

Changes in the concentration of selected minerals in milk and blood of high-milking cows during lactation

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Abstract: *Changes in the concentration of selected minerals in milk and blood of high-milking cows during lactation.* The aim of this research was the analysis of the content of calcium, phosphorus and magnesium in milk and blood of Polish Holstein-Friesian (PHF) milking cows during full lactation. The research was conducted on 100 PHF cows during two years (50 cows in each year). Samples of milk and blood were taken in each month of lactation (10 samples) in order to determine minerals concentration. Additionally, samples of forage were pooled out. Study revealed that the level of calcium in the feed is too low, the level of phosphorus – optimal, whereas the content of magnesium exceeds animal demand. There were significant differences in the content of calcium, phosphorus and magnesium in the consecutive months of cows' lactation. The content of minerals in blood was normal; similar situation was observed in the case of the calcium and phosphorus in milk, with the exception of milk magnesium concentration, which was too low and most diversified during the lactation.

Key words: minerals, blood, milk

INTRODUCTION

The concentration of minerals in the blood can diagnose many diseases, such as pasture tetany, kidney disease or postnatal paralysis (Kowalski 2012). In turn, their content in milk is important in

processing, it is also a direct indicator of the quality of the raw material and milk products, and indirect indicator of environmental pollution (Brodziak 2011). Minerals affect the physical properties of the milk and the stability of the proteins. Increasing concentration of magnesium ions reduces the thermal stability of milk protein (Jaworski and Kuncewicz 2008). The amount of calcium determines the suitability of milk for cheese production and the magnesium participates in the construction and activation of enzymes (Król et al. 2006, Kuczyńska 2011).

According to Soszka (2012), there are numerous papers on the mineral nutrition of dairy cows. Few, however, is a work depicting the interrelationships between minerals. Most balanced minerals are calcium and phosphorus, less magnesium. Appropriate calcium to phosphorus ratio is very important in the prevention of metabolic diseases, which often occurs in dairy herds. Mineral content in milk is variable and depends on many factors (genetic and environmental) (Dymnicka 1998). According to Jaworski and Kuncewicz (2008), skimmed milk has a mineral content as follows (in mg per

100 cm³): Ca – 100–140, P – 75–110 and Mg – 75–110.

The aim of this research was to analyze the mineral content in the milk and blood of high-yielding cows during full lactation and to determine the relationship between them.

MATERIAL AND METHODS

The experiment was conducted at the Agricultural Experimental Farm at Wilanów-Obory.

Cows were kept in free-stall system and were fed Total Mixed Ration (TMR) adapted to milk performance. TMR included: corn silage, hay silage, alfalfa hay silage, corn silage, straw and ration appropriate for the technology group. The organoleptic evaluation confirmed good feed quality. Feeds have a pleasant smell, the right color, hay and silage well preserved. The composition of the rations is presented in Table 1.

TABLE 1. Daily ration for experimental cows (kg)

Feeds	TMR-1	TMR-2	TMR-3
Corn silage	28	23	20
Grass silage	–	–	–
Alfalfa haylage	8.5	10	15
Corn grain silage	5.8	4.4	1
Concentrate	7.76	5.1	2.2
Straw	–	0.7	1

TMR-1 was prepared for cows with daily milk yield of 39 kg, TMR-2 for cows with a capacity of 28 kg, while TRM-3 for cows with a yield of 18 kg of milk. Total mixed rations were supplemented with tray elements and vitamins according to cows requirements. The research was conducted on 100 PHF cows during

two years (50 cows in each year). Samples of milk and blood were taken (at the same day) in each month of lactation (10 samples) in order to determine minerals concentration. Additionally, samples of forage were pooled out.

Milk samples were collected in accordance with the requirements of PN-EN ISO 707:208 from the evening milking (250 ml) into sterile plastic containers containing Mlekostat CC preservative. The samples were transported to the Laboratory Milk Evaluation at the Department of Animal Breeding.

Blood was collected from the tail vein. The sample containing 1 ml of blood and the preservative was transported to the Laboratory of the Veterinary Medicine Faculty. Blood minerals (calcium, phosphorus and magnesium) were determined by biochemistry analyzer BT-200 (Cormay).

The milk samples minerals were determined test strips by REFLEKTOQUANT Merck.

Statistical analysis were performed using IBM SPSS 21.0 statistical package.

To estimate the impact of the analyzed factors on minerals blood and milk concentration two-way analysis of variance was used (GLM procedure) by following model:

$$Y_{ijk} = \mu + R_i + P_j + (R \times P)_{ij} + e_{ijk}$$

where:

Y_{ijk} – variable;

μ – average general;

R_i – influence of year, $i = 1, 2$;

P_j – the effect of the j lactation month, $j = 1, 2, 3, \dots, 10$;

$(R \times P)_{ij}$ – the effect of the lactation month and year interaction;

e_{ijk} – random error.

To determine the relationship between the minerals in the blood and milk, and between minerals and other constituents of milk Pearson correlation was calculated.

RESULTS AND DISCUSSION

Table 2 presents a comparison of the demand and minerals intake of cows depending on their daily performance. It contains information on the coverage of the daily requirement of the animals.

Comparing calcium intake and animals requirements, it was observed, that the requirement coverage fluctuates

around 74.64–86.13%. This indicates inadequate cover of the animals needs.

The coverage ratio for phosphorus was lowest in cows with the lowest productivity. Cows fed TMR-1, producing 40 kg of milk per day, had covered 114% of their requirements. Analyzing the values shown in Table 5 it can be seen that the animals magnesium supply was above the norm and ranges between 128 and 132%.

Mineral content in the blood

Figure 1 presents the amount of calcium in the blood of cows during the 10 consecutive months of lactation. The results

TABLE 2. Minerals requirement and consumption

Milk performance (kg)	Requirement (g)			Consumption (g)			Coverage of requirement (%)		
	Ca	P	Mg	Ca	P	Mg	Ca	P	Mg
17.5	111	60.5	23.5	95.6	55	31.1	86.13	90.91	132.17
27.5	138	75.5	29.5	103	77.6	38.2	74.64	102.78	129.42
40	163	88.5	37	136	101	47.4	83.44	114.12	128.05

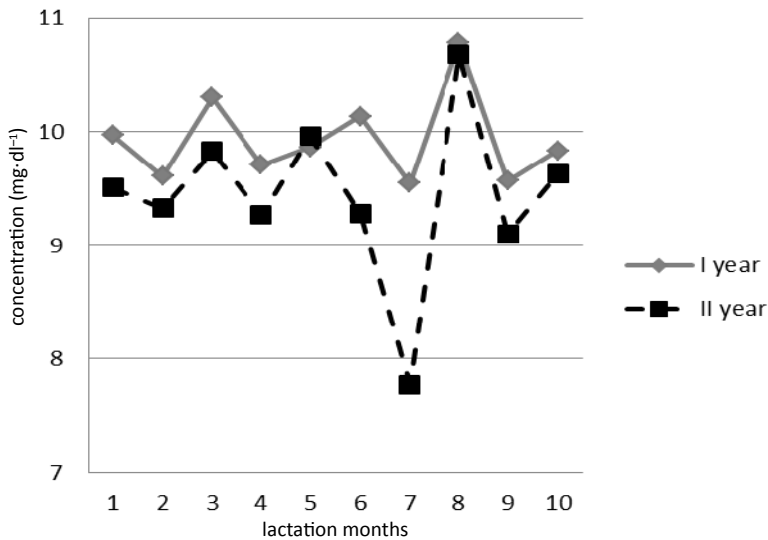


FIGURE 1. The blood calcium content of the cows

in both the first and second year of the experiment were in the range of 7.777 to 10.783 mg·dl⁻¹. A statistically significant difference in the blood Ca content between lactation months ($P \leq 0.01$) and the years, was observed. The reference values given by Winnicka (2011) range from 9.00 to 12.10 mg·dl⁻¹.

In both the first and second year of experience in the seventh month of lactation, the lowest content of Ca was found in the blood, 9.547 mg·dl⁻¹ in the first year and 7.777 mg·dl⁻¹ in the second year, respectively. However, in the eighth month of lactation blood contained the highest content of Ca. In the first year of the experiment observed value 10.783 mg·dl⁻¹, and the second 10.684 mg·dl⁻¹, respectively. Study revealed that the Ca content in the blood of cows was normal, except for the its concentration in the seventh month (7.777 mg·dl⁻¹) in the second year of the study. According to Winnicka (2011), analysis of the Ca content in the blood helps diagnose kidney malfunction, parathyroid and

pancreas dysfunction. However, clinical hypocalcemia, due to a decrease in blood Ca levels below 5 mg·dl⁻¹, is the main cause of *post partum* retention – a frequent problem of many breeders. The obtained results indicate that the animals were not at risk due to the Ca content in the blood.

Figure 2 presents the content of phosphorus in the blood of cows during 10 consecutive months of lactation. The results obtained in the first and second year of experience fluctuated between 5.309 and 7.005 mg·dl⁻¹. There were a statistically significant differences in the content of P in the blood between successive months of the first ($P \leq 0.01$) and second ($P \leq 0.05$) year of the study. Statistically significant differences in the contents of the P in the blood between the years stated in the following months of lactation: fourth, seventh and tenth ($P \leq 0.01$), as well as the fifth and eighth ($P \leq 0.05$). Winnicka (2011) stated that values are correct for cattle at a level of 5.6–6.5 mg·dl⁻¹.

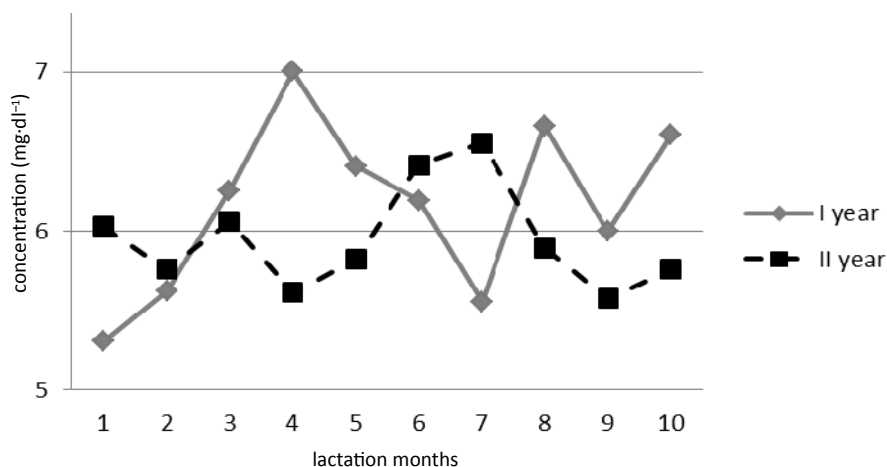


FIGURE 2. The content of phosphorus in the blood of cows

The lowest phosphorous content in the first year of the study was found in the first month of lactation, it was $5.309 \text{ mg}\cdot\text{dl}^{-1}$, while in the second year – the lowest value of $5.575 \text{ mg}\cdot\text{dl}^{-1}$ was observed in the ninth month. Study revealed that the highest content of P was observed in fourth month of the first year of the study and the seventh month the second year (7.005 and $6.556 \text{ mg}\cdot\text{dl}^{-1}$, respectively). Researches confirmed that P content in the blood was physiologically normal, with the exception of the level of $5.309 \text{ mg}\cdot\text{dl}^{-1}$ observed in the first year of the study. Winnicka (2011) reported the content of phosphorus in the blood can be helpful in the diagnosis of hyperparathyroidism and thyroid dysfunction. Jamroz (2001) indicates that P level it is not accurate source of information, since the element concentration in the blood is dependent on the concentration of Mn, Mg and Cu in the feed.

Figure 3 presents the concentration of magnesium in the blood of cows during 10 consecutive months of lacta-

tion. The results obtained within two years of research range from 1.769 to $2.555 \text{ mg}\cdot\text{dl}^{-1}$. There was a statistically significant differences in the content of magnesium in the blood between following months of lactation: first, second, fourth, fifth, eighth, ninth and tenth ($P \leq 0.01$) and sixth ($p \leq 0.05$) and the years. The reference values given by Winnicka (2011) ranged from 1.90 to $3.00 \text{ mg}\cdot\text{dl}^{-1}$.

The lowest concentration of the Mg was observed in the first year of the study reported in the eighth month of lactation ($1.769 \text{ mg}\cdot\text{dl}^{-1}$), while in the second year of the study the lowest value was reported in the seventh month of lactation ($2.023 \text{ mg}\cdot\text{dl}^{-1}$). The highest concentration of Mg in the first year of the experiment was $2.538 \text{ mg}\cdot\text{dl}^{-1}$ and was recorded in the third month of lactation, and in eight months ($2.555 \text{ mg}\cdot\text{dl}^{-1}$) in the second year of the study. The results revealed that the Mg content in the blood of analyzed cows was physiologically normal. Symptoms of tetany may occur

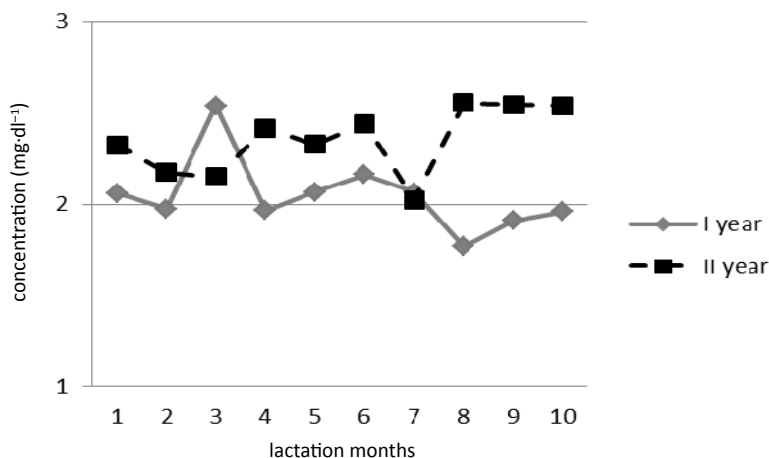


FIGURE 3. The content of magnesium in the blood of the cows

when magnesium concentrations fall below $1.7 \text{ mg}\cdot\text{dl}^{-1}$.

To conclude that the studied mineral content in the blood of the test animals were ranged within normal limits (with just a few exceptions). Low feed coverage for Ca was not reflected in its concentration in the blood.

Mineral content in the milk of cows

Figure 4 presents the calcium content in milk of cows during 10 consecutive month of lactation.

The results of milk Ca concentration obtained in the experiment of both the first and second year of the experiment are in the range of 598 to $1096.6 \text{ mg}\cdot\text{l}^{-1}$. There were a statistically significant differences in Ca concentration in the milk between successive months ($P \leq 0.01$) and between successive years. According to Gabryszczuk et al. (2010), the calcium content in milk varies from 600 to $1200 \text{ mg}\cdot\text{l}^{-1}$. Research conducted by Kuczyńska (2011) indicated that contents of the Ca in milk was aver-

aging $1020 \text{ mg}\cdot\text{l}^{-1}$. According to the researchers conducted by Krzyżewski et al. (2009), the content of calcium in 100 g of milk was 119 mg . Similar results were presented by Kuczyńska et al. (2009). Lower Ca concentration of PHF breed cows reported Brodziak et al. (2011) averaging $919.0 \text{ mg}\cdot\text{dm}^{-3}$. Black and White breed variety cows milk was characterized by the lowest Ca content ($108.6 \text{ mg}\%$), and the highest was reported in the Simmental ($138.2 \text{ mg}\%$), according to Litwińczuk (2004). According to the research of Mountain (2002), the calcium content of milk in winter and was higher than in the summer (1.12 vs $1.05 \text{ g}\cdot\text{kg}^{-1}$, respectively). Milk from different regions of the Poland characterized by the difference in calcium and magnesium, which is reported in the Górska (2002) study.

In the first year of the experiment the lowest content of the element in the milk was recorded in the seventh month of lactation and it was $614.5 \text{ mg}\cdot\text{l}^{-1}$, while the highest in the eighth – $989.7 \text{ mg}\cdot\text{l}^{-1}$.

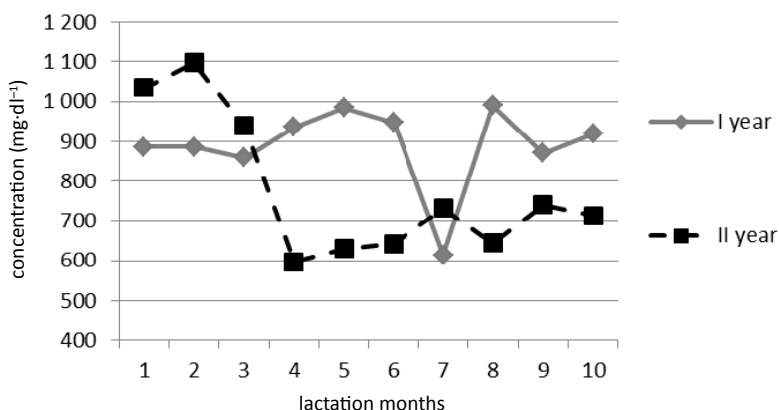


FIGURE 4. The content of calcium in milk of trial cows

In the second year of the experiment the lowest calcium content in milk was characterized by milk from the fourth month of lactation and was $598.0 \text{ mg}\cdot\text{l}^{-1}$, while the highest in the second month of lactation – $1096.6 \text{ mg}\cdot\text{l}^{-1}$.

Drop in the content of Ca in milk in the seventh lactation month was probably the result of its lowest concentration in the blood of experimental animals. Figure 5 shows the phosphorus content in the milk of cows during lactation.

The results in both the first and second year of the study are in the range of from 348.8 to $1024.6 \text{ mg}\cdot\text{l}^{-1}$. There was a statistically significant differences in the content of P in the milk between successive months ($P \leq 0.01$) and between studied years. Statistically significant differences in the content of the P in the milk between the years stated in each month of lactation ($P \leq 0.01$) with the

exception of the first month. Kuczyńska (2011), reported that reference value of phosphorus in milk ranges between 750 and $1100 \text{ mg}\cdot\text{l}^{-1}$, and the results of her study revealed that P content in milk originated from intensive and organic farms fluctuated at 807 and $824 \text{ mg}\cdot\text{l}^{-1}$ respectively. According to the research Krzyżewski et al. (2009), the phosphorus content in milk was $93 \text{ mg}\cdot 100 \text{ g}^{-1}$. Research of Litwińczuk (2004) confirmed that milk of Black and White breed variety cows contained the lowest phosphorus concentration ($80.8 \text{ mg}\%$), and Simmentals' milk was the richest in P ($108.3 \text{ mg}\%$).

The lowest content of the P in the first year of the experiment was $348.8 \text{ mg}\cdot\text{l}^{-1}$ and was recorded in the eighth month of lactation. In the second year of the experiment the lowest content was $542.1 \text{ mg}\cdot\text{l}^{-1}$, and was observed in tenth month

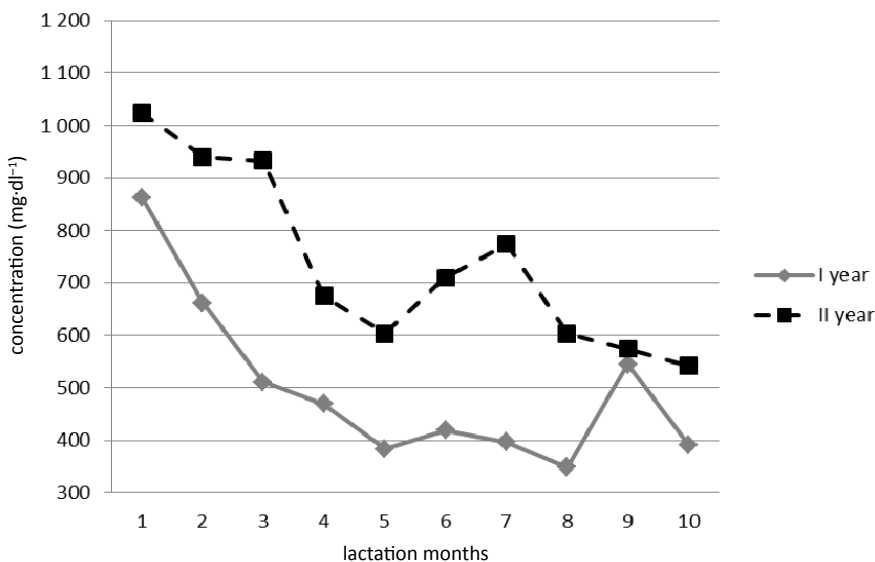


FIGURE 5. Phosphorus content in the milk of trial cows

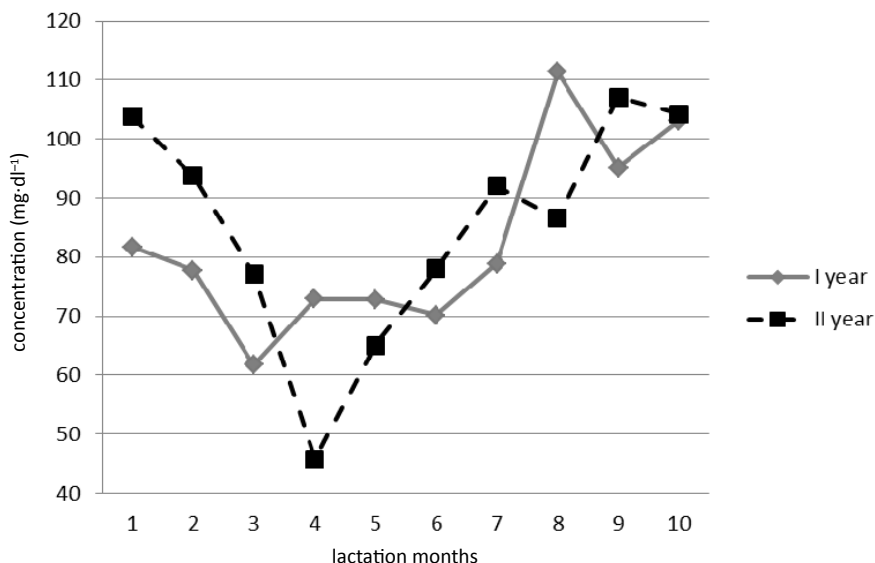


FIGURE 6. Magnesium content in the milk of trial cows

of lactation. In both the first and second year of study in the first month of lactation the maximum P content in milk was observed (863.3 and 1024.6 mg·l⁻¹ in the first and year respectively). Study revealed that phosphorus content was decreasing with consecutive lactation months. Figure 6 presents the magnesium content in the milk of cows during 10 consecutive months of lactation.

The results in both the first and second year of the experiment were in the range of 45.69 to 111.33 mg·l⁻¹. There was a statistically significant differences in Ca concentration in the blood between successive months ($P \leq 0.01$) and studied years. Statistically significant differences in the content of the Mg in the milk was stated between first, second, third, fourth, seventh and eighth month, however, however, the biggest differences were observed between the fifth

and ninth month. The reference values given by Kuczyńska (2011) range from 120 to 134 mg·l⁻¹. In a study conducted by Kuczyńska (2011) the magnesium content in milk from conventional farms averaged 112 mg·l⁻¹ and organic at 107 mg·l⁻¹. Studies of Brodziak et al. (2011) revealed that the Mg content in milk averaged 127.9 mg·dm⁻³, while Krzyżewski (2009) reported the average Mg content of 13 mg per 100 g of milk. Mountain research (2002) confirmed higher magnesium content in milk harvested in winter (91.38 mg·kg⁻¹) than in summer (85.13 mg·kg⁻¹). In the experiment, the maximum magnesium content of the milk was observed in eight months and ninth month of lactation, 111.33 mg·l⁻¹ in the first and 107.07 mg·l⁻¹ in the first and second year of lactation, respectively. The lowest values milk magnesium content were reported in

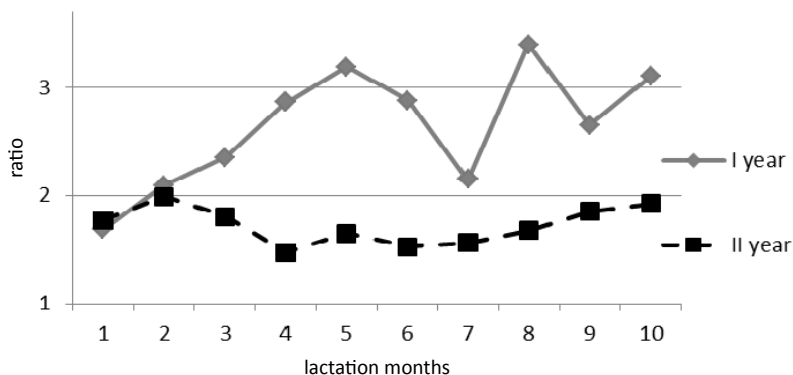


FIGURE 7. The calcium to phosphorus ratio in milk cows during 10 consecutive months of lactation

the third and fourth month of lactation (61.71 and 45.69 mg·l⁻¹, for the first and second year respectively). Our study revealed that the magnesium content in the milk of cows are normal in the early and late lactation, and from the second to the seventh month of lactation were obtained lower values than in the studies Górska (2002) and Kuczyńska (2011). Figure 7 presents the calcium to phosphorus ratio in milk consecutive months.

The results in both the first and second year of the experiment ranged between 0.974 to 2.896. A statistically significant difference in ratio of calcium to phosphorus in milk between successive months ($P \leq 0.01$) and years were reported. Significant differences in the Ca : P in milk were stated in the third, fourth, fifth, sixth, seventh, eighth and ninth month. In the experiment, the high values of Ca : P was reported in the eighth and second month of lactation, in the first and second year respectively (2.896 (at first) and 1.488 (in the second year of the experiment)). The lowest ratio of Ca and

P in the first year of experience characterized by the milk from the first month of lactation (1.191), while in the second year of milk from the fourth month of a characterized by the lowest Ca : P – 0.974. According to Kłobukowski and Kozikowski (2008), the most advantageous relation between Ca and P should be established at 1.2 : 1. Kuczyńska (2011) studies reported that Ca : P in milk ranged between 1.2 and 1.3. The study results obtained in the second experiment are similar to those reported in the literature.

Table 3 presents the correlation coefficients between the minerals contained in milk and its concentration in the blood. Analysis of these values, revealed that there is a negative, highly significant relationship between the content of magnesium in the blood and the content of calcium in milk (-0.116) and the Ca to P ratio. Also negative correlation between the content of phosphorus in the blood and phosphorus in milk was reported. However, the relationship between the content of phosphorus in the blood and

TABLE 3. Correlation between the mineral components in the milk and blood

Chemical element		Ca milk	Mg milk	P milk	Ca : P milk	Ca blood	Mg blood	P blood
Ca milk	r	1	0.334**	0.068*	0.515**	0.006	-0.116**	0.071
	significance $P \leq$		0.000	0.045	0.000	0.884	0.003	0.074
	n	866	866	866	866	642	642	642
Mg milk	r	0.334**	1	0.016	0.174**	-0.019	-0.077	0.023
	significance $P \leq$	0.000		0.639	0.000	0.639	0.051	0.559
	n	866	866	866	866	642	642	642
P milk	r	0.068*	0.016	1	-0.725**	-0.066	0.078*	-0.079*
	significance $P \leq$	0.045	0.639		0.000	0.096	0.049	0.045
	n	866	866	866	866	642	642	642
Ca : P milk	r	0.515**	0.174**	-0.725**	1	0.067	-0.150**	0.142**
	significance $P \leq$	0.000	0.000	0.000		0.091	0.000	0.000
	n	866	866	866	866	642	642	642
Ca blood	r	0.006	-0.019	-0.066	0.067	1	0.154**	0.229**
	significance $P \leq$	0.884	0.639	0.096	0.091		0.000	0.000
	n	642	642	642	642	642	642	642
Mg blood	r	-0.116**	-0.077	0.078*	-0.150**	0.154**	1	0.114**
	significance $P \leq$	0.003	0.051	0.049	0.000	0.000		0.004
	n	642	642	642	642	642	642	642
P blood	r	0.071	0.023	-0.079*	0.142**	0.229**	0.114**	1
	significance $P \leq$	0.074	0.559	0.045	0.000	0.000	0.004	
	n	642	642	642	642	642	642	642

r – Pearson's correlation coefficient; n – number;

* correlation significant at the 0.05 level; ** correlation significant at the 0.01 level.

the Ca to P ratio is positive and highly significant.

CONCLUSIONS

Study brought to following conclusions:

- calcium in the blood and milk during lactation was physiologically normal, except for the seventh month of the second year of the study (blood) and the fourth month of the second year of the study (milk);

- phosphorus level in the blood in full lactation period was physiologically normal except for the first and the seventh month of the first year of the study and the ninth of the second year of the study, while the content of the milk showed a declining trend during lactation;
- magnesium concentration in the blood during a full lactation was physiologically normal with the exception of the eighth month of the first year of the

study, while the milk was lower than the reference values (except the first and the tenth month of lactation);

– there were significant correlation between blood and milk minerals.

In summary, the properly fed an managed high-milk yielding cows at various stages of the lactation may suffer from slight calcium, phosphorus and magnesium deficiency what is reflected in blood and milk tests.

Acknowledgements

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Streszczenie: *Zmiany zawartości wybranych składników mineralnych w mleku i krwi wysokomlecznych krów w okresie pełnej laktacji.* Celem badań była analiza zawartości wapnia, fosforu oraz magnezu w mleku i we krwi wysokomlecznych krów w okresie pełnej laktacji. Badania przeprowadzono na 100 krowach rasy PHF w okresie dwóch lat (50 krów w każdym roku). Próbkę mleka i krwi pobierano w każdym miesiącu laktacji (10 pobrań) i określano w nich zawartość składników mineralnych. Dodatkowo pobrano próby pasz. Wykazano, że poziom wapnia w dawkach jest zbyt niski, poziom fosforu optymalny, a zawartość magnezu w dawkach przekraczała zapotrzebowanie zwierząt. Stwierdzono statystycznie

istotne różnice w zawartości Ca, P i Mg w poszczególnych miesiącach laktacji krów. Zawartość składników mineralnych we krwi była w normie, podobną sytuację zaobserwowano w przypadku zawartości wapnia oraz fosforu w mleku. Wyjątek stanowi stężenie magnezu w mleku, które jest zbyt niskie i najbardziej zróżnicowane w okresie laktacji.

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