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BLOOD MINERAL STATUS INFLUENCE ON MINERAL NUTRITIONAL VALUE OF MILK OBTAINED FROM A DAIRY FARMING INTENSIVE SYSTEM

Gheorghe V. GORAN, Elena ROTARU, Liliana TUDOREANU, Emanuela BADEA, Victor CRIVINEANU

University of Agronomic Sciences and Veterinary Medicine of Bucharest, Faculty of Veterinary Medicine, Interdisciplinary Laboratory for the Study and Modelling of Heavy Metals Accumulation in the Food Chain, 105 Splaiul Independentei, District 5, 050097, Bucharest, Romania

Corresponding author email: gvgoran@gmail.com

Abstract

Milk from cattle species is an important part of human alimentation due to its mineral content, among other nutritional substances. Researchers have conducted studies to improve milk nutritional value, even reaching genetic manipulation in order to enrich cow milk with lysozyme, lactoferrin, and lactalbumin, components usually found in human milk. Mineral concentration in milk is an important quality parameter for human nutrition. Mineral concentrations from raw milk and blood were measured by inductively coupled plasma optical emission spectrometry (ICP-OES) in samples taken from 15 dairy cows farmed in a dairy farming intensive system situated in the south of Romania. Blood concentrations of all analyzed minerals registered strong difference to their concentration in milk. However, strontium concentration in milk is linearly correlated to calcium concentration in milk. This finding suggests that calcium and strontium use similar transporters at cellular level and compete for the same transport system. There has not been found a positive correlation between the milk obtained from daily production and the blood level of some minerals, although it can be observed that at productions of 53.9 L/day all elements, with the exception of iron, have higher levels comparative with the lowest milk production (15 L milk), that could be explained by the differentiated feeding required by the productive capacity of animals.

Key words: *dairy cows, milk, blood, minerals.*

INTRODUCTION

Cattle research knows unexpected developments. Cow milk quality registers improved quality through genetic manipulation. In April 2011, Chinese researchers have announced the creation of a herd of 300 cows able to produce milk enriched with three components of human milk, respectively lysozyme, lactoferrin, and lactalbumin (Wang et al., 2008; Yang et al., 2011, http://www.telegraph.co.uk/news/earth/agriculture/geneticmodification/8423536/Genetically-modified-cows-produce-human-milk.html).
In June 2011, Argentinean scientists have grafted two human genes to a cow in order to produce lactoferrin and lysozyme in human breast milk specific concentrations (http://www.telegraph. co.uk/news/worldnews/southamerica/argentina/8569687/Scientists-create-cow-that-produces-human-milk.html).
Beside these genetic manipulations, research interventions by genetic selection with the aim of improving the productive performance in terms of milk and meat can be added. Considering the physiological aspects of "functioning" body including homeorhesis phenomenon it is natural in this context to ask ourselves how such interventions are beneficial for cattle homeostasis.
Trace minerals are essential for human and animal organisms. They occur in the composition of enzymes or act as a cofactor in antioxidant mechanisms. For cattle meat and milk production, performance level induces oxidative stress that can lead to health disorders (Sundrum, 2015).
Overall composition of milk (Figure 1) shows only the main categories of its constituents and the values given are average values. We notice immediately that the primary constituent of milk is water with 902 g/L, while dry weight is

only 130 g/L (http://www.ulb.ac.be/sciences/cudec/ LaitComposition.html).
Milk contains 7-8 g/L minerals as calcium, sodium, potassium, magnesium, citrates, chlorides, phosphates. Milk mineral salts are the same to blood mineral compounds, but their concentrations are different. Mineral absorption from the blood stream by the mammary gland is a selective process rather than a simple filtration (Ghergariu, 1980).

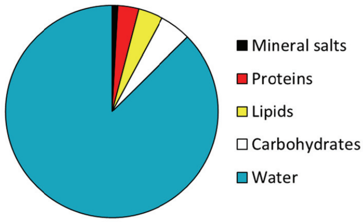

Figure 1. Global chemical composition of milk (g/L) (http://www.ulb.ac.be/sciences/cudec/LaitComposition.html)

Compared to blood mineral components, milk is richer in calcium, phosphorus and potassium, but it contains less sodium and chloride.
Average milk mineral composition is presented in Table 1.

Table 1. Average values for milk salt constituents (mg/dl) in whole milk (http://ansci.illinois.edu/static/ansc438/Milkcompsynth/milkcomp_minerals.html)

Mg	Na	Ca	K	S	P	Cl	Citrates
12	58	123	141	30	95	119	160

MATERIALS AND METHODS

Milk and blood samples were collected from a group of 15 lactating Holstein cows. The milk production of the selected group varied between 15 L/day and 53.9 L/day. The cows are representative for all lactation stages and total lactations days for the animals raised in the farm. The animals are farmed in a dairy farming intensive system from the south of Romania. Feeding is done based on physiological status and production level and water is provided *ad libitum*. A nutritionist calculated the forage rations based on productive performance, physiological status, and age using a computer software, which chose the appropriate menu for the category of animals and their productive performance. Then the mixture of ten ingredients was prepared as directed by the computer software. Samples were collected during winter period, thus winter specific feed influenced mineral concentrations in milk. Blood samples were taken from the mammary vein, collecting 10 ml from each animal, after disinfecting the puncture site with alcohol. After eliminating the first jets, milk samples were collected manually, taking 20 ml from each animal. Blood and milk samples were collected on the same day and at the same time. Plastic bottles (including lids) were used for storing the samples in order to avoid possible contamination by oligominerals contained in rubber or glass.
In order to destroy the organic matter, HNO_3 and H_2O_2 were added to milk and blood samples. Then the samples were mineralized by microwave digestion at 190°C for 30 minutes. Suitable dilutions were made to ensure the elements fell within the calibration range.
Three standards of 0.01ppm, 0.1ppm and 50ppm were obtained from a multielement standard (MERK) containing 1000 mg/L of Ag, Al, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, K, Li, Mg, Mn, Na, Ni, Pb, Se, Sr, Tl, Zn.
The instrument was calibrated using a blank and three standards for each element and, after inspection, a linear fit was applied to all elements. Samples were analyzed in a single sequence. The sample data was measured by interpolation. Instrument Configuration: Pump rate 50 rpm; Nebulizer Standard concentric; Nebulizer Argon Pressure 0.6 L/min; Spray Chamber Standard cyclonic; Centre tube 2.0 mm. RF Forward Power 1150 W; Purge Gas Argon; Coolant flow 12 L/min; Auxiliary flow 0.5 L/min; Integration times: High Wavelengths 5 seconds; Low Wavelengths 15 seconds; Analysis mode: Speedy.

RESULTS AND DISCUSSIONS

Age, lactation number and daily milk production for each cow of the study group are presented in Table 2. Cows have been assigned a number in ascending order of their daily milk production. Cow no. 2, in its second lactation registered the lowest milk iron level (0.31 mg/dl) and the highest blood sodium level (132.481 mg/dl). Cow no. 6, also in its second lactation, registered the majority of the lowest milk mineral levels (Ca 601.5 mg/dl, K 842 mg/dl, Mg 70 mg/dl) and also the highest milk zinc level (5.35 mg/dl).

Table 2. Age, lactation number and daily milk production for each cow of the study group

Cow	Age	Lactation number	L milk/day
1	6	3	15
2	4	2	16.5
3	4	2	23.2
4	5	3	31.2
5	4	2	35.5
6	3	1	33.8
7	4	2	42.2
8	6	4	35.9
9	6	4	41.3
10	3	1	38.9
11	7	4	40.8
12	7	4	43.9
13	7	4	47.7
14	5	3	51.4
15	6	4	53.9

Cow no. 7, in its fourth lactation, registered the lowest milk zinc level (2.355 mg/dl), and also all the lowest blood mineral levels (Fe 3.254 mg/dl, Ca 1.485 mg/dl, K 5.174 mg/dl, Mg 0.318 mg/dl, Zn 0.038 mg/dl, Na 30.122 mg/dl). Cow no. 13, also in its fourth lactation, registered the lowest milk sodium level (269.65 mg/dl). Cow no.11, in its second lactation, registered the lowest milk strontium level (0.25 mg/dl).

As presented in other research (Roussel et al., 1982; Eicher, 2003), all serum values were influenced by age, and the majority of the highest milk mineral levels were registered in cows in their third lactation, as opposed to the majority of the highest blood mineral levels, which were registered in cows in their second lactation. Gadberry et al. (2003) indicated that no differences were observed in some minerals for cows and heifers.

Cow no.1, in its third lactation, registered the majority of the highest milk mineral levels (Fe 21.3 mg/dl, Ca 1471 mg/dl, Mg 174 mg/dl, Na 726 mg/dl). Cow no. 1 also registered the highest milk strontium level (4.35 mg/dl), which is thought to come from feed and water as well. The highest strontium and calcium levels were registered in the same individual, from which the conclusion drawn is that strontium concentration in milk is linearly correlated to calcium concentration in milk. This finding suggests that calcium and strontium use similar transporters at cellular level and compete for the same transport system.

Cow no. 4, also in its third lactation, registered the highest milk potassium level (1650.5 mg/dl).

Cow no.3, in its second lactation, registered the majority of the highest blood mineral levels (Fe 14.379 mg/dl, Ca 6.096 mg/dl, Mg 1.406 mg/dl), and cow no. 2, also in its second lactation, registered the highest milk sodium level (132.481 mg/dl).

Cow no. 10, in its fourth lactation, registered the highest blood potassium level (21.63 mg/dl), and cow no. 12, also I n its fourth lactation, and registered the highest blood zinc level (0.166 mg/dl).

Blood concentrations of calcium and zinc do not linearly correlate to their concentration in milk.

Milk and blood zinc levels based on daily milk productions are presented in Figure 2.

Milk and blood iron levels based on daily milk productions are presented in Figure 3.

The majority of the highest milk mineral levels are found in cow no. 1, which has the lowest daily milk production, of 15 L/day. Exceptions are the highest level of potassium (registered in cow no. 4, with a 31.2 L/day milk production) and the highest level of zinc (registered in cow no. 6, with a 35.5 L/day milk production), both milk productions being below the average productions of the analyzed cows. The highest blood mineral levels are found in cows with daily milk productions that vary between wide limits, as follows: highest sodium level is found in cow no. 2 (16.5 L/day), highest iron, calcium and magnesium levels are found in cow no. 3 (23.2 L/day), highest potassium level is found in cow no. 10 (41.3 L/day), and highest zinc level is found in cow no. 12 (43.9 L/day).

The lowest milk mineral levels are found in cows with daily milk productions that also vary between wide limits, as follows: lowest iron level is found in cow no. 2 (16.5 L/day), lowest calcium, potassium and magnesium levels are found in cow no. 6 (35.5 L/day), lowest zinc level is found in cow no. 7 (35.9 L/day), and lowest sodium level is found in cow no. 13 (47.7 L/day).

All the lowest blood mineral levels are registered in cow no. 7, with a milk production of 35.9 L/day, which is about the average daily milk production of the analyzed cows.

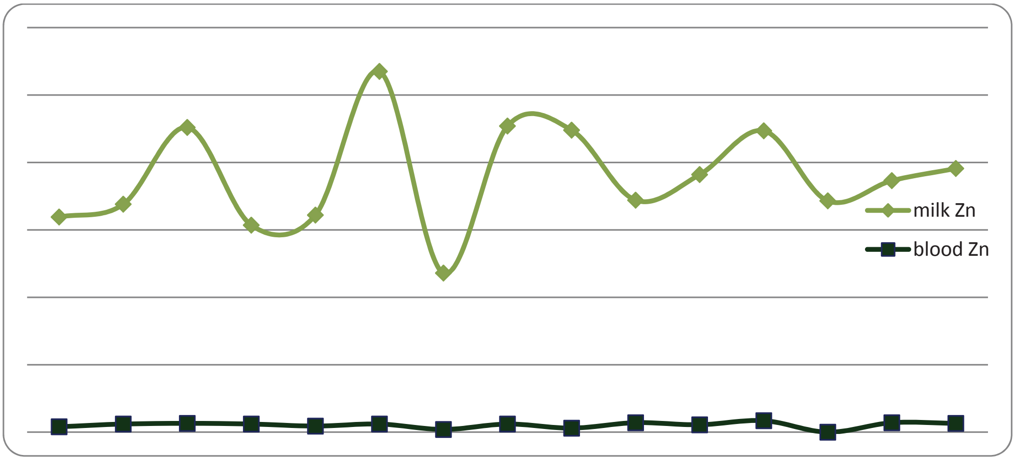

Figure 2. Milk and blood zinc levels based on daily milk productions

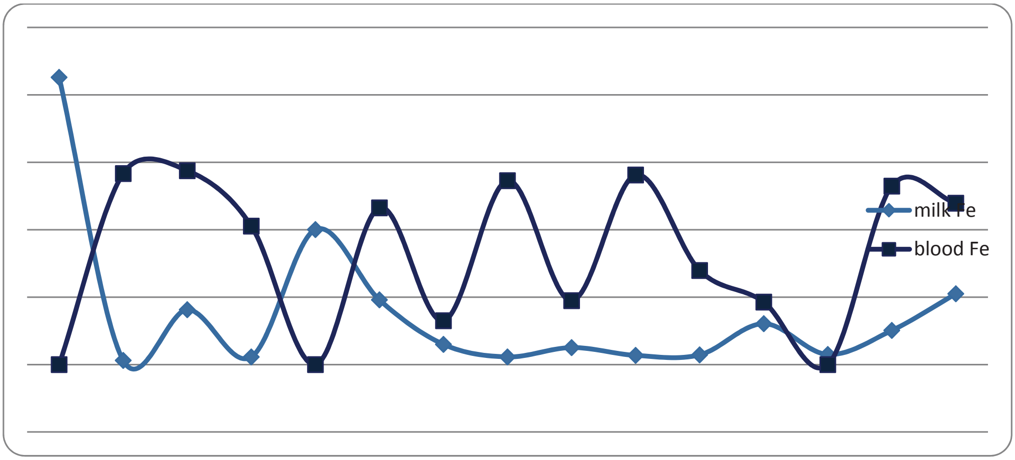

Figure 3. Milk and blood iron levels based on daily milk productions

Cow no. 1 (15 L/day milk production) had iron and sodium levels below the method detection limit. Cow no. 5 (33.8 L/day milk production) had iron levels below the method detection limit. Cow no. 12 (43.9 L/day milk production) had sodium levels below the method detection limit. Cow no. 13 (47.7 L/day milk production) had all blood mineral levels below the method detection limit.

A statistical analysis of the data by two-way ANOVA was performed in order to determine the influence of lactation number and daily milk production on the total mineral levels (Table 3 and Table 4). No significant difference was found between mineral concentrations in both blood and milk samples due to lactation number (Table 3) or due to daily milk production (Table 4).

However, in almost all determined minerals there is a strong significant difference between these two types of samples (p-value <0.0001). Fe levels in blood and milk samples registered a significant difference influenced by both analyzed variables, showed by a p-value <0.05 – lactation number (p-value $= 0.0463$) and daily milk production (p-value $= 0.0263$).

Table 3. Two-way ANOVA for total minerals concentrations (mg/dl) in blood and milk samples depending on lactation number

Element	**Type of samples**	**Mean (mg/dl)***				**Total Mean (mg/dl)**	**SD Mean**	**Std Err Mean**	***p*-value**
		1st Lactation	2nd Lactation	3rd Lactation	4th Lactation				
Ca	Blood	4.797[a]	5.343[a]	4.087[a]	3.079[a]	4.113	1.75	0.45	<0.0001
	Milk	1031.25[a]	934[a]	1140.67[a]	988.58[a]	1010.13	204.62	52.83	
Fe	Blood	6.822[a]	11.791[a]	7.837[a]	6.444[a]	8.199	5.64	1.46	0.0463
	Milk	5.29[a]	2.4738[a]	8.1317[a]	2.075[a]	3.821	5.5	1.42	
K	Blood	14.779[a]	16.053[a]	14.059[a]	9.182[a]	12.736	6.47	1.67	<0.0001
	Milk	1554.5[a]	1314.25[a]	1503.5[a]	1516.0[a]	1464.83	215.98	55.76	
Mg	Blood	1.118[a]	1.108[a]	0.954[a]	0.655[a]	0.897	0.45	0.12	<0.0001
	Milk	142.225[a]	122.025[a]	146.483[a]	132.425[a]	133.77	25.54	6.59	
Na	Blood	93.233[a]	113.250[a]	75.453[a]	58.589[a]	81.157	52.2	13.48	<0.0001
	Milk	393.825[a]	430.613[a]	560.733[a]	469.367[a]	467.233	137.22	35.43	
Sr**	Milk	0.355	0.359	1.677	0.41	0.642	1.029	0.266	0.3057
Zn	Blood	0.1065[a]	0.12[a]	0.1117[a]	0.0883[a]	0.104	0.04	0.01	<0.0001
	Milk	3.8775[a]	4.265[a]	3.33[a]	3.6783[a]	3.792	0.76	0.2	

* Levels not connected by the same letter are significantly different. No comparisons can be made between different elements concentration.
** One-way ANOVA was performed for strontium concentrations (mg/dl) in milk samples depending on lactation number.

Table 4. Two-way ANOVA for total minerals concentrations (mg/dl) in blood and milk samples depending on daily milk production

Element	**Type of samples**	**Mean (mg/dl)***				**Total Mean (mg/dl)**	**SD Mean**	**Std Err Mean**	***p*-value**
		<30 L/day	30-40 L/day	40-50 L/day	>50 L/day				
Ca	Blood	4.657[a]	4.188[a]	4.174[a]	5.044[a]	4.407	1.38	0.37	<0.0001
	Milk	1220[a]	976.8[a]	970.1[a]	878.75[a]	1010.13	204.62	52.83	
Fe	Blood	9.516[a]	7.761[a]	7.605[a]	12.605[a]	8.784	5.36	1.43	0.0263
	Milk	8.560[a]	3.487[a]	1.287[a]	3.885[a]	3.821	5.5	1.42	
K	Blood	14.750[a]	13.229[a]	9.184[a]	17.361[a]	12.736	6.47	1.67	<0.0001
	Milk	1399.83[a]	1429.10[a]	1508.10[a]	1543.50[a]	1464.83	215.98	55.76	
Mg	Blood	1.061[a]	0.9[a]	0.806[a]	1.276[a]	0.961	0.38	0.1	<0.0001
	Milk	154.533[a]	123.9[a]	135.91[a]	121.95[a]	133.77	25.54	6.59	
Na	Blood	87.776[a]	90.472[a]	88.885[a]	117.51[a]	93.643	43.73	12.13	<0.0001
	Milk	542.083[a]	392.27[a]	488.96[a]	488.05[a]	467.233	137.22	35.43	
Sr**	Milk	1.738	0.379	0.367	0.345	0.642	1.0289	0.2657	0.2454
Zn	Blood	0.110[a]	0.098[a]	0.094[a]	0.133[a]	0.104	0.04	0.01	<0.0001
	Milk	3.695[a]	3.706[a]	3.924[a]	3.82[a]	3.792	0.76	0.2	

* Levels not connected by the same letter are significantly different. No comparisons can be made between different elements concentration.
** One-way ANOVA was performed for strontium concentrations (mg/dl) in milk samples depending on milk quantity per day

Although there is no positive correlation between the milk obtained from daily production and the blood level of some minerals, it can be observed that, at productions of 53.9 L milk, all elements, with the exception of iron, register higher levels comparative with the lowest milk production (15 L milk). The explanation can be found in the differentiated feeding required by the productive capacity of animals that is done based on physiological status and production (Rotaru et al., 2012).

Because strontium was found only in milk samples, one-way ANOVA was performed for strontium concentrations (mg/dl) in milk samples depending on number of lactations and daily milk production. In both analyzed variables, no significant difference was registered, showed by a *p*-value > 0.05 (*p*-value = 0.3057 in the case of lactation number and 0.2454 for daily milk production).

CONCLUSIONS

Minerals identified in milk are identical with those found in blood, but their concentrations are different.

Blood concentrations of all analyzed minerals registered strong differences as opposed to their concentration in milk.

Strontium concentration in milk is linearly correlated to calcium concentration in milk.

In highest milk productions, all elements registered higher levels compared to the elements' values in lowest milk productions.

The lactation number or daily milk production variables did not influence the analyzed minerals levels.

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