生物圏科学
Biosphere Sci.
54：99－111 (2015)

総　説

Osteoporosis in lactating dairy cows

Shigeru Yoshida
Professor emeritus

Graduate School of Biosphere Science, Hiroshima University,
Higashi-Hiroshima 739-8528, Japan

Abstract　Cows in a certain dairy herd were affected by abnormal milk secretion and the frequent occurrences of paresis. The younger cows, with 1 calving, had low magnesium (1.84 mEq) but high calcium (4.63 mEq) serum levels and the older cows, with more than 5 calvings, had low magnesium (1.68 mEq), low calcium (3.90 mEq), whereas control cows had normal levels of 2.00 mEq for magnesium and 4.28 mEq for calcium, respectively. In Cow 12, the blood serum magnesium levels decreased from 1.68 mEq to 0.64 mEq at the first onset of hypomagnesemic tetany. In Cow 1, the blood serum calcium levels decreased from 4.21 mEq to 1.42 mEq and the blood serum magnesium levels increased to 2.20 mEq from 1.39 mEq at the first onset of hypocalcemic coma. Before detectable changes, the cows were suffering from chronic hypomagnesemia. Blood samples of downer cows were obtained from 18 cows exhibiting paresis and semi-comatose state from other dairy farms. Their blood serum magnesium level was 1.54 mEq, and their blood serum calcium level was 3.40 mEq. Hypomagnesemic tetany is cause by a low intake of magnesium from roughage. This chronic hypomagnesemia of these cows must also be caused by a low intake of magnesium. Bone samples obtained from the cows from the dairy farm showed osteoporosis. Bone sample of Cow E had been fed highly concentrated the food at a private dairy farm for a year, and her osteoporosis was accelerated due to the excess of phytic acid in the food. Nephrocalcinosis was observed in some cows in the herd. Increased blood serum calcium in younger cows was released from the bone into milk and urine, which caused the bone demineralization, calcium accumulation in the kidney, and alcohol-positive milk, i.e. osteoporosis, nephrocalcinosis and “the Utrecht abnormality of milk”, respectively.
Key words: Osteoporosis, Hypomagnesemia, Grass tatany, Downer, Ketosis, Utrecht abnormal milk

INTRODUCTION

A certain dairy herd show a marked tendency to the higher occurrence of reproductive problems, such as increased incidences of abortion and stillbirth, when their milk quality were low fat content and/or low solid not fat. The dairy herd was also affected by parturient paresis. Milk and blood samples were collected from the cows throughout the year. Grass tetany (“hypomagnesemic tetany”), milk fever (“hypocalcemic coma”) and other unknown paresis often called “downer cow syndrome”, frequently

Accepted on September 9, 2015　＊ E-mail: yosida_sigeru@yahoo.co.jp

occur in lactating dairy cows. When a cow becomes grass tetany, her blood serum magnesium decreases to approximately one half of the normal values of 2 mEq (2.43 mg/dl). The cow falls down in a semi-comatose state and experiences slight convulsions of the hind leg. When a cow becomes milk fever, her blood serum calcium decreases to one half of the normal values of 4.28 mEq (8.56 mg/dl), and the cow enters a coma. When a cow is affected by any type of paresis, the cow (a so-called "downer cow") falls down in a semi-comatose state with or without convulsion of the hindquarters. Blood, bone, and various soft tissues were obtained from such cows in this study. This paper describes the occurrence of osteoporosis accompanied by chronic hypomagnesemia. The body weight of a normal Holstein cow is 650 kg. The cow yields 6,000 liters of milk and a calf with a weight of 50 kg yearly. One liter of milk contains 1 g of calcium and 0.1 g of magnesium. A calf contains 650 g of calcium and 16 g of magnesium. It is estimated that approximately 6,650 g of calcium and 616 g of magnesium are discharged from cow's body through the milk and calf in a year. A lactating dairy cow is always at risk for demineralization. One dairy cow contains 8,500 g of calcium and 159 g of magnesium in the bone, 44 g of magnesium in the muscle and 5 g of magnesium in various soft tissues, including the blood. It is calculated that the turnover is approximately 80 % for calcium and 300 % for magnesium in a year.

MATERIALS AND METHODS

Milk and blood samples were taken from lactating Holstein cows, Cow 1 to Cow 25, were fed at the dairy farm of Hiroshima University. Blood samples of 18 downer cows, 11 cows with milk fever and 54 control cows were taken from private dairy farms located near the university dairy farm. Bone and various soft tissues were collected from 12 lactating dairy cows (Cow 1～ Cow 8, Cow 13, Cow 14, Cow 19, Cow 20), other 2 lactating dairy cows (Cow 28 and Cow 30) and 2 heifers (H1 and H2) from the university dairy farm. Cow E was taken from the cow suffering from downer syndrome at the private dairy farm. A 1 ml sample of blood serum was incubated with 2 ml of 70 % $HClO_4$ in a micro-Kjeldahl flask at 130-160 ℃ in a glycerin bath. After the blood serum had dissolved, calcium and magnesium were determined by atomic absorption . One gram of soft tissues were wet ashed with 2 ml of 70% $HClO_4$. Ca, Mg, Na and K were determined in solution by atomic absorption. Mandible bones were obtained from a slaughter house and their connective tissues and muscles were removed from the bone after soaking in water at 90℃ for 2 h.

RESULTS

Hypomagnesemic Tetany and Chronic Hypomagnesemia

Table 1 shows the blood serum values of the cows yielding alcohol-positive milk. The milk shows a strong positive result for alcohol-induced coagulation for younger cows, and a strong positive result for heating-induced coagulation for older cows. Table 1 also shows that the blood serum magnesium levels of these cows were reduced by more than 10 % compared to control cows. Table 2 shows that the younger cows with 1 calving had high blood serum calcium (4.63 mEq) but low blood serum magnesium (1.84 mEq) levels compared to control cows, which had calcium and magnesium levels of 4.28 mEq and 2.00 mEq, respectively. On the contrary, the older cows with more than 5 calvings had low blood serum calcium (3.90 mEq), low blood serum magnesium (1.68 mEq) and high blood serum globulin (6.09 mg/dl) levels compared to controls. The increase in blood serum globulin had occurred concomitant with

Table 1. Milk quality and blood serum values for cows of the University dairy farm

Cow		Milk		Blood-Serum				
Cow NO	NO of calvings	A-test	H-test	Ca mEq	Mg mEq	Pi mg/dl	Al mg/dl	Gl mg/dl
1	12	+	++	4.21	1.39	8.52	2.87	6.48
2	10	+	+++	3.84	1.62	7.50	2.25	7.61
3	7	+	++	3.27	1.57	6.00	1.45	10.39
4	6	±	+	3.52	2.02	9.50	2.51	4.63
5	6	+	+	3.68	1.74	7.42	2.97	5.77
6	6	+	+	3.49	1.51	7.23	2.97	9.69
7	6	+	+++	4.25	1.97	7.40	3.65	4.72
8	5	++	+	4.08	1.77	6.73	3.20	3.37
9	5	++	±	4.28	1.66	6.66	3.19	4.39
10	6	+++	+	4.22	1.46	6.38	2.76	5.30
11	6	++	±	4.20	1.79	5.65	3.03	5.34
12	5*1	+++	++	3.70	1.68	6.98	3.29	5.42
13	4	++	+	4.35	1.85	8.50	3.01	4.98
14	4	+++	±	4.32	1.99	9.10	3.40	4.93
15	4	+++	± −	3.83	1.64	6.38	3.35	4.61
16	4	+++	++	4.25	1.78	7.84	2.80	6.42
17	2*1	+++	++	4.08	1.84	6.67	3.29	5.48
18	3	+++	+	4.06	1.97	6.27	3.65	4.27
19	2	+++	+	4.06	1.81	6.36	3.01	4.37
20	1	+++	±	4.63	1.83	5.28	3.47	4.75
21	2*1	+	±	4.69	1.82	7.13	3.46	3.84
22	1	+	+	4.51	1.97	6.38	3.76	4.36
23	1	++	+	4.63	1.84	6.80	2.82	4.28
24	1	++	+	4.60	1.67	7.80	3.57	4.26
25	1	++	+	4.69	1.92	6.68	3.57	4.05
average				4.14	1.76	7.09	3.09	5.29

*1 : including abortion, A-test : Alcohol test, H-test : Heating-test 100℃, 30 min..

Table 2. Blood serum values for cows from the university dairy farm and control cows.

	NO of cows	Ca mEq	Mg mEq	Pi mg/dl	Al mg/dl	Gl mg/dl
Control	54	4.28^{a}	2.00^{a}	7.81^{a}	3.13^{a}	4.23^{c}
Cows*1	25	4.14^{d}	1.76^{a}	7.09^{a}	3.09^{ns}	5.34^{a}
Old*2	12/25	3.90^{a}	1.68^{a}	7.16^{c}	2.85^{ns}	6.09^{b}
Middle*3	7/25	4.14^{d}	1.84^{b}	7.30^{ns}	3.22^{ns}	5.01^{c}
Young*4	6/25	4.63^{d}	1.84^{c}	6.68^{d}	3.44^{ns}	4.26^{ns}

*1 : Cows from the university dairy farm.
*2 : Old cows, produced more than 5 calves.
*3 : Middle cows, produced 2-4 calves.
*4 : Young cows, produed 1 calf.
ns : not significant, a : P<0.01, b : P<0.02, c : P<0.05, d : P<0.1
P : calculated by t-test.

blood serum magnesium levels less than 1.7 mEq in the cows from the university dairy farm. The increased blood serum globulin was observed in the older cows, such as Cow 3 (7 calvings, 10.39 mg/dL), Cow 6 (6 calvings, 9.69 mg/dl) and Cow 2 (10 calvings, 7.61 mg/dl). Those globulin levels were very high compared with the normal serum globulin level of 4.58 mg/dl, as shown in Table 2. These results were plotted as (○) for older cows, (△) for younger cows, (□) for intermediate and (●) for control cows in Figure 1.

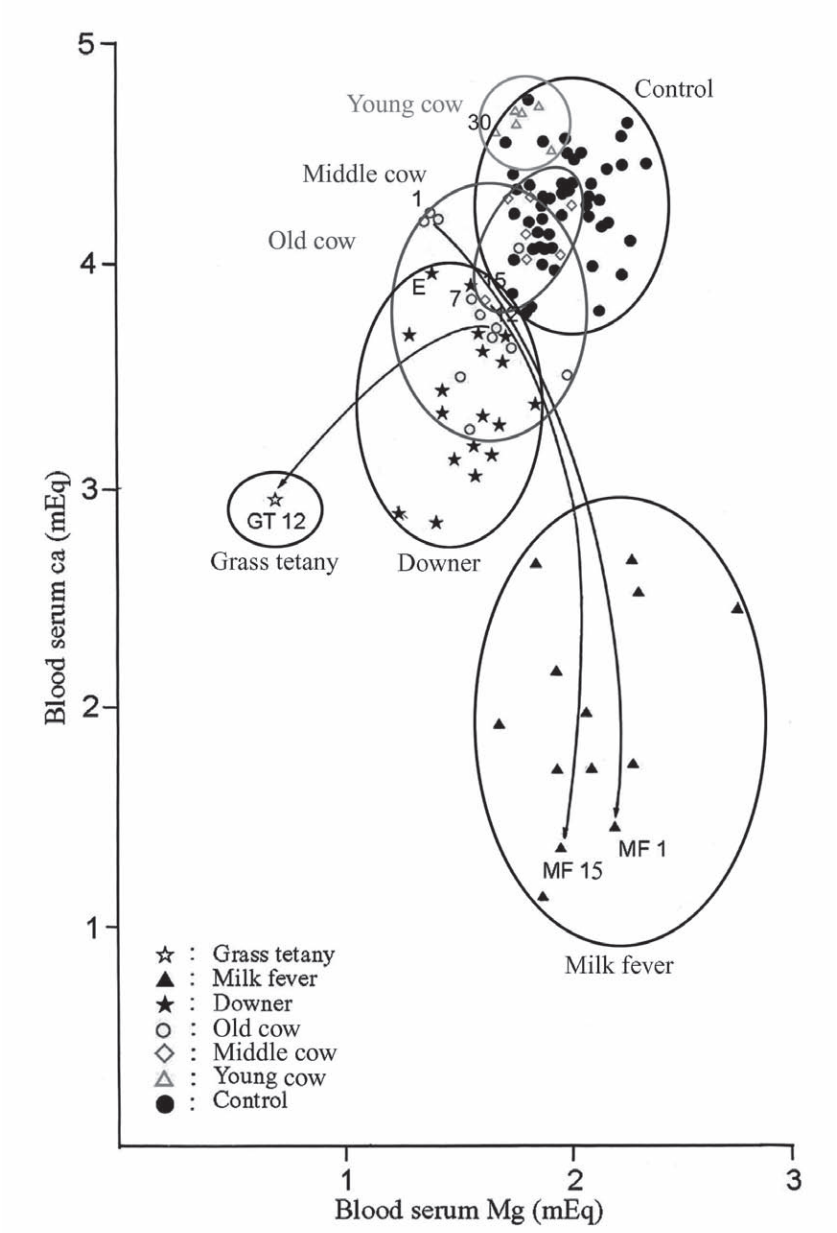

Fig. 1. Relationship between Blood serum Ca and Mg of Cows suffering from Abnormal milk, Grass tetany, Milk fever, and Downer, compared with Control cows.

Cow 12 had grass tetany, while Cow 1 and Cow 15 had milk fever. Figure 2 shows the serum change of Cow 12 before (○:12) and after (☆:GT 12) she became grass tetany. Cow 12 also suffered ketosis, when she became tetanic. Figure 2 also shows the serum changes for Cow 1 and Cow 15 before (○:1, ○:15) and after (▲:MF 1, ▲:MF 15) they became milk fever. In Cow 1, the blood serum calcium level decreased to 1.42 mEq from 4.21 mEq, and the blood serum magnesium level increased to 2.20 mEq from 1.39 mEq. In Cow 15, the blood serum calcium level decreased from 3.83 mEq to 1.32 mEq, and the blood serum magnesium level increased from 1.64 mEq to 2.00 mEq. At the time of milk fever, the blood serum calcium level was reduced to one half the normal value, however, the blood serum magnesium level increased concomitant with the first onset of this disease. The mandible bones were shown in Fig. 4 for Cow 1 and Fig. 5 for Cow 12.

Eleven other blood samples (▲) from milk fever, were obtained from several private dairy farms after the first onset of the disease. These cows also had a low blood serum calcium level (2.03 mEq) but a normal blood serum magnesium level (2.08 mEq). Three of the 13 milk fever also developed ketosis. Eighteen other blood serum samples (★) were taken from cows suffering from unknown paresis and were obtained from several private dairy farms with the help of a veterinarian. Those cows were called downer cows but they did not have grass tetany or milk fever. The blood serum magnesium level was 1.54 mEq and the blood serum calcium level was 3.40 mEq. The downer cows suffered from chronic hypomagnesemia and mild hypocalcemia in turn. Fifteen of the 18 cows of downer cows also developed ketosis as shown in Figure 1. Figure 1 also shows that the blood serum calcium and blood serum magnesium for Cow 7, Cow 8, and Cow E. Cow 7 and Cow No 8 were kept at the university dairy farm and Cow E was from the nearby private dairy farm. These cows suffered from chronic hypomagnesemia. Osteoporosis in these cows is described in the figure.

The younger cows showed a decrease in blood serum magnesium levels but an increase in blood serum calcium levels, while the older cows showed a greater decrease of blood serum magnesium levels, a decrease of blood serum calcium levels and an increase of blood serum globulin levels. Table 1 and Table 2 show that the increase in blood serum globulin occurred concomitant with blood serum magnesium levels less than 1.7 mEq in the certain dairy farm. The increased blood serum globulin levels were observed in the older cows, such as Cow 3 (7 calvings, 10.39 mg/dl), Cow 6 (6 calvings, 9.69 mg/dl), Cow 2 (10 calvings, 7.61 mg/dl), and Cow E (7 calvings, 8.60 mg/dl). Those globulin levels were very high compared with the normal serum globulin level of 4.58 mg/dl, as shown in Table 2.

Osteoporosis

Mandible bone was obtained from Cow 7 (8 calvings). Many reddish-brown spots were observed on the surface of the *compacta* of the mandible bone of lateral aspect, and medial aspect. These spots were attributed to many capillary vessels in the *Haversian* canal being engorged with blood because of the increased demineralization. This phenomenon was also observed in the bones of the whole body, especially the vertebrae, rib, and jaw bone. The incisor was broken as shown in this Figure 2. Figure 2 also show the demineralization site of the medial aspect. This medial aspect and the alveolar part were not covered with muscle but with connective tissue. The occipital aspect of the mandible bones clearly was porous, as shown in Figure 6. The serum values of these cows before slaughter are shown in Table 4. The younger Cow 28 also shown Osteoporosis as in Figure 3.

Fig. 2. Mandible bone of Cow 7 (8 calvings)

Fig. 3. Mandible bone of Cow 28 (1st calving)

Fig. 4. Mandible bone of Cow 1, suffering from Milk fever (11 calvings)

Fig. 5. Mandible bone of Cow 12, suffering from Grass tetany (5 calvings)

Nephrocalcinosis

Accumulation of calcium in the kidney medulla layer was observed in many of the cows, such as Cow 8 (34.67 mEq/kg), Cow 4 (19.63 mEq/kg) as shown in Figure 8. The calcium contents of other cows was higher than 10 mEq/kg, including Cow 14 (12.67 mEq/kg), Cow 28 (12.79 mEq/kg), and Cow 19 (10.81 mEq/kg). Normal values were approximately 5 mEq/kg, based on values from H1 (4.18 mEq/kg) and H2 (6.24 mEq/kg), which were not lactating dairy cows but heifers. The magnesium content in the kidney cortex layer was 11.67 mEq/kg and this levels was lower than heifer, as shown in Table 4.

Table 3. Blood serum values for cows suffering from Grass tetany, Milk fever, Downer cows and suffering from Ketosis.

	NO of cows	Ca mEq	Mg mEq	Pi mg/dl	Al mg/dl	Gl mg/dl
Control	54	4.28[a]	2.00[a]	7.81[a]	3.13[a]	4.23[c]
Grass tetany	1	2.29	0.64	7.01		
Milk fever	13	2.03[a]	2.08[ns]	2.45[a]	3.03[ns]	5.59[a]
Downer	18	3.40[a]	1.54[a]	5.05[c]	2.53[a]	5.83[a]

[ns] : not significant, [a] : P<0.01, [c] : P<0.05, P : calculated by t-test.

Table 4. Blood serum value of the cows just before slaughter, shown in Figure 2-6

Cow NO	NO of calvings	Ca mEq	Mg mEq	Pi mg/dl	Al mg/dl	Gl mg/dl
Cow 7	8	3.85	1.59	5.99	2.80	7.97
Cow 30	1	4.31	1.90	7.13	3.54	3.38
Cow 12 at aliving	7	3.70	1.68	6.98	3.29	5.42
after Grass tetany		2.29	0.64			
Cow 1 at aliving	11	4.21	1.39	8.52	2.87	6.48
after Milk fever		1.42	2.20	4.82	2.94	6.35
Cow E	7	3.90	1.42	4.05	2.04	8.60

Table 5. Ca and Mg contents of soft tissues and bone ash of Cows

	NO of cows	Ca (mEq/kg)	Mg (mEq/kg)
Kidney cortex	14	3.33	11.67
Kidney medulla	14	10.66	10.46
Skeletal muscle	14	2.71	14.59
Cardiac muscle	14	2.25	17.26
Liver	14	1.88	13.57
Kidney cortex[*1]	2	3.29	13.28
Kidney medulla[*1]	2	5.21	10.32
Mandible bone[*2]	12	36.44(%)	0.682(%)
Candal vertebrae[*2]	12	36.46(%)	0.683(%)

[*1] : heifer
[*2] : in bone ash

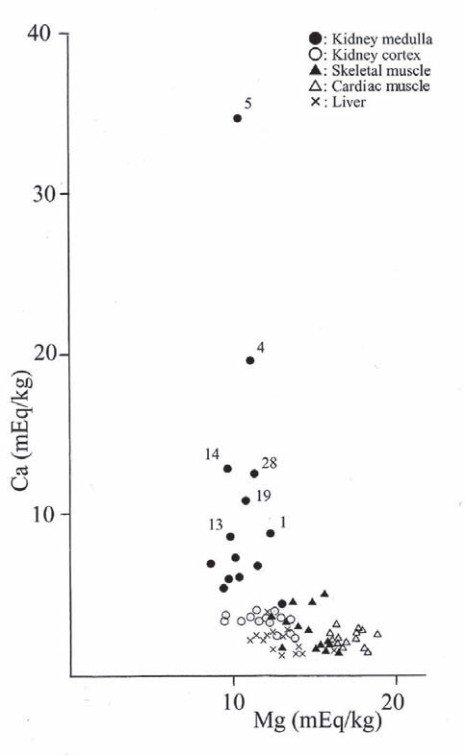

Fig. 6 Relationship between Ca and Mg in Soft tissues

DISCUSSION

The blood serum levels for the certain dairy herd were 1.78 mEq for magnesium, 4.14 mEq for calcium and 5.29 mg/dl for globulin. These magnesium and calcium values were low compared with the control values of 2.00 mEq for magnesium and 4.28 mEq for calcium, but the value for globulin was high compared to the control (4.58 mg/dl). The blood serum for younger cows with 1 calving in the dairy herd showed low magnesium (1.84 mEq), high calcium (4.63 mEq), and normal globulin (4.26 mg/dl) levels. The blood serum for older cows with more than 5 calvings showed low magnesium (1.68 mEq), low calcium (3.90 mEq) and high globulin (6.09 mg/dl) levels. Grass tetany and milk fever had occurred in these older cows. The hypomagnesemic Cow 12 showed very low blood serum magnesium (0.64 mEq) levels. The hypocalcemic cows, Cow 1 and Cow 15, showed blood serum calcium levels less than one half of normal but had normal blood serum magnesium levels at the first onset of the disease. When the blood serum calcium levels suddenly decreased, their blood serum magnesium levels increased. Before these cows were affected by these changes in mineral levels, their blood serum magnesium levels had been at moderately low levels for many years. This dairy herd was suffering from chronic hypomagnesemia. It had been reported that grass tetany was caused by magnesium deficiency as Voisin (Voisin, 1963). The so-called chronic hypomagnesemia must also be caused by low magnesium intake. A decrease in blood serum magnesium had also been described in cows suffering from chronic magnesium deficiency as Onderscheka (Onderscheka *et al.,* 1967). Downer cows also showed low blood serum magnesium levels at 1.54 mEq (1.17～1.89 mEq) and low blood serum calcium levels at 3.40 mEq (2.83

～3.90 mEq). In downer cows, blood serum magnesium and calcium levels were not lower than those of the grass tetany and milk fever cows, respectively. Downer cows also suffered from chronic hypomagnesemia. Some reports were concerned for mgnesium and milk fever (Sanson *et al*, 1981) and subclinical hypomagnesaemia (Whitaker and Kelly, 1982), however, there is no description for osteoporosis and abnormal milk.

Bone showed typical patterns of osteoporosis and their kidneys showed calcium accumulation, so-called nephrocalcinosis. However the magnesium contents of these bones and kidneys were normal. It was reported that the magnesium content in bones of cows that died from grass tetany was not reduced as Voisin (Voisin, 1963). The younger cows in the university dairy farm had been suffering from chronic hypomagnesemia and osteoporosis as shown in Fig. 3. These cows showed a slight decrease in serum magnesium levels but a slight increase of serum calcium levels during the initial period. Increased calcium must flow from bones to the milk and urine, resulting in bone demineralization, calcium accumulation in the kidney, and alcohol-positive milk, i.e. osteoporosis, nephrocalcinosis and "the Utrecht abnormality of milk" as Boogaerdt (Boogaerdt, 1954), respectively. The older cows showed a greater decrease in blood serum magnesium levels, a decrease in blood serum calcium levels and an increase in serum globulin levels during the secondary period. Calcium must have been lost, and their osteoporosis increased. The increased globulin must indicate osteoporosis. The role of increased globulin is not clear, but the author hypothesizes that globulin levels may regulate the calcium and magnesium levels in blood serum.

The nephrocalcinosis was consistent with some reports of magnesium deficient animals. (George *et al,* 1974, Goulding and Malthus, 1968, MacIntire and Davidsson, 1958, Martindale and Heaton, 1964, Maynard *et al,* 1958). It was reported that the blood serum magnesium levels rapidly decreased on the first day of a low magnesium diet in rats, while their blood serum calcium levels slowly increased as George (George *et al*, 1974).

One paper reported that cows with chronic magnesium deficiency also suffered from the accumulation of calcium in the kidney and a decrease in blood serum magnesium as Onderscheka (Onderscheka *et al*, 1967).

The experimental animals were fed a special diet, such as a magnesium-free diet or one with a very low magnesium content, however, the lactating dairy cows had been fed an average diet. The lactating dairy cows had received slightly less than the minimum requirement of magnesium for many years, and the cows with high milk yield needed high levels of magnesium. It seems that the lactating dairy cows in the certain dairy farm had experienced chronic hypomagnesemia with high blood serum calcium for many years. In previous studies, it was shown that the magnesium contents of the bones of magnesium-deficient experimental animals declined as MacIntire (Macintire and Davidsson, 1958) and Martindale (Martindale and Heaton, 1964), however, osteoporosis and the elevation of blood serum globulin has not been previously reported.

The cows of the university dairy farm suffer from chronic hypomagnesemia caused by a shortage of magnesium intake from roughage. Legumes, such as alfalfa and clover, are rich in magnesium, which constitutes more than 0.3% of their DM. In contrast, grass, such as timothy and ryegrass, is poor in magnesium, which represents less than 0.2% of the DM. A. Kemp (Kemp, 1960) recommended a magnesium content greater than 0.2% of the DM of the roughage for lactating dairy cows to prevent grass tetany. The manager of the university dairy farm was responsible for failing to give legumes to lactating dairy cows for many years. All of the cows from the university dairy farm showed

osteoporosis. Reproductive disorders, such as paresis, abortion, and stillbirth, were observed in cows at this dairy farm. Many cows were suffering from renal cysts, kidney stones, and atorophy.

Cow E had been given a high-concentrate diet with a shortage of roughage at the private dairy farm. The chronic hypomagnesemia was caused by a low magnesium intake from roughage and the osteoporosis was accelerated by the excess of phytic acid in the food. The lactating dairy cows had been fed with various concentrates with high phosphorus contents. Calcium carbonate was used as a feed additive and the herd had no shortage of calcium. A.Kemp (Kemp, 1960) also noted that an excess of calcium and phosphorus can reduce the availability of magnesium.

Lactating dairy cow, she produce 6000 kg of milk and a calf every year, is the economic farm animal. If she once fall down osteoporosis, the recovery is very difficult on the case of lactating dairy cow. The importance must be the prevention before the cow fall osteoporosis. The lactating dairy cow must be fed roughage, containing the legume more than 1/3 and the grass less than 2/3, for prevent osteoporosis

CONCLUSION

Grass tetany and chronic hypomagnesemia in cows must be caused by the shortage of magnesium in the diet. Hypocalcemic cows and downer cows were also suffering from chronic hypomagnesemia before they were affected by perturbations in mineral levels. Younger cows showed a slight decrease of serum magnesium levels but a slight increase of serum calcium levels. The increased calcium must be transferred from the bones to the milk and urine. This results in bone demineralization, calcium accumulation in the kidney, and alcohol-positive milk, i.e. osteoporosis, nephrocalcinosis and “the Utrecht abnormality of milk”, respectively. The older cows showed a greater decrease in blood serum magnesium levels, a decrease of blood serum calcium levels and an increase of serum globulin levels during the secondary period. Calcium must also have been lost from their bones, increasing their osteoporosis. The decreased magnesium levels, increased calcium levels in the blood serum and nephrocalcinosis of younger cows was consistent with the findings in magnesium-deficient animals, however, decreased calcium and increased globulin levels in the blood serum of older cows and osteoporosis in lactating dairy cows were not observed in the experimental animals.

ACKNOWLEDGMENTS

The author wish to thank veterinarians for collecting blood samples with this study.

REFERENCES

Boogaerdt, J., 1954. Instability of Milk due to a High Content of Calcium Ions. *Nature* **174**: 884.

George, E., Wang, B., Nelson., L., Price, O., Greenstreet, R., 1974. Distribution of calcium and magnesium in rat kidney homogenate fractions accompanying magnesium deficiency induced Nephrocalcinosis. *Experimental and Molecular Pathology* **21**: 16-28.

Goulding, A., Malthus, R. S., 1968. Effect of dietary magnesium on the development of nephrocalcinosis in rats. *Journal of Nutrition* **97**, 353-358

Kemp, A., 1960. Hypomagnesaemia in milking cows: The response of serum magnesium to alterations in

herbage composition resulting from potash and nitrogen dressings on pasture. *Netherland Journal of Agricultural Science* **8**: 281-304.

MacIntire, I., Davidsson, D., 1958. The production of secondary potassium depletion, sodium retention, nephrocalcinosis and hypercalcaemia by magnesium deficiency. *Biochemical Journal* **70**: 456-462

Martindale, L., Heaton, F. W., 1964. Magnesium deficiency in the adult rat. *Biochemical Journal* **92**: 119-126.

Maynard, L. A., Boggs, D., Fisk, G., Seguin, D., 1958, Dietary mineral interrelations as a cause of soft tissue calcification in guinea pigs. *Journal of Nutrition* **97**: 64-96.

Onderscheka, K., Laber, B., Szekely, H., Binder, K., 1967. Chronischer Magnesiummangel bei Kuhen. *Wien. WIENER TIERARZTLICHE. MONATSSCHRIFT* **4**: 219-236

Sansom, B., Manston, F. R., Vagg. M. J., 1983. Magnesium and milk fever. *Veerinary Record* **110**: 447-449.

Tufts, E. V., Greenberg, D. M., 1937. The biochemistry of magnesium deficiency, 1.chemical changes resulting from magnesium deprivation. *Journal of Biological Chemistry* **122**: 693-714.

Voisin, A., 1963. Grass Tetany, Crosby Lockwood & Son LTD., London, UK.

Whitaker. D. A., Kelly, J. M., 1982. Incidence of clinical and subclinical hypomagnesaemia in dairy cows in England and Wales. *Veterinary Record* **110**: 450-451.

Explanations of Figure and Table

乳牛に発生した骨粗鬆症

吉田　繁
広島大学名誉教授

広島大学大学院生物圏科学研究科，東広島市 739-8528

要　旨　全ての搾乳牛がアルコール試験で凝固，ときには熱凝固する低酸度二等乳の集団発生がみられた。この現象は1940年代にオランダで発生した “The Utrecht abnormality of milk” と同一の現象であった。とくに若い牛はアルコール試験に強く反応し，老齢牛は熱凝固する傾向が見られた。牛乳と同時に血液を採取したところ，正常値 Ca 4.28meq，Mg 2.00meq，Gl 4.23 mg/dl に対して，平均値で Ca 4.14 mEq，Mg 1.74 mEq と血清 Mg が低い傾向がみられた。 なかでも若い牛は血清 Ca 4.63 mEq が高く血清 Mg 1.84 mEq が低い，老齢牛は血清 Ca 3.90 mEq，血清 Mg 1.68 mEq 共に低く血清 Gl 6.09 mg/dl が高い傾向がみられた。淘汰された乳牛の骨は骨粗鬆症（Osteoporosis）を呈し，腎臓結石がみられ腎臓髄質部分に Ca の沈着がみられた。この乳牛群を追跡したところ乳熱（Hypocalcaemia），グラステタニー（Hypomagnesemia），ケトージスが発生した。この乳牛群にグラステタニーが発生したことは血清 Mg が低いことと密接な関係があり，祖飼料中の Mg 不足に起因することが推定された。 乳牛のグラステタニーは粗飼料中の Mg 不足であることが知られている。

動物実験では Mg 欠乏食を与えると直ちに血清 Mg は直ちに低下し血清 Ca は上昇すると報告されている。さらに Mg 欠乏の実験動物では腎臓の石灰化が報告されていることもよく一致する。しかし高齢牛のような血清 Ca と血清 Mg の減少と血清 Gl の増加は報告されていない。これは動物実験では殆ど Mg を含まない飼料を投与するのに対し，乳牛では必要量よりもやや低い Mg を含む粗飼料で長期間飼育し、妊娠・出産・泌乳を繰り返す為と考えられる。さらに骨粗鬆症，ケトージス，起立不能症などについては殆ど知られていない。

キーワード：骨粗鬆症，低 Mg 血症，慢性低 Mg 血症，グラステタニー，起立不能症，低酸度二等乳，乳熱，低 Ca 血症