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BONE MINERAL CHANGES IN DAIRY COWS

THE EFFECT OF LOW AND HIGH CALCIUM FEEDING DURING THE HIGH YIELDING PERIOD*

By

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ZETTERHOLM, R.: *Bone mineral changes in dairy cows. The effect of low and high calcium feeding during the high yielding period.* Acta vet. scand. 1978, *19*, 39—48. — Bone mineral content in two coccygeal vertebrae of 14 cows of Swedish Red and White Breed were investigated using the dichromatic photon absorptiometry. The investigation started at parturition and continued for 120 days. Each animal received a controlled amount of hay, ensilage and concentrate, and the milk yield was measured and registered. Seven cows (group L) received Ca and P close to the ARC standard. The other seven cows (group H) received a 30 % higher amount of Ca and P (15—20 % above Swedish standard) than the ones in group L. The bone mineral content in group L decreased by 10 % up to 90 days postpartum, and thereafter increased. In group H, the mean bone mineral content increased.

absorptiometry; bone mineral measurement; calcium metabolism; cattle; gamma ray source; phosphorus.

Metabolism of Ca and P in dairy cows have mainly been studied by the balance technique. Ca balance was found to be negative in early lactation (*Forbes* 1916, *Miller et al.* 1924, *Ellenberger et al.* 1931. *Meigs* 1935, *Benzie et al.* 1956, *Atkinson & West* 1970). *Duckworth & Hill* (1953) found considerable vari-

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ations in Ca metabolism between individual animals. Input and output of Ca and the size of the exchangeable Ca pool was studied, using radioactive Ca (*Manston* 1967, *Ramberg et al.* 1970). The first to report the use of direct measurement of bone mineral content (BMC) were *Sansom* (1969) and *Wentworth et al.* (1971). Dichromatic photon absorptiometry was used with good precision to follow changes in BMC (*Zetterholm* 1974, *Zetterholm & Dalén* 1978). This technique was applied to cows. It was shown that BMC is lowered during early lactation and increased during the dry period (*Zetterholm* 1978 a). In another study it was found that BMC was not lowered during late pregnancy by giving the animals a low calcium feed — 37 g Ca/day (*Zetterholm* 1978 b).

The aim of the present investigation was to study by means of dichromatic photon absorptiometry to what extent low and high Ca feeding affects BMC during the first four months of lactation.

MATERIAL AND METHODS

The present material consists of 14 cows of the Swedish Red and White Breed. The animals had previously been used in an investigation in which the effect of low and high Ca feeding during late pregnancy was studied (*Jönsson & Pehrsson* 1974, *Zetterholm* 1978 b). Seven of those cows which had previously been on a low Ca diet (37 g Ca/day) and which were the last to calve in this group were put in group H in the present investigation. Another seven cows which had previously been on a high Ca feed (76 g Ca/day) and which were the last to calve in this group were put in group L. In both groups each animal was given a controlled amount of fodder calculated on the weight of the animal and milk yield. The fodder consisted of hay (7.5 kg), ensilage (8—15 kg), and concentrates (6—13 kg). There was no mineral supplementation to the animals in group L other than traces of minerals, which in the feed mixer had contaminated the concentrates, while those in group H had their fodder enriched with a mineral supplementation consisting of 19 % Ca and 10 % P. The intention was to feed the animals according to Swedish standards, which are for maintenance 37 g Ca* and 26 g P. For each litre of milk yielded (4 % fat), the

* 1976, 30 g Ca.

requirement is 2.6 g Ca and 1.8 g P. The fodder analyses showed that the actual feeding exceeded the Swedish standards with 15—20 % (Tables 1 and 2). The daily milk yield in the present study was measured once a week (Figs. 1 and 2).

There was a gradual shift (third to sixth day postpartum) from the feed in the previous experiment to the one in the present study. Fodder samples were continuously taken and analysed every second week.

Four cows in group L and one in group H had parturient paresis at the most recent calving. The present experiment was begun in November—January. The cows were five—nine years old, the mean age for group L being six years and nine months, and from group H six years and two months. The mean milk yield was 6,564 kg yearly for group L and 6,398 kg for group H.

The cows were inseminated at varying times postpartum, and the insemination leading to conception is indicated in Figs. 1 and 2. Two of the cows in group L did not become pregnant during the experiment.

Blood samples for analyses of Ca, Mg, inorg. P and alkaline phosphatase were taken once a month. Serum Ca and Mg were determined by atomic absorption spectrophotometry, and inorg. P by using the technique by Fiske & Subarrow. Alkaline phosphatase was determined using the Boehringer's reagent.

The changes in bone mineral content of two coccygeal vertebrae (V and VI or VI and VII) were followed by dichromatic photon absorptiometry (methodological error 1.5 %).

Measurements were made on six—eight occasions, the first ten—three days before calving and the others at varying times. The last measurement was made as seen in Figs. 2 and 3 from 120 to 150 days postpartum.

Bone mineral content for the day of calving was calculated by interpolation of the value obtained just before and the one just after calving. The two groups were compared in the following manner. The mean for each 10 day period of both groups was calculated by interpolation, using the measurement just before and after as points of reference. The difference between the calculated value for the day of calving and the result of the other measurements was expressed in percentage. Comparisons between the groups were made at 60 and 120 days postpartum, using t-test.

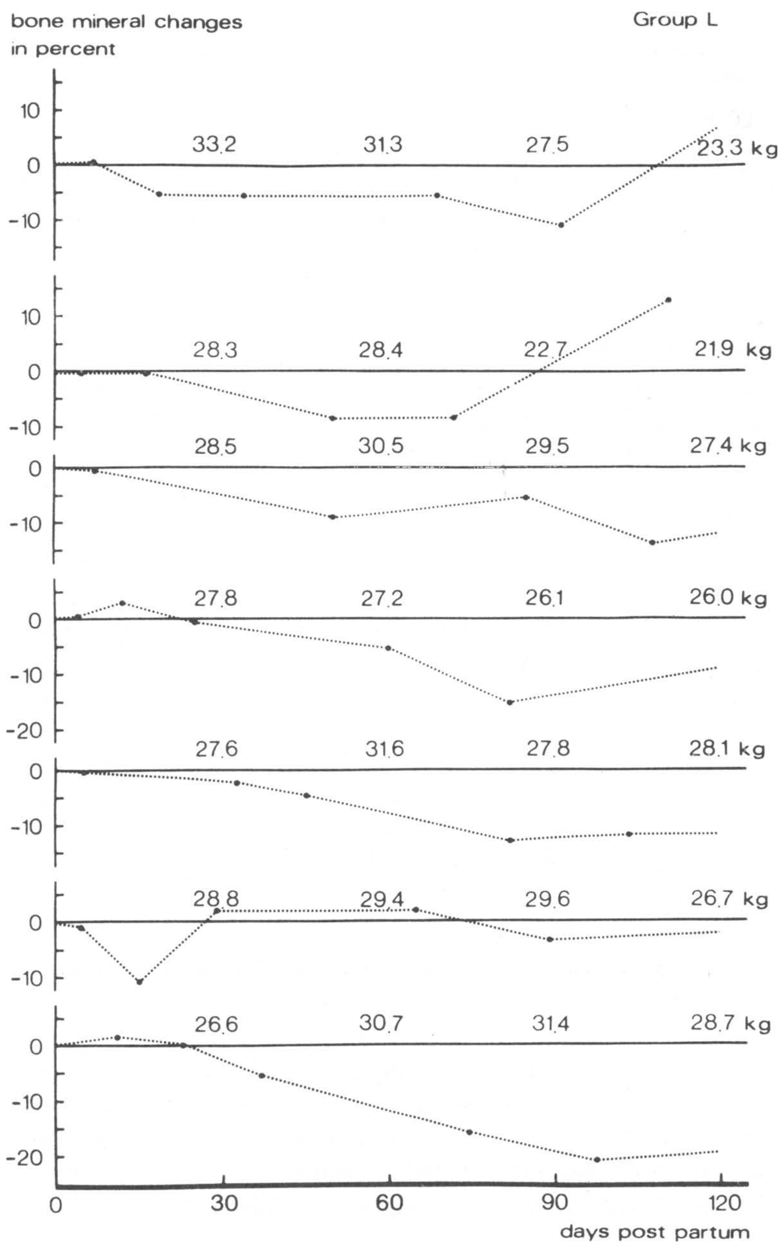


Figure 1. Group L. BMC for the individual animals in group L expressed in percentage difference between the calculated BMC on the day of calving and the BMC determined at various times. Daily milk yield in kg is indicated.

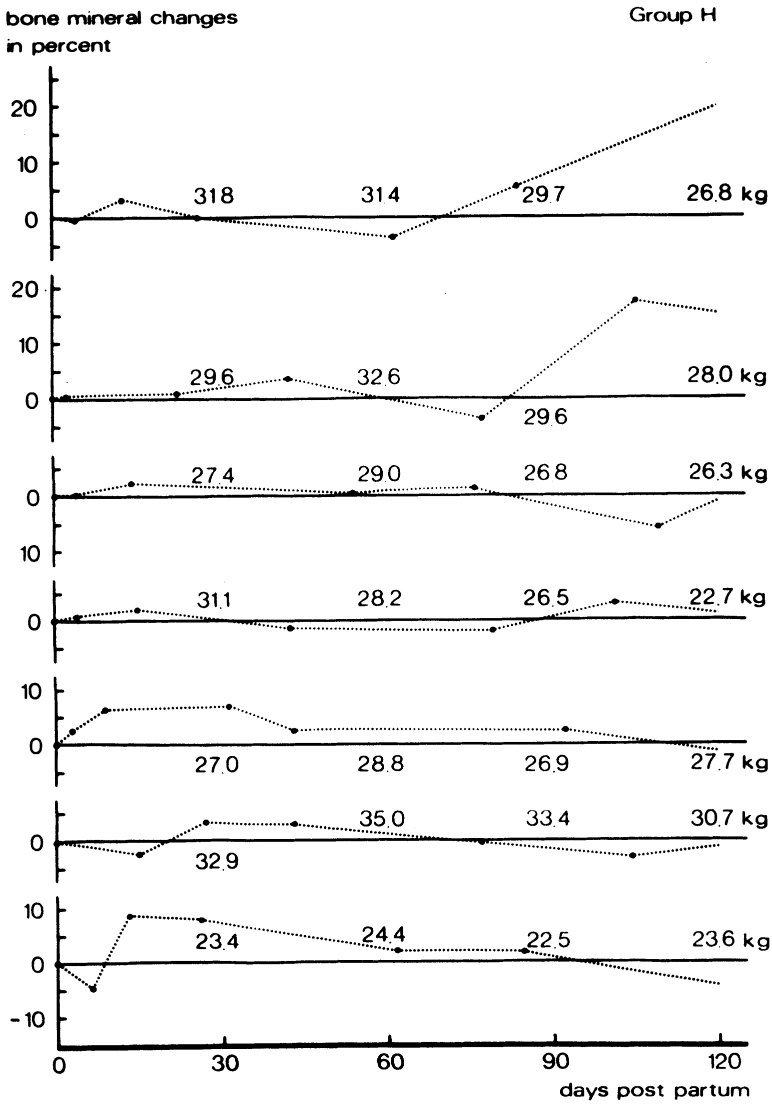
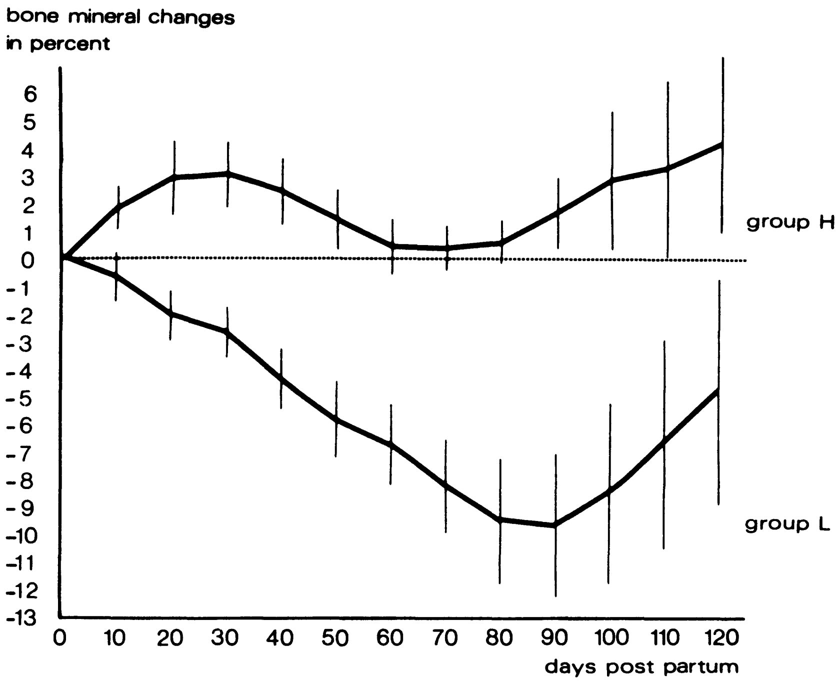


Figure 2. Group H. BMC for the individual animals in group H expressed in percentage difference between the calculated BMC on the day of calving and the BMC determined at various times. Daily milk yield in kg is indicated.



F i g u r e 3. The values (mean ± 1 s.e.m.) of BMC for the two groups. The values are given in percentage deviations from the BMC on the day of calving.

RESULTS

In group L the mean BMC decreased by about 10 % during the first 90 days of lactation. From 90 days to 120 days of lactation there was an increase in the mean BMC of about 6 %. In group H the mean BMC increased with 3 % during the first 30 days. It then decreased but increased again at about 80 days (Fig. 3).

There was a significant difference ($P < 0.01$) between the two groups at 60 days postpartum, but not at 120 days postpartum ($P > 0.05$).

As is seen from Figs. 1 and 2, six of the cows in group L lost some bone mineral during the first 90 days of lactation. Only in one animal there was no loss of bone mineral during this time. In group H there were five cows in which the BMC remained at about the level which it had immediately postpartum. There were two animals in which there was an evident increase in BMC from day 60 to 75.

Table 1. Group L. Milk yield in kg, Ca and P requirements according to Swedish standards, the amount of Ca and P given, and the difference in percentage between this and the Swedish and ARC standards, respectively. Blood analyses.

Days post partum	10	20	30	40	50	60	70	80	90	100	110	120
Milk yields in kg		28.4	28.7	27.9	29.0	29.8	29.3	28.4	27.8	27.3	27.0	26.9
Requirement according to Swedish standard												
Ca		110.8	111.6	109.5	112.4	114.5	113.2	110.8	109.3	108.0	107.0	106.9
P		77.1	77.7	76.2	78.2	79.6	78.7	77.1	76.0	75.1	74.6	74.4
Ca/P		1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Amount of given												
Ca		91.9	96.5	96.5	97.3	101.6	101.9	103.4	100.8	102.7	101.4	91.4
P		68.0	68.7	69.0	70.0	74.7	76.4	78.1	76.4	76.5	75.6	79.2
Ca/P		1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.2
Difference in percentage between given amount and Swedish standard												
Ca		—17	—14	—12	—13	—11	—10	—7	—8	—5	—5	—15
P		—12	—12	—10	—11	— 6	— 3	+ 1	± 0	+ 2	+ 1	+ 6
Difference in percentage between given amount and ARC standard												
Ca		—6	—2	± 0	—2	± 0	+ 2	+ 6	+ 5	+ 9	+ 8	—2
P		—8	—8	—6	—7	—3	+ 1	—5	+ 4	+ 6	+ 5	+ 11
Blood analyses												
Ca (mg/100 ml)			9.7			9.6		9.7			9.9	
P (mg/100 ml)			4.2			5.1		5.0			5.2	
Mg (mg/100 ml)			2.2			2.4		2.3			2.3	
Alk. phosphatase m.u./ml			10.0			12.3		13.3			7.5	

The results of the blood analyses are shown in Tables 1 and 2.

DISCUSSION

The present investigation demonstrates that it is possible to influence BMC by nutritional means during the peak of lactation.

The animals on low Ca feeding (group L) decreased their BMC. The ones which were on high Ca feeding (15—20 % higher than what is usually recommended in Sweden, group H) had an increase in BMC.

Within the two groups, the changes in BMC were not consistent. While five of the animals in group L had a slight decrease in BMC during the experiment, two had a rise in BMC from about day 90. There is a possible explanation for this. The two cows with rise in BMC had a more rapid decrease in milk

Table 2. Group H. Milk yield in kg, Ca and P requirements according to Swedish standards, the amount of Ca and P given, and the difference in percentage between this and the Swedish and ARC standards, respectively. Blood analyses.

Days post partum	10	20	30	40	50	60	70	80	90	100	110	120
Milk yields in kg		28.7	28.5	29.3	29.7	30.0	30.1	29.3	27.2	27.8	26.5	25.4
Requirement according to Swedish standard												
Ca		111.6	111.1	113.2	114.2	115.0	115.3	113.2	107.7	109.3	105.9	103.0
P		77.7	77.3	78.7	79.5	80.0	80.2	78.7	75.0	76.0	73.7	71.7
Ca/P		1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Amount of given												
Ca		124.2	128.6	131.3	132.7	133.4	137.4	138.3	131.8	130.6	128.6	119.9
P		86.4	94.0	94.4	95.4	95.7	107.0	107.5	109.4	109.2	104.0	108.6
Ca/P		1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.2	1.2	1.2	1.1
Difference in percentage between given amount and Swedish standard												
Ca		+ 11	+ 16	+ 16	+ 16	+ 16	+ 19	+ 22	+ 22	+ 20	+ 21	+ 16
P		+ 11	+ 22	+ 20	+ 20	+ 20	+ 33	+ 37	+ 46	+ 44	+ 41	+ 51
Difference in percentage between given amount and ARC standard												
Ca		+ 26	+ 32	+ 31	+ 31	+ 31	+ 34	+ 38	+ 40	+ 28	+ 40	+ 35
P		+ 16	+ 26	+ 25	+ 25	+ 24	+ 39	+ 42	+ 52	+ 49	+ 46	+ 57

Blood analyses						
Ca	mg/100 ml	10.0	9.7	9.8	9.9	9.9
P	mg/100 ml	5.4	4.2	5.5	5.5	5.2
Mg	mg/100 ml	2.2	2.3	2.4	2.3	2.2
Alk. phosphatase	m.u./ml	22.5	29.7	22.0	17.8	23.5

yield than the other cows during the last half of the experiment. As mineral supplementation was adjusted to the milk yield only every second week, a certain discrepancy between input and output of Ca may have arisen. In group H there were two cows which had a BMC at the end of the experiment slightly different from the ones of the other five animals. The increase in BMC in these two animals cannot be explained in terms of difference in milk yield or in different time of conception. It is likely, however, that there is a greater individual variation in BMC changes in animals on a very high Ca feeding than in animals which are fed a suboptimal amount of mineral.

Little can be said about the result of the various laboratory tests in the present investigation. One comment is necessary, however. The level of alkaline phosphatase in two animals of group H was high. This was apparently not due to the feed, as the level was consistently high both before and after the experiment.

The results of the present investigation is consistent with previous findings in balance studies on lactating cows (*Ellenberger et al.* 1931, *Stott* 1968).

Considering the fact that parturient paresis is one of the most important diseases in dairy herds, one question remains to be answered: What is to be preferred in lactating dairy cows? Decrease or increase in BMC? It would be logical to assume that decrease in BMC would prevent hyperostosis and osteopetrosis (*Zetterholm* 1972) from occurring and instead enhance bone remodeling. In this way, Ca should be more readily available when needed at start of lactation. As was shown previously, a decrease of BMC cannot be obtained during the dry period under field conditions.

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SAMMANFATTNING

Benmineralförändringar hos mjölkkor.
Effekten av låg och hög calciumutfodring under höglaktationen.

Benmineralinnehållet i två svanskotor hos 14 kor av SRB-ras mättes med dikromatisk foton absorptiometri. Undersökningen började vid kalvningen och fortsatte under 120 dagar. Varje djur erhöll kontrollerade mängder hö, ensilage och kraftfoder och avkastningen mättes och registrerades. Sju kor (grupp L) erhöll Ca och P ungefär enligt ARC-standarden. De andra 7 korna (grupp H) erhöll 30 % mer Ca och P än korna i grupp L. Benmineralinnehållet i grupp L minskade under de första 90 dagarna, därefter skedde en ökning. I grupp H ökade benmineralinnehållet under de 120 dagar som undersökningen omfattade. Undersökningen visar att Ca-dränaget under laktationen kan motverkas genom ett högt tillskott av mineralfoder under höglaktationen.

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