason why certain animals were more susceptible to hypomagnesaemia than others.*

The term used above is defined as follows: "available" is the difference between food and faecal magnesium in weight units per day. This variable in per cent of daily feed magnesium is "availability".

"Available" and urinary magnesium. Kemp et al. were able to demonstrate a very strong, positive correlation between "available" minus milk magnesium and the rate of urinary magnesium excretion. They concluded that the last mentioned variable was

a better indicator of the "magnesium status" of an individual than the blood serum level of the element. Taking the variability of the serum-urine relationship into account, this must be true when blood levels are within a normal range. At sub-threshold levels, however, when all urines are magnesium-poor, serum analyses may provide the best estimates of the severity of deficiency conditions.

Prognosis and urinary magnesium. While all serum levels were still normal, at the initiation of the grass-feeding experiments of *Rook & Balch,* great differences were recorded between individual cows in urinary magnesium concentration. The lowest initial urine values were found in animals which subsequently became severely hypomagnesaemic. This point, apparent from the analytical figures, was not specifically commented upon by the authors. Therefore a statistical test was performed which gave the following exceptionally high correlation coefficients: between (1) magnesium concentration in urine before grass feeding and (2) serum magnesium on the fourth day on grass, $r = +0.91$ ($n = 12$, $P < 0.001$), between (1) and (3) serum magmesium on the eighth day of grass feeding, $r = +0.86$ ($n = 8$, $P < 0.01$). Evidently, future reactions to hypomagnesaemia-producing stresses are more reliably predicted from levels in the urine than in the blood serum ($r = +0.64$, see above).

Special errors must be reckoned with in balance experiments with ruminants immediately after a change in feeding. But still the figures obtained in the experiments mentioned for "available" magnesium during early grass feeding were significantly correlated to urinary magnesium concentration before grass was given, with $r = +0.67$, $n = 10$, $P < 0.05$.

The paradox that animals with great initial urinary losses of magnesium appeared specially protected seems to indicate that the ability to replenish body reserve of the mineral (or magnesium "availability") is an important variable in the determination of individual susceptibility or resistance to hypomagnesaemia.

Magnesium utilization and the functioning of the digestive system. Larvor & Brochart (1960) and *Larvor et al.* (1960) found that hypomagnesaemia in cows on spring pastures could largely be prevented by the feeding of hay supplements but not with the same amount of hay after grinding. Since the grinding of roughage is known to influence digestive processes in many ways,

T a b l e 9. Serum Mg under hypomagnesaemia-producing conditions classified according
groups of equally treated cows during previous control period. Frequency of clinical cas
Numbers of clinical cases (C) and of apparently healthy animals

Source	Control level	Serum Mg, mg/100 ml: control range (I)	Serum Mg, mg/100 ml: hypomagnesaemia period (II) mean ± s or range (mean)	Number of animals, Control levels, low: C	low: H	high: C	high: H	
Herd no. 1	low	1.70—2.10	1.39±0.32	3	7			l
Fig. 1 and								c
Table 4	high	2.15—2.50	1.73±0.28			1	8	
Rook & Balch	low	1.85—2.40	0.51±0.10	3	1			l
	high	2.50—2.90	1.53±0.63			1	7	f
Hvidsten et al.	low	2.10—2.10	0.30—1.10 (0.63)	1	2			l
1st year	high	2.50—2.70	0.40—1.50 (1.10)			0	3	r
Hvidsten et al.	low	2.2	0.5	1	0			a
2nd year	high	2.60—2.80	0.20—1.80 (1.23)			0	3	f
Breirem et al.	low	1.70—1.80	0.55—0.60	2	0			l
AIV silage-								r
cellulose group	high	1.90—2.15	0.70—1.35			0	2	
Breirem et al.	low	1.45—1.65	0.55—0,70	1	1			a
Cellulose group	high	1.70—1.90	0.80—1.10			0	2	s
Sums, animals				11	11	2	25	

In the "low" category: 8 hypomagnesaemic cows with genuine tetany or paresis. *Rook e*
at an early stage, see text.

it is likely that the pretreatment also served to reduce magnesium "availability". By analogy one might suggest that quite subtle differences between individuals in the functioning of the complicated ruminant digestive system could account for variations in the ability to maintain the magnesium equilibrium of the body under adverse conditions.

Prediction of the severity of hypomagnesaemia. Disease frequencies. Table 9 demonstrates the existence in other materials from the literature of the same relationship as in herd no. 1 during let-out to pasture and in the grass-fed cows of *Rook & Balch*. Exceptions are found, as might be expected from the magnitude of the correlation figures discussed previously. *But generally the severest degrees of hypomagnesaemia were observed in cows which were at the lower end of the range within groups of seemingly identically treated individuals before being subjected to hypomagnesaemia-producing conditions.* The striking difference between disease-frequencies provides further evidence that this category of animals were specially predisposed.

Of special interest is the conformity to the general rule of the observations by *Breirem et al.* (1949), since they were made under feeding conditions quite different from those of the other studies. Hypomagnesaemia occurred after calving on low-magnesium indoor diets which had been just sufficient for the maintenance of a low-normal serum level during the dry period.

The rule discussed was found to be valid even in two cows from herd no. 1 which were fasted simultaneously for 2 days late in the pasture season (*Halse* 1961). They showed decreases in serum magnesium respectively from 2.45 to 1.3 and from 2.05 to 0.45 mg/100 ml. The clinical importance of this difference is somewhat uncertain since both got sick at the same stage of the fast with marked hypocalcaemia. It should be noted, however, that the first cow recovered rapidly after treatment while the second one, which had suffered from grass tetany 1 month earlier, was lost.

The analytical figures from the different investigations in Table 9 are not directly comparable. The hypomagnesaemia period is alternatingly represented with group averages on a given day and minima obtained during a prolonged time interval. Furthermore, "low" and "high" control ranges have been differently defined in different materials. In each case the ranges chosen represent the highest possible difference in the frequency of subsequent clinical reactions.

Some reservations should be made concerning the clinical criteria used in the preparation of Table 9. Genuine tetany or paresis was reported in eight of the clinical cases listed. All qualified for the "low" category. The single "high"-bracket case in herd no. 1 was a light one (no treatment needed, see Results). But Table 4 confirms that the cow concerned was hypomagnesaemic at the time. The four cases of *Rook & Balch* are somewhat doubtful since treatment was given or the experiment interrupted at an early stage, to prevent serious clinical reactions. Evidently there was no tetany. But two of the "low" cases had become inappetent.

From the experiments on pasture fertilization and hypomagnesaemia published by *Hvidsten et al.* (1959) those animals have been included in Table 9 which received the same preparatory indoor diets and subsequently grazed the same pastures as two tetany-cows. Actually, the same indoor diets were given to 12 cows in the first year and to 16 in the second. Even within these larger groups the two animals referred to marked themselves out with serum magnesium values at the minimum end of the range (first year: four cows as low as 2.1 mg/100 ml, second year: 2.2 mg/100 ml in the tetany cow alone, compare table).

Statistically significant differences in serum magnesium between individuals were mentioned in *Breirem et al.*'s article. By checking the original data not published in extenso, it was found that serum minima occurring between the first and fifth week after calving were significantly correlated to levels recorded before parturition in 13 cows in three feeding groups (within groups: $r = +0.65$, $P < 0.05$). One of the groups used in this estimate has been deleted in Table 9 since serum magnesium was only moderately decreased and there was no tetany. Also deleted was a fourth cow with tetany, because her blood had not been analyzed before calving (AIV-group).

Low initial control values, in the presumed "threshold range" for serum magnesium, in *Breirem et al.*'s cows may be accounted for by low intakes of the element before as well as after calving, due mainly to the inclusion of large quantities of mineral-poor fodder cellulose in the rations. Obviously, both dietary-environmental and individual sources of variation in serum magnesium must be reckoned with. Therefore discrepancies between different studies in the relationship between initial absolute range and apparent susceptibility to hypomagnesaemia represent no contradiction. Susceptibility must be judged on a relative scale, by comparing animals treated as equally as possible.

Otherwise, it should be kept in mind that it is the *probability* of severe hypomagnesaemia which has been found to vary with the control level for serum magnesium. Behaviour contrary to the rule is exemplified by the cow of *Hvidsten et al.* with a high initial value and a minimum at pasture of 0.2 mg Mg/100 ml. Statistically, however, this animal has got to be counted as healthy according to the information supplied by the authors.

CONCLUSIONS

The relationship observed between previous blood magnesium level and susceptibility to hypomagnesaemia might be accounted for by assuming that certain cows suffer from a more or less chronically reduced ability to utilize feed magnesium. The defect could be responsible both for low-normal serum magnesium values under ordinary conditions and for a high susceptibility to hypomagnesaemia on special diets low in "available" magnesium.

Reservations must be made to this simple explanation. Serum levels are influenced by variations in renal handling of the element as well as in the net supply of magnesium to the blood from the digestive tract, and the relative importance of these variables is not known.

However, the reproducibility of magnesium values close to the assumed renal threshold level in certain individuals in all the herds which were tested may mean that freedom from hypomagnesaemic disorders in the field is mainly a question of day to day feeding practices.

Practically it seems possible to single out within herds groups of animals specially susceptible to grass tetany by determining serum magnesium before let-out to pasture. This would naturally be of help in the planning of preventive measures. However, the uncertainties of judgements based on small differences in a blood component are obvious. It seems likely that better predictions can be obtained by estimating urinary magnesium. Therefore it is of interest that Dutch workers have announced the introduction of an indicator paper for the testing of the magnesium contents of urine from cows (*de Groot & Marttin* 1967).

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SUMMARY

1. Within a normal range for blood magnesium in cows, 1.55—3.0 mg of Mg per 100 ml of serum or plasma, statistically significant differences between individuals were detected.

2. Reference was made to studies of the renal handling of magnesium and to demonstrations in the literature of large individual variations in the ability of cows to utilize magnesium from the diet. It is logical to assume that such variations will contribute to the creation of individual differences in plasma levels of the element. The point was emphasized that to moderate differences in plasma

concentration can correspond large quantitative differences in magnesium metabolism.

3. A positive correlation was demonstrated in one herd between earlier individual plasma magnesium levels within the normal range and decreased levels after one week on a tetany-producing pasture.
4. Cows with initial plasma magnesium values in the lower part of the range of a group of animals appeared specially susceptible to disease when subsequently the whole group was subjected to hypomagnesaemia-producing conditions. This rule was detected within the limited material from the mentioned herd with tetany and also in materials from the literature.
5. The possibility that certain individuals within herds can be pointed out as specially susceptible to hypomagnesaemic disturbances before the beginning of a tetany season may be of practical interest.

SAMMENDRAG

Individuelle variasjoner i blodmagnesium og hypomagnesemi-tilbøyelighet hos kyr.

1. Innen et normalt variasjonsområde for blodmagnesium hos kyr, 1,55—3,0 mg Mg/100 ml serum eller plasma, ble det funnet statistisk signifikante forskjeller mellom individer.
2. I diskusjonen ble det henvist til studier over magnesiumtransporten i nyrene og til litteraturkilder som viser store individuelle variasjoner hos kyr i evnen til å utnytte magnesium fra foret. Det er å vente at slike variasjoner vil bidra til framkomsten av individuelle nivåforskjeller for magnesium i blodplasma. Det ble særlig understreket at det til moderate forskjeller i plasma konsentrasjon kan svare store kvantitative forskjeller i magnesiumstoffskiftet.
3. En positiv korrelasjon ble påvist i en besetning mellom tidligere observerte individuelle plasma magnesiumnivåer innen et normalt variasjonsområde og nedsatte nivåer etter en uke på et tetaniframkallende beite.
4. Kyr med utgangsverdier for plasmamagnesium i den lavere del av variasjonsområdet for en gruppe av dyr viste spesielt stor tilbøyelighet til sykdom når hele gruppen etterpå ble utsatt for hypomagnesemiframkallende påkjenninger. Denne regelen ble påvist i det begrensede materialet fra tetanibesetningen nevnt ovenfor og i observasjonsmaterialer fra litteraturen.
5. Muligheten av å peke ut innen besetninger før begynnelsen av en tetanisesong kyr med spesiell tilbøyelighet til hypomagnesemiske forstyrrelser antas å være av praktisk interesse.

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