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CONTENT OF MINERAL ELEMENTS IN MILK AND HAIR OF COWS FROM ORGANIC FARMS

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Abstract

The value of the routine analyses, applied until present, of whole blood, serum and urine for bioelements is limited. The blood mineral level does not often correspond to the content of minerals in the whole body because the composition of plasma results from supplementation of deficiencies by different homeostatic mechanisms. Moreover, the blood concentration of bioelements is relatively low and depends on a current diet, therefore the diagnostic value of such analytical results may be fairly small. Studies have shown that the analysis of hair and nails are an appropriate alternative for blood and urine tests or for biopsy. Chemical treatments in agriculture, animal production and food processing introduce many food contaminants into the food chain. Organic methods in agriculture are safer and therefore very important. Nutrition based on organically produced foods and anthroposophic lifestyle can play an important role in health prophylaxis The objective of this study was to determine correlations between concentrations of 29 major and trace elements in cow's milk and hair. The experimental material consisted of 33 cows of Polish Holstein-Fresian (HF) breed from three dairy organic farms. All the farms were located in one climatic zone and under similar soil conditions. The cows were kept in traditional tied-up barns. The feeding was traditional, with ration components given separately. The cows were grazed from May to October. Depending on pasture yield and availability of other feeds, the feeding ration was supplemented with hay, straw, silage and cereals. Samples of milk and hair for analyses of minerals were collected in September, *i.e.* during the pasture feeding. The hair was taken from the poll. The concentration of Ca, K, Mg, Na, P, S, B, Ba, Co, Cr, Cu, Fe, Ge, I, Li, Mn, Mo, Ni, Se, Si, Sn, Sr, V, Zn, Al, As, Cd, Hg, Pb was determined. The content of toxic elements in milk was low and below the admissible level. The statistically significant positive correlations between concentration in milk and in hair were detected for such elements as Ba, Ge, Mo and Pb. In the case of major elements K and Mg and trace elements Al, As, Co, Fe, Hg, Se, Sr, positive correlations were observed but they were not statistically significant. Negative correlations occurred for such elements

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as Cr, Cu, I, Li, Ni, S, Si, Sn, V and Zn. It was only for V and Zn that they were statistically significant. Very low values (near zero) of coefficient r were observed for Ca, Cd, Li, Mn, Na, Ni, P, S and Sn. It seems that broader investigations of mineral composition of cow's hair could be useful for establishing reference values for some elements and would make a contribution to better animals' welfare.

Key words: cow, hair, milk, macro- and microelements, organic farms.

ZAWARTOŚĆ SKŁADNIKÓW MINERALNYCH W MLEKU I WŁOSACH KRÓW Z GOSPODARSTW EKOLOGICZNYCH

Abstrakt

Badanie zawartości biopierwiastków w pełnej krwi, surowicy i moczu ma ograniczoną wartość. Poziom składników mineralnych we krwi często nie odpowiada ich zawartości w całym organizmie, ponieważ skład osocza jest wynikiem kompensowania deficytów przez różne mechanizmy homeostazy. Poza tym zawartość biopierwiastków we krwi jest relatywnie niska i zależy od stosowanej diety. Wobec tego wartość diagnostyczna jej wyników, w dłuższym okresie prowadzenia obserwacji, może być ograniczona. Badania pokazują, że analizy zawartości biopierwiastków we włosach i paznokciach mogą być alternatywne dla analiz zawartości we krwi, moczu lub biopsji. Chemizacja rolnictwa, produkcji zwierzęcej i przetwórstwa żywności wprowadza wiele zanieczyszczeń w łańcuch produkcji żywności. Ekologiczne (organiczne) metody w rolnictwie są bezpieczniejsze. Żywienie oparte na żywności produkowanej w gospodarstwach ekologicznych i proekologiczny styl życia mogą odgrywać ważną rolę w profilaktyce zdrowia ludzi. Celem badań było obliczenie korelacji między zawartością 29 makro- i mikroelementów we włosach a ich zawartością w mleku krów. Do badań wybrano 33 krowy rasy polskiej holsztyńsko-fryzyjskiej (hf) z trzech gospodarstw ekologicznych. Wszystkie gospodarstwa były położone w tej samej strefie klimatycznej i miały podobne warunki glebowe. Krowy były utrzymywane w tradycyjnej oborze uwięziowej. Krowy korzystały z pastwiska od maja do października. W zależności od wydajności pastwiska i potrzeb krów dawka pokarmowa była uzupełniana o siano, słomę, kiszonkę i zboża. Próbki mleka i włosów do oznaczenia składników mineralnych pobrano we wrześniu, w trakcie żywienia pastwiskowego. Włosy pobrano z wału międzyrożnego. W mleku i włosach oznaczono zawartość Ca, K, Mg, Na, P, S, B, Ba, Co, Cr, Cu, Fe, Ge, I, Li, Mn, Mo, Ni, Se, Si, Sn, Sr, V, Zn, Al, As, Cd, Hg i Pb. Poziomy elementów toksycznych w mleku okazały się niskie i leżały poniżej wartości dopuszczalnych. Korelacje między zawartością Ba, Ge, Mo, Pb we włosach i w mleku były dodatnie i statystycznie istotne. Korelacje między zawartością makroelementów K i Mg oraz mikroelementów Al, As, Co, Fe, Hg, Se, Sr były również dodatnie i wysokie, ale nieistotne statystycznie. Ujemne korelacje uzyskano między zawartościami Cr, Cu, I, Li, Ni, S, Si, Sn, V oraz Zn. Bardzo niskie wartości (bliskie zeru) współczynnika korelacji otrzymano dla zawartości Ca, Cd, Li, Mn, Na, Ni, P, S i Sn. Wydaje się, że dalsze badania składu mineralnego włosów u krów mogą być przydatne do oszacowania w przyszłości wartości referencyjnych dla niektórych pierwiastków i mogą się przyczynić do lepszego dobrostanu zwierząt.

Słowa kluczowe: krowy, włosy, mleko, makro- i mikroelementy, rolnictwo ekologiczne.

INTRODUCTION

Proper growth and functions of plants and animals require basic nutrients as well as mineral components. Out of more than a hundred elements occurring in nature, four organically bound elements (carbon, hydrogen, oxygen and nitrogen) make up 96% of the animal's body weight. The principal cations and anions together account for 3.5% of the body weight, the remainder comprising additional elements. The progress in analytical methods has led to elucidation of the biological role of many elements occurring in plant, animal and human organisms. Mineral distribution within the body's tissues is not uniform, since some tissues selectively concentrate specific elements. There is no disagreement concerning the essential nature of major and trace elements for livestock (Mcdowell 1992).

The value of the routine analyses, applied until today, of whole blood, serum and urine samples for bioelements is limited. The blood level of minerals does not often correspond to the content of minerals in the whole body because the composition of plasma results from supplementation of deficiencies by different homeostatic mechanisms. Moreover, the blood concentration of bioelements is relatively low and depends on a current diet, therefore the diagnostic value of such analytical results may be fairly small. Studies have shown that the analysis of hair and nails are an appropriate alternative for the analysis of blood and urine, and for biopsy. The diagnostic value of hair analysis is confirmed by many authors, who have demonstrated the presence of correlation between the levels of principal elements in hair and their content in the body, both at the physiological equilibrium and during pathological disturbances (Radomska et al. 1993, 2005). Milk is important for satisfying the nutritional demands of mammalian neonates. Data on minerals are limited to identifying the nutrients in milk required for optimal growth and health of mammalian species, including humans (Anderson 1992). Chemical treatments in agriculture, animal production and food processing introduce many food contaminants into the food chain. Organic methods in agriculture are safer and therefore very important. Nutrition based on organically produced foods and anthroposophic lifestyle can play an important role in health prophylaxis (Rembiałkowska 2003). Gabryszuk at al. (2008) suggested that the mineral composition of milk and hair depended on a production system (conventional *vs.* organic system). It seems that broader investigations of mineral composition of cow's hair could be useful for establishing reference values for some elements.

The objective of this study was to determine correlations between concentrations of 29 major and trace elements in cow's milk and hair.

MATERIAL AND METHODS

The experimental material consisted of 33 cows of Polish Holstein-Fresian (HF) breed from three dairy organic farms. All the farms were located in one climatic zone and under similar soil conditions. The cows were kept in traditional tied-up barns. The feeding was traditional, with ration components given separately. The cows were grazed from May to October. Depending on pasture yield and availability of other feeds, the feeding ration was supplemented with hay, straw, silage and cereals. All of the herds were under the official milk recording system, provided by the Polish Society of Cattle Breeders and Dairy Farmers.

Samples of milk and hair for analyses of minerals were collected in September, *i.e.* during pasture feeding. Hair was taken from the poll. It was washed with analytically pure acetone pure and rinsed 3 times with deionized water. The concentration of Ca, K, Mg, Na, P, S, B, Ba, Co, Cr, Cu, Fe, Ge, I, Li, Mn, Mo, Ni, Se, Si, Sn, Sr, V, Zn, Al, As, Cd, Hg, Pb was determined. Samples of hair (0.3 g) and milk (1 ml) were mineralised in a mixture of 4 ml HNO_3 and 1 ml H_2O_2 in hermetic high-pressure vessels by heating in a microwave oven. Content of mineral elements was determined by inductively coupled plasma atomic emission spectroscopy in a (ICP-AES) Optima 5300 DV, Perkin Elmer.

Preliminary statistical evaluation showed no significant effect of parity and milk yield on the content of minerals in cows' hair and milk. Pearson's correlation coefficients between the content of the same element in milk and in hair were computed from raw data, with no adjustments. The GLM procedure from the SAS package (1999) was used for computation.

RESULTS AND DISCUSSION

The mean concentrations and their standard deviations (SD) for macro- and micronutrients in milk and hair of cows are shown in Tables 1 and 2. It is quite interesting to notice that the concentration of Ca, Na, P was higher in milk than in hair. PULS (1994) reported that levels of macroelements in hair do not correlate with their dietary intake. Maintaining plasma Ca constant during lactation presents a formidable challenge to a dairy cow. If dietary sources of Ca are consumed at only 38% availability and dietary P at 45% availability, the cow must consume, on average, 90 to 100 g Ca and 60 to 70 g P daily just to meet her needs for lactation. Additional 25 to 30 g Ca and 15 to 20 g P must be supplied for daily maintenance of the cow (HORST et al. 1997). During the early weeks of lactation, most cows remain under the negative Ca balance. To maintain normal plasma Ca, resorption of bone Ca stores and absorption of Ca from intestines counterbalance the

Table 1

Means, standard deviations and correlations of macroelements in cow's milk and hair

Element	Milk (mg dm^{-3})		Hair (mg kg^{-1})		Correlation
	mean	SD	mean	SD	*r*
Ca	637.4	138.4	586.9	222.0	0.047
K	894.6	179.5	1297	592.8	0.237
Mg	61.85	12.35	63.24	25.59	0.205
Na	421.0	108.0	368.3	227.2	0.007
P	456.3	105.0	38.32	30.13	0.063
S	14.22	3.091	3968	675.7	-0.097

negative Ca balance. Bone Ca mobilisation is stimulated by a concerted effort of parathyroid hormone (PTH) and 1,25-dihydroxyvitamin D [1,25$(OH)_2$D]. The adaptation process begins with a dramatic increase in the plasma concentrations of PTH and 1,25$(OH)_2$D at the onset of hypocalcemia (Horst et al. 1997). Polish soils are considered to be low or very low in Mg. This can explain the fact that grazed cows showed significantly lower concentration of Mg in milk compared with TMR-fed cows (Gabryszuk et al. 2008). The levels of Ca, Mg and P in milk were generally lower compared to values reported by Kunachowicz et al. (2005). Disorders of calcium, phosphorus and magnesium homeostasis in ruminants provide natural models for the study of the physiology and pathophysiology of these minerals. The knowledge that can be acquired by improving our understanding of the pathogenesis of these diseases could give useful clues for solving the puzzle of human osteoporosis (Riond et al. 1995).

The content of trace elements in milk and hair is shown in Table 2. The levels of trace elements were within published ranges. Concentrations reported in the literature for cow's milk are (mg dm^{-3}): 3.3 for Zn, 0.559 for I, 217.2 for Ba, 0.079 for Cu, 84.9 for Cr, 74.3 for Mn, 84.5 for V, 61.0 for Ni, 60.5 for Se, 28.2 for Ge, 11.5 for Mo, and 6.5 for Co (Dobrzański et al. 2005). Other authors reported the following trace element content in cow's milk: 300-600 μg dm^{-3} Fe, 2-6 mg dm^{-3} Zn, 0.1-0.6 mg dm^{-3} Cu, 20-50 μg dm^{-3} Mn, 0.26 mg dm^{-3} I, 5-67 μg dm^{-3} Se, 0.5-1.3 μg dm^{-3} Co, 8-13 μg dm^{-3} Cr, 18-120 μg dm^{-3} Mo, 0-50 μg dm^{-3} Ni, 750-7000 μg dm^{-3} Si and 0-310 μg dm^{-3} V (Goff 1995). Differences in the concentrations of major and trace elements in milk of cows depended on nutrition, breed, age, dairy period and performance, geographical location, location of an experiment, occupation, production system, mineral status of cows and animal welfare. Hermansen et al. (2005) observed that organically produced milk in Denmark, compared with conventionally produced milk, contained a significantly higher concentration of Mo and lower concentrations of Ba, Mn and Zn.

Table 2

Means, standard deviations and correlations of trace elements in cow's milk and hair

Element	Milk (μg dm^{-3})		Hair (μg kg^{-1})		Correlation
	mean	SD	mean	SD	r
Al	63.64	52.37	14224	4928	0.247
As	12.27	4.010	34.82	8.091	0.287
B	90.91	30.25	810.0	500.3	0.114
Ba	26.36	32.19	298.7	279.4	0.594^{A}
Cd	1.130	0.141	2.700	0.254	0.005
Co	1.320	0.456	58.27	45.11	0.231
Cr	15.76	11.73	75.76	50.31	-0.121
Cu	157.6	197.3	2263	667.2	-0.128
Fe	785.7	656.4	15925	11737	0.315
Ge	14.13	7.300	41.58	12.37	0.786^{A}
Hg	0.396	0.346	82.78	59.83	0.225
I	309.1	91.83	9712	6180	-0.387
Li	59.09	37.45	11.85	8.290	-0.055
Mn	23.33	4.790	3587	1056	0.046
Mo	85.45	20.93	204.2	196.1	0.435^{a}
Ni	43.70	4.420	69.45	11.10	-0.011
Pb	6.210	2.580	32.67	16.15	0.480*A*
Se	18.79	1.371	912.4	259.4	0.268
Si	90.00	51.60	5060	1196	-0.236
Sn	13.88	2.990	133.9	27.79	-0.063
Sr	135.4	40.16	594.8	212.9	0.225
V	16.06	4.580	37.95	21.71	-0.425^{a}
Zn	1588	441.2	37 552	21 498	-0.410^{a}

A – highly significant at $P \leq 0.01$; *a* – significant at $P \leq 0.05$

The reference concentrations of minerals in cow's hair dry matter are for example 0.1-2.5% for Ca, 130-455 ppm for Mg, 0.2 ppm for Cr, 6.7-32 ppm for Cu, 59-200 ppm for Fe, 0.5-1.32 ppm for Mn, 0.5-1.32 ppm for Se and 100-150 ppm for Zn (Puls 1994). According to this author, determination of certain elements in hair may be useful for long-term monitoring of mineral status of animals (Puls 1994). Also, the mineral element status in the sheep's flock determined by wool analysis can be a good method. The content of mineral elements in wool showed statistically significant differences between Booroola and Polish Merino ewes. The results of concentration

of the same minerals in the blood plasma of the same ewes were within the reference value, and no significant differences were observed between breeds (GABRYSZUK et al. 2001). The mineral content of wool depended also on the physiological status (parturition, gestation, mating) of sheep (GABRYSZUK et al. 2000).

Milk yield may affect the mineral status of cows. The main problem in pasture feeding is that the composition and digestibility of nutrients, including the content of mineral elements, are highly affected by the stage of plant growth and can vary significantly in relatively short periods. Eventually, it is difficult to maintain constantly high milk production based on pasture feeding, even when the quality of grass is high and soil and water conditions are suitable for grass production.

A change in the body condition is a common physiological phenomenon in dairy cows. Usually, the condition worsens after parturition and then is gradually regained, which is more evident in the later part of lactation and during the dry period. This can also be related to cows' mineral supply. A clear difference between production systems was observed for cow's herd lifespan. The period from the first calving to disposal (culling) was around 2.5 years in the intensive (conventional) herd, while in the extensive (organic) herds it was twice as long (GABRYSZUK et al. 2008).

The content of toxic elements in milk was low and below the admissible level (*Ordinance of minister for health* 2003). The content of heavy metals in milk and hair depends on feed, content of these metals in soil, environmental contamination as well as the antagonistic interaction between bioelements and heavy metals, which influence their absorption and metabolism. For these reasons, the content of toxic elements in milk from ecological farms was not lower than in milk from conventional herds.

The statistically significant positive correlations between concentration in milk and in hair were determined for such elements as Ba, Ge, Mo, Pb. In respect of major elements K and Mg and trace elements Al, As, Co, Fe, Hg, Se, Sr, positive correlations were observed but they were not statistically significant. The negative correlations concern such elements as Cr, Cu, I, Li, Ni, S, Si, Sn, V and Zn. It was only for V and Zn that they were statistically significant. Very low values (near zero) of coefficient r were observed for Ca, Cd, Li, Mn, Na, Ni, P, S and Sn. DOBRZEŃSKI et al. (2005) reported that positive significant correlations between concentration in milk and in blood concern such elements as Mn, Ga, Ni, Ge, Mo, while for Al and V negative correlation were observed.

CONCLUSIONS

This study has demonstrated that the hair levels of macroelements (Ca, Na, P) do not correlate with their levels in the milk. The determination of K, Mg, Al, As, Bo, Co, Fe, Ge, Hg, Pb, Se and Se in hair can be useful for long-term monitoring of the mineral status of cows. It seems that broader investigations of mineral composition of cow's hair could be useful for establishing reference values for some elements and would make a contribution to better animals' welfare.

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