Journal of Elementology ISSN 1644-2296

Nogalska A., Momot M., Sobczuk-Szul M., Pogorzelska-Przybyłek P., Nogalski Z. 2017. *Calcium and magnesium contents in the milk of high-yielding cows.* J. Elem., 22(3): 809-815. DOI: 10.5601/jelem.2016.21.4.1365

ORIGINAL PAPER

CALCIUM AND MAGNESIUM CONTENT IN THE MILK OF HIGH-YIELDING COWS

Anna Nogalska[1], Martyna Momot[2], Monika Sobczuk-Szul[2], Paulina Pogorzelska-Przybyłek[2], Zenon Nogalski[2]

[1]Department of Agricultural Chemistry and Environmental Protection
[2]Department of Cattle Breeding and Milk Evaluation
University of Warmia and Mazury in Olsztyn

Abstract

Cow's milk has the highest share of total milk production and consumption in the world, including Poland. Milk is the most important source of readily available minerals, particularly calcium, in the human diet. The chemical composition of milk varies depending on genetic, environmental and physiological factors. Changes in the composition and physicochemical properties of milk affect its biological value and processing suitability. The objective of this study was to determine the effect of age of high-yielding Polish Holstein-Friesian (PHF) cows and lactation day on the calcium (Ca) and magnesium (Mg) content of milk. The average milk yield increased significantly during three consecutive lactations. The age of cows had a significant effect on the average Ca and Mg content of milk throughout lactation. Milk from younger cows had higher concentrations of the analyzed macronutrients. The concentrations of Ca and Mg in milk varied considerably depending on the stage of lactation. A substantial decrease in the milk Ca content was noted in the first stage of lactation. The calcium concentration in milk stabilized in the second month post partum, and it remained stable until the end of lactation. A decrease in the Mg content was noted until day 30 of lactation in milk from primiparous cows and cows in their second lactation. The oldest cows produced milk with the lowest Mg concentration, which resulted from a steady decrease in the milk Mg content until the fourth month of lactation. The Mg content of milk continued to increase from the fourth month until the end of lactation, regardless of a cow's age. The Ca and Mg content of milk from the analyzed high-yielding cows was below the normal ranges (by approximately 24% and 6%, respectively). This is the reason why dairy products are often fortified with minerals.

Keywords: cow's milk, macronutrients, lactation, age.

Anna Nogalska dr hab. inż., Department of Agricultural Chemistry and Environmental Protection, University of Warmia and Mazury in Olsztyn, Oczapowskiego 8, 10-719 Olsztyn, Poland, e-mail: anna.nogalska@uwm.edu.pl

INTRODUCTION

Calcium (Ca) and magnesium (Mg) are alkaline minerals which play important roles in the human body. Milk and dairy products are rich sources of both macronutrients, in particular Ca (Stasiuk, Przybyłowski 2011, Miciński et al. 2013). The concentrations of Ca and Mg are approximately 4-fold higher in cow's milk than in human milk (Posati, Orr 1976). The milk Mg content is considerably lower than the Ca content, but the presence of lactose and proteins contribute to high Mg availability. The concentrations of Ca and Mg in milk are closely related (Litwińczuk et al. 2004). The Ca:Mg ratio is responsible for milk's heat stability, whereas Ca levels determine milk's suitability for cheese production.

In Poland, the dietary intake of calcium is well below the recommended optimal levels in more than half of children and adolescents. Poor eating habits, including insufficient milk consumption, increase the risk of osteoporosis. Calcium absorption from milk ranges from 21% to 45%, and it is much higher than from vegetables and cereal products. People who do not consume milk and dairy products as part of their daily diet have difficulty meeting their Ca requirements (Canabady-Rochellea, Mellemab 2010, Zamberlin et al. 2012, Kuczyńska et al. 2013). Drinking at least 2 glasses of milk and eating 2 slices of hard cheese a day would meet our calcium needs in around 70% to 80% (Zmarlicki 2009).

A glass of cow's milk (250 ml) contains 300 mg Ca and 32 mg Mg on average (Brodziak et al. 2011, Kuczyńska et al. 2013). The chemical composition of milk varies depending on a variety of genetic (cattle breed), environmental (diet, season) and physiological (lactation phase, udder health) factors. An evaluation of the influence of a lactation stage on milk yield and quality may help optimize the functional properties of milk, thus improving the quality of dairy products. The aim of this study was to determine the effect of age of high-yielding cows and lactation day on the Ca and Mg content of milk.

MATERIAL AND METHODS

The experimental material comprised 55 Polish Holstein-Friesian (PHF) cows from two different herds kept in the regions of Warmia and Mazury (NE Poland). A total of 1021 milk samples were collected from cows in their first (18 animals), second (20 animals) and third (17 animals) lactation. The share of cows in two herds in different age groups was similar. Feeding regimes, cow productivity and the quality of genetic material were comparable in both farms. All animals were housed in free-stall barns. The cows were fed a total mixed ration based on maize silage, and grass and alfalfa haylage. The

complete basic diet was supplemented with farm-made concentrates containing protein, minerals, vitamins, and feed additives improving milk production efficiency and the nutritive balance of the ration (protein, protected fat, active yeast cultures, energy supplements). Cows in the dry period and lactation were provided with the full coverage of the minerals. The composition of feed given the blood indicators were regularly studied and analyzed. The mineral supplement contained: 19% of Ca, 4% of P and 7% of Mg. Cows with similar expected calving dates were selected for the study to eliminate the effect of season.

Milk samples were subjected to wet mineralization in a microwave oven in the presence of a mixture of nitric acid and hydrochloric acid, in accordance with the relevant standards. The Ca and Mg content of mineralized milk samples was determined by atomic emission spectrometry (AES) and atomic absorption spectrometry (AAS), respectively. The results were analyzed statistically by one-way ANOVA for non-orthogonal designs, with the use of Statistica 10.0 software. The significance of differences between means was estimated by the Tukey's range test at $P < 0.05$ and $P < 0.01$.

RESULTS AND DISCUSSION

Holstein-Friesians (HF) are known as the world's highest yielding dairy cattle breed. Unfortunately, their high productivity may negatively affect performance traits, mostly fertility, herd life and milk composition (Nogalski et al. 2012). In the analyzed cows, the average milk yield over a 305-day lactation reached 11140 kg (Table 1), whereas the average milk production in Poland is only 5400 kg (Statistical Yearbook of Agriculture 2015). In the present study, milk production was affected by the age of PHF cows (Table 1). The average milk yield increased significantly during three consecutive lac-

Table 1

Milk yield and the average content of magnesium and calcium in the milk of cows ($x \pm$ SE)

Specification	Lactation I	Lactation II	Lactation III
Number of cows	18	20	17
Number of milk samples	341	368	312
Milk yield in 305-day lactation (kg)	10 279±130.1^{A}	11 020±154.2^{B}	12 186±101.9^{C}
Daily milk production (kg)	36.9±0.69^{Aa}	39.8±0.85^{b}	43.7±0.64^{B}
Content of calcium (mg dm^{-3})	783.9±13.54^{a}	755.4±12.03^{b}	749.1±19.02^{b}
Content of magnesium (mg dm^{-3})	99.1±1.15^{a}	92.4±1.39^{b}	90.6±1.27^{b}

$A, B - P \leq 0.01$; $a,b - P \leq 0.05$
x±SE – standard error of mean

tations in the analyzed high-producing PHF cows, as follows: 1st lactation – 10 279 kg, 2nd lactation – 11 020 kg, 3rd lactation – 12 186 kg. A similar rising trend in the milk performance of PHF cows was reported by Sablik et al. (2001). In contrast, Pilarska (2014) observed the highest milk yield in much older cows, in their fifth lactation. In our study, daily milk yield continued to increase until day 50 of lactation, and then it decreased steadily until the end of lactation (Figure 1). Similar results were reported by Antkowiak

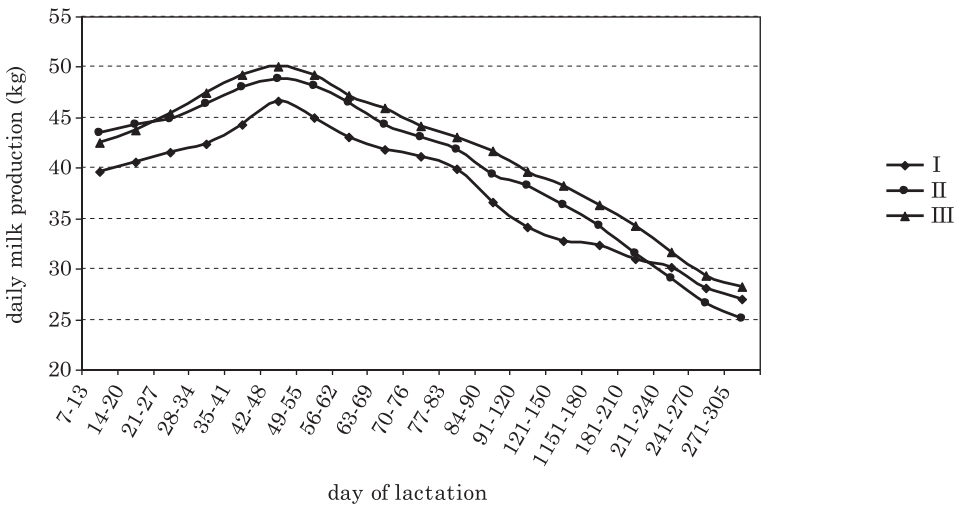

Fig. 1. Daily milk production, depending on the number of cows' lactation

et al. (2007). Other authors who investigated PHF cows demonstrated that milk yield continued to increase until day 60 of lactation, and it remained stable until day 120 (Pollot 2004, Miciński et al. 2008).

Lactation was an important factor influencing the calcium content of milk (Table 1). Milk from high-producing primiparous cows (1st lactation) had significantly higher Ca concentration as compared with milk from cows in their second and third lactation (by 3.6% and 4.5%, respectively). The average Ca content of milk reached 763 mg dm^{-3}, and it was approximately 24% below the lower limit of the normal range (1000-1400 mg Ca dm^{-3}) (Litwińczuk et al. 2004). Similar results were obtained by Stasiuk and Przybyłowski (2011), at 801 mg Ca dm^{-3} milk on average. Other authors (Rodriguez et al. 2001, Gaucheron 2005, Zamberlin et al. 2012) reported a considerably higher Ca content of milk. The noted differences could have resulted from differences between cattle breeds, although researchers vary in their opinions on the matter. According to many authors, the milk of Simmental cows is most abundant in Ca and Mg (Grega et al. 2000, Brodziak et al. 2011), whereas Barłowska (2007) demonstrated that the concentrations of the above macronutrients were highest in the milk of Jersey cows. Król et al. (2010) found that milk quality was determined by the cattle management system. The ci-

ted authors noted higher concentrations of Ca and Mg in milk from cows raised in the conventional system rather than in the intensive production system.

The calcium concentration in milk varied widely depending on the stage of lactation (Figure 2). In the first phase of lactation (until day 50), when

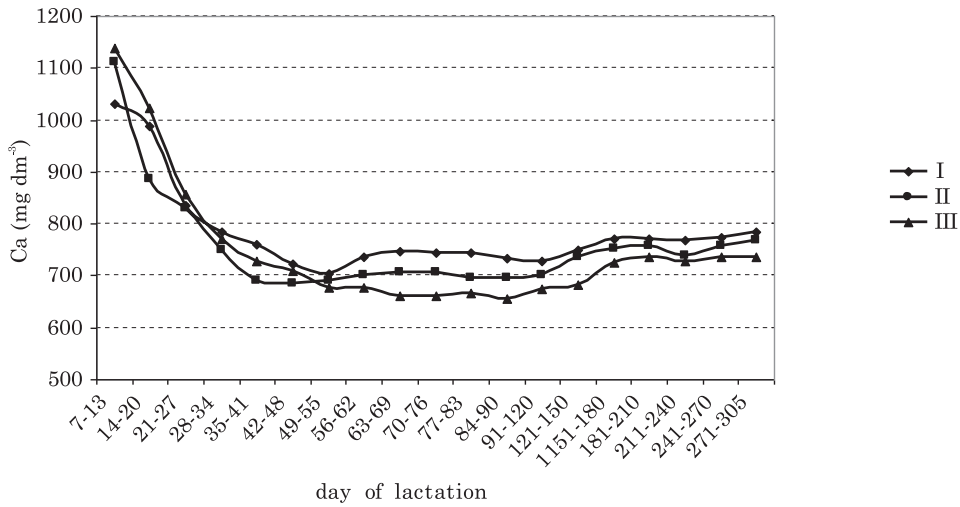

Fig. 2. Calcium content in the milk of cows in the subsequent days of lactation

milk yield was on the rise, the Ca content decreased considerably. During the early weeks of lactation, most cows remain under the negative Ca balance (Gabryszczuk et al. 2010). The lowest decrease in the milk Ca content was observed in primiparous cows that produced significantly less milk than cows in their second and third lactation, by 741 and 1907 kg of milk, respectively, over a 305-day lactation. The calcium concentration in milk stabilized in the second month post partum, and it remained stable until the end of lactation.

The Mg content of milk ranged from 90.6 mg dm^{-3} in cows in their third lactation to 99.1 mg dm^{-3} in primiparous cows (Table 1). Milk from primiparous cows had significantly higher Mg concentration than milk from older cows. The average Mg content of milk was approximately 6% below the lower limit of the normal range (100-150 mg Mg dm^{-3}) (Litwińczuk et al. 2004). According to many authors, the lower limit for the Mg content of cow's milk is 62-126 mg dm^{-3} (Sola-Larranaga, Navarro-Blasco 2009, Gabryszczuk et al. 2010), 71.5-159.0 mg dm^{-3} (Rodriguez et al. 2001), 84-135 mg dm^{-3} (Stasiuk, Przybyłowski 2011) and 90-160 mg dm^{-3} (Zamberlin et al. 2012).

A substantial decrease in the Mg content of milk from younger cows was noted until day 30 of lactation (Figure 3). In the milk of the oldest cows (3rd lactation), characterized by the lowest Mg content, the Mg concentration continued to decrease until 4 months post partum. This implies that older cows have a limited ability to make up for the Mg deficiency in the diet. The

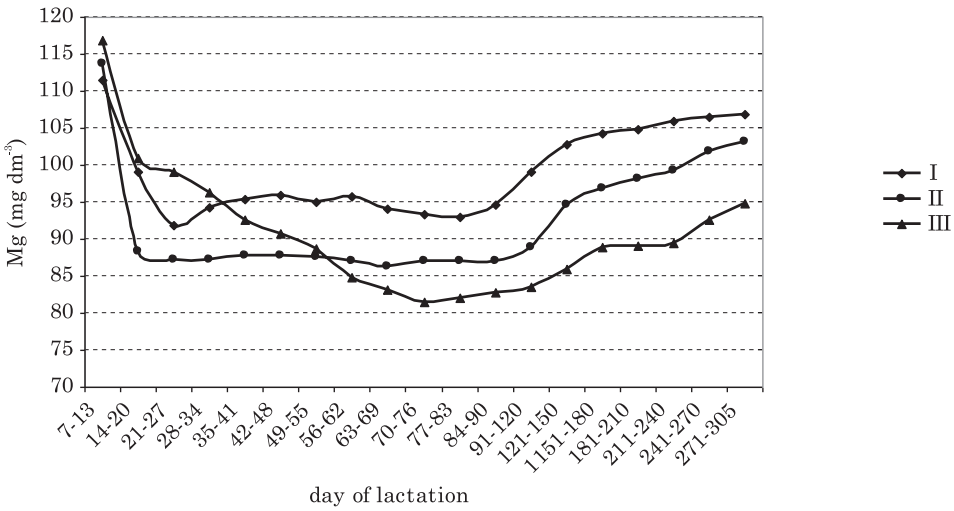

Fig. 3. Magnesium content in the milk of cows in the subsequent days of lactation

Mg content of milk continued to increase from the fourth month until the end of lactation, when milk production decreases regardless of a cow's age.

High milk yield is not always accompanied by high milk quality. Therefore, milk producers often enrich dairy products with minerals, in particular Ca and Mg (Ziarno et al. 2009).

CONCLUSIONS

The average milk yield increased significantly during three consecutive lactations in the analyzed high-producing PHF cows. The age of cows had a significant effect on the average Ca and Mg content of milk throughout lactation. Milk from primiparous cows had higher concentrations of the analyzed macronutrients. The Ca and Mg content of milk from the analyzed cows was below the normal ranges. This suggests that milk from high-yielding cows can be deficient in Ca and Mg, and supports the view that dairy products should be fortified with these minerals.

REFERENCES

Antkowiak I., Pytlewski J., Skrzypek R. 2007. *Effect of a successive lactation and its stages on milk performance of Jersey and Polish Holstein-Friesian cows.* Med. Wet., 63(11): 1366-1369. (in Polish)

Barłowska J., Szwajkowska M., Litwińczuk Z., Król J. 2011. *Nutritional value and technological suitability of milk from various animals species used for dairy production.* Compr. Rev. Food Sci. F., 10(6): 291-302. DOI:10.1111/j.1541-4337.2011.00163.x

Brodziak A., Litwińczuk A., Kędzierska-Matysek M., Król J. 2011. *Content of selected macro-*

and microelements in milk of different cows breeds and rennet whey. Ochr. Śr. Zasob. Nat., 48: 467-474. (in Polish)

Canabady-Rochellea L.S., Mellemab M. (2010). *Physical-chemical comparison of cow's milk proteins versus soy proteins in their calcium-binding capacities*. Colloids and Surfaces A: Physicochem. Eng. Aspects, 366: 110-112. DOI: 10.1016/j.colsurfa.2010.05.030

Dobrzańska A., Tymolewska-Niebuda B., Salamandra K. 2001. *The evaluation of the nutrition of children and youth suffering from primary osteoporosis in their own home conditions*. Nowa Pediatr., 1: 27-32. (in Polish)

Gabryszczuk M., Słoniewski K., Metera E., Sakowski T. 2010. *Content of mineral elements in milk and hair of cows from organic farms*. J. Elem.,15(2): 259-267.

Gaucheron F. 2005. *The minerals of milk*. Reprod. Nutr. Dev., 45(4): 473-483. DOI: 10.1051/rnd:2005030

Grega T., Sady M., Farot A., Pustkowiak H. 2000. *The content of calcium, phosphorus, lactose and citric acid in the milk of cows of different races*. Rocz. Nauk. Zoot., 5: 27-30. (in Polish)

Kuczyńska B., Nałęcz-Tarwacka T., Puppel K. 2013. *Bioactive components as an indicator of the health-beneficial quality of the milk*. Med. Rodz., 1: 11-18. (in Polish)

Litwińczuk A., Litwińczuk Z., Barłowska J., Florek M. 2004. *Animal materials - Evaluation and use*. PWRiL, Warszawa. (in Polish)

Miciński J., Pogorzelska J., Barański W. 2008. *Relationships between the performance traits of primiparous cows and the genetic variants of selected milk proteins*. Med. Wet., 64(9): 1136-1140. (in Polish)

Miciński J., Zwierzchowski G., Kowalski I.M., Szarek J. 2013. *Health-promoting properties of selected milk components*. J. Elem., 18(1): 165-186. DOI: 10.5601/jelem.2013.18.1.14

Nogalski Z., Wroński M., Lewandowska B., Pogorzelska P. 2012. *Changes in the blood parameters and body condition of high yielding Holstein cows with retained placenta and ketosis*. Acta Vet. Brno, 4: 389-394. DOI:10.2754/avb201281040000

Pilarska M. 2014. *Effect of season of the year and number of lactation on performance of cows and physico-chemical parameters of their milk*. Wiad. Zoot., R. 52(2): 3-12. (in Polish)

Pollott G.E. 2004. *Deconstructing milk yield and composition during lactation using biologically based lactation models*. J. Dairy Sci., 87: 2375-2387. DOI: 10.3168/jds.S0022-0302(04)73359-7

Posati, L.P., Orr, M.L. 1976. *Composition of foods. Dairy and egg products*. USDA-ARS, Consumer & Food Economics Inst., Agr. Handbook, Washington D.C., (8-1): 77-109.

Statistical Yearbook of Agriculture. 2015. (in Polish)

Rodriguez E.M., Sanz Alaejos M. Diaz Romero C. 2001. *Mineral concentration in cow's milk from the Canary Island*. J. Food Com. Anal., 14: 419-430. DOI:10.006/jfca.2000.0986

Sablik P., Kamieniecki H., Grzesiak W. 2001. *Comparing the level of production traits, and some indicators of the reproduction Holstein-Friesian cows imported from France as pregnant heifers with the results obtained from the local cows*. Zesz. Nauk. PTZ, Prz. Hod., 59: 239-245. (in Polish)

Sola-Larranaga C., Navarro-Blasco I. 2009. *Chemometric analysis of minerals and trace elements in raw cow milk from the community of Navarra, Spain*. Food Chem., 112: 189-196. DOI: 10.1016/j.foodchem.2008.05.062

Stasiak E., Przybyłowski P. 2011. *Content of calcium and magnesium in samples of milk of different origin*. Bromat. Chem. Toksykol., 44(3): 581-584. (in Polish)

Zamberlin Š., Antunac N., Havranek J., Samaržija D. 2012. *Mineral elements in milk and dairy products*. Mljekarstvo, 62(2): 111-125.

Ziarno M., Zaręba D., Piskorz J. 2009. *Fortifying buttermilk with calcium, magnesium, and whey proteins*. ŻNTJ, 2(63): 14-27. (in Polish)

Zmarlicki S. 2009. *Dairy and dairy products as a source of calcium*. Przem. Spoż., 10: 42-47. (in Polish)