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Assessment of sodium and potassium levels in soil, feeds and hair of dairy cows in east-central Poland

Ocena poziomu sodu i potasu w glebie, paszach i sierści krów mlecznych z rejonu środkowo-wschodniej Polski

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Abstract
Studies were conducted on farm "A" located in east-central Poland to assess the mineral content in cows, taking into account individual links of the soil–feed–animal trophic chain. The mineral assessment included the determination of Na and K. Soil samples were taken once from the humus layer (that is at the depth of 0–15 cm) of pastures and arable fields in mid-growing season by means of a soil sampling stick. Feed samples were taken regularly when the feeds were included in rations (all year round), making sure the samples were representative. Sodium and potassium contents in soil and feeds were determined by the Atomic Absorption Spectrometry methods and in hair by the Inductively Coupled Plasma-Optical Emission Spectrometry method. There were two dates for hair sample collection: I (10–14 days prior to calving) and II (after the first month of lactation). The results showed that Na and K concentrations were sufficient to meet animal needs. The sodium level in cow's hair fell within the physiological range. Also potassium concentration complied with the referential standards (2000 mg·kg^{-1} d.m.) and approximated 2040 mg·kg^{-1} d.m.

Streszczenie
W fermie „A" znajdującej się na terenie środkowo-wschodniej Polski przeprowadzono badania mające na celu ocenę stanu zaopatrzenia mineralnego krów, biorąc pod uwagę poszczególne ogniwa łańcucha troficznego gleba-pasza-zwierzę. W ocenie mineralnej oznaczony został poziom Na i K. Próbki gleb pobierano jednorazowo z pastwisk i pól uprawnych w szczycie sezonu wegetacyjnego, z poziomu próchniczego (tj. głębokości 0-15 cm), za pomocą laski gleboznawczej. Próbki pasz pobierano systematycznie we wszystkich okresach wprowadzania ich do dawek pokarmowych (przez cały rok), przestrzegając zasady reprezentatywności prób. Zawartość sodu i potasu w glebie i paszach oznaczono metodą AAS. Zawartość Na i K w sierści oznaczono metodą ICP-OES. Próbki sierści pobierano od krów dwukrotnie: 10-14 dni przed porodem i po pierwszym miesiącu laktacji. Koncentracja badanych pierwiastków w paszach była wystarczająca w stosunku do potrzeb zwierząt. Poziom sodu w sierści krów z analizowanego stada utrzymywał się w granicach normy fizjologicznej. W sierści krów koncentracja potasu była prawidłowa biorąc pod uwagę wartości referencyjne (2000 mg·kg^{-1} s.m.) i oscylowała wokół poziomu 2040 mg·kg^{-1} s.m.

1. INTRODUCTION

Health maintenance and good performance of animals depend on a balance between the supply in the diet and mineral demand of the animal body, the minerals including macroelements (Ca, P, Mg, Na and K) which, due to their physiological role, cannot be replaced [Wnuk *et al*. 2002]. However, feeds used in rations of fast-growing and high-performing animals do not fully meet their demands. Continuous intake of feeds containing insufficient mineral amounts leads to biochemical and functional disorders in animal bodies. Their intensity depends on the length of deficiency period, age, sex and species of an animal [Suttle 2010]. Mineral disorders often take place during the perinatal period when, due to enhanced metabolism, nutrients are obtained from the deepest bodily reserves [Wilde 2006].

It is widely believed that the assessment of mineral supply based on nutrient levels in body fluids is very dynamic and reflects the current body reserves [Krupa and Budzyńska 2011]. Determination of levels of macroelements in animals based on their concentration in blood serum is not a reliable diagnostic criterion due to the fact that there are no clear early changes in their concentrations in blood. Sodium level in blood serum is not constant and changes with Na supply to the body. Only when sodium deficiency is substantial, can any changes in Na concentration in serum be noticeable [Philips *et al*. 2000]. In turn, hair is a biological material in which minerals accumulate for a long period of time thus providing more objective information about the level of supply of the body with essential elements [Patra *et al*. 2007].

Sodium and potassium are basic cations of bodily fluids and are of great importance for proper body function because they affect the water, electrolyte and acid–base balance [Krupa and

Budzyńska 2011, Soetan *et al*. 2010]. The objective of a one-year study was to evaluate the characteristics of mineral concentration of dairy cattle in east-central Poland in the trophic chain: soil–feed–animal.

2. MATERIAL AND METHODS

Research lasted for one year and was carried out in east-central Poland on 24 black and white Polish Holstein-Friesian dairy cows (dairy farm 'A'). Soil samples were taken once from the humus layer (that is at the depth of -–15 cm) in pastures and arable fields in the mid-growing season using a soil sampling stick. The total content mineral content was determined by the ASA method. Analysis of mineral content in feeds fed to the dairy cows was conducted. Feeds were sampled regularly in all the periods when they were used to formulate feeding rations (all year round) making sure the samples were representative. Sodium and potassium contents were determined by the Atomic Absorption Spectrometry method. The cows were clinically healthy, free of infectious diseases and included in the prophylactic programme of invasive disease control. The research was conducted during summer and winter feeding. In winter, animals were kept in a barn where the parameters met the animal hygiene standards for dairy cattle. The cows were offered corn silage, meadow hay and barley straw. Over summer months, feeding rations included pasture green feed and arable crop green feed, both supplemented with hay and barley straw. Concentrated feed was used depending on the performance of individual cows. Nutritional requirements of cows were established based on feeding standards [NRC 2001]. Hair samples were taken from cows in the first lactation month.

One-colour (white) hair regrowth (after shaving off) was sampled from the back as recommended by Brochart [1971]. There were two hair sampling dates: I (1—14 days prior to calving) and II (after the first month of lactation). The hair was carefully cleaned and degreased using detergents and alcohol. Dried and weighed samples were placed in Teflon containers and spectrally pure concentrated nitric acid and hydrogen was poured over them (Merck, Germany). After mineralisation of samples in a microwave station they were analysed using spectrophotometry. Sodium and potassium contents in hair were determined by Inductively Coupled Plasma method using a plasma spectrometer Philips SC-PU 7000 coupled with a CETAC U-5000 AT Ultrasonic Nebulizer. The methodology is described in more detail in the works by Bodak and Dobrzański [1997] and Górecka [1995]. Data are reported as mean ± standard deviation. Analyses of the data were performed using Statistica 10® PL. Differences between means were investigated using Student *t*-test.

3. RESULTS AND DISCUSSION

Sodium and potassium concentration values in Polish soils are usually low. In the present study, both sodium content and potassium content in the soil samples were low and did not exceed 0.11 and 2.20 g·kg^{-1} d.m, respectively. The lighter the soil is, the less potassium it contains because, among others, the element is more readily leached out of light mineral soils [Czuba 1996]. It should be mentioned that, unlike sodium, potassium is usually supplied to the soil with mineral fertilisers [Wesołowski *et al*. 2003, Barłóg *et al*. 2013]. Soil potassium reserves fluctuate with changing amounts of floatable fractions and acidity [Błaszczyk and Dudys 2000].

Sodium levels in corn silage, pasture forage and meadow hay approximated 2.0 g·kg^{-1} d.m. which, according to Grela [2001], is an optimum value in feeding of dairy cows. Lower Na values, around 1 g·kg^{-1} d.m., were determined in barley straw whereas for concentrate they were clearly higher and amounted to around 5.5 g·kg^{-1} d.m. (Table 1). The potassium levels in feeds recorded in this study, ranging between 6.44 and 14.43 g·kg^{-1}d.m., were quite high (Table 2). According to Hart *et al.* [1997], high potassium levels in feeds, exceeding 15 g·kg^{-1} d.m., may promote the following metabolic diseases in cows: grass tetany, mastitis and milk fever. A decline in magnesium ion absorption due to a high concentration of potassium in the diet may result in hypomagnesaemia [Schonewille *et al*. 1997]. In turn, too much potassium in the diet may lead to sodium deficiency in animals as potassium contributes to the marked removal of sodium from the body due to increased urine production [Brzóska 2008]. Potassium concentration in plant feeds depends on Na content in

Table 1. Sodium content in soil, each feedstuff and hair of studied cows in farm „A"

Material	Soil g·kg^{-1} d.m.	Feedstuff type g·kg^{-1}d.m.					Hair mg·kg^{-1}d.m.	
		Corn silage	Pasture forage	Concentrate	Meadow hay	Barley straw	I	II
$\overline{x}$	0.11	1.98	1.86	5.54	1.70	0.98	355.20^{NS}	356.66^{NS}
SD	0.33	0.53	0.23	0.64	0.44	0.24	15.34	16.64

$\overline{x}$ - mean
SD - standard deviation
NS - differences insignificant
I, II - sampling

Table 2. Potassium content in soil, each feedstuff and hair of studied cows in farm „A"

Material	Soil g·kg^{-1} d.m.	Feedstuff type g·kg^{-1}d.m.					Hair mg·kg^{-1}d.m.	
		Corn silage	Pasture forage	Concentrate	Meadow hay	Barley straw	I	II
$\overline{x}$	2.20	13.76	10.88	14.43	14.35	6.44	2045.27^{NS}	2036.00^{NS}
SD	0.98	6.78	1.23	1.08	1.61	2.73	63.54	61.51

$\overline{x}$ - mean
SD - standard deviation
NS - differences insignificant
I, II - sampling

soil, plant species and maturity and fertilisation applied. Excess potassium in plants is observed when too high rates of nitrogen and potassium fertilisers have been applied, which contributes to the reduced uptake of other cations such as sodium, magnesium and calcium [Preś and Kwiatkowski 1990].

Sodium and potassium levels in the animal body can be assessed based on the concentration of these macroelements in hair [Budzyńska *et al*. 2006]. This method is no-invasive, rapid, does not disrupt tissue continuity and may be used to assess mineral deficiencies in the body [Cygan-Szczegielniak *et al*. 2014, Gratacos-Cubarsi *et al*. 2006, Kazi *et al*. 2006]. Sodium content in cow's hair did not exceed 356.66 mg·kg^{-1} d.m. There were no statistical differences between hair samplings (Table 1). Sodium levels in cow's hair in the examined dairy herd were similar to values reported by Bis-Wencel [2001]. They fell within the range of physiological standard values so no Na deficiency in the animal body occurred.

In the study discussed here, the level of potassium in cow's hair only slightly exceeded 2045 mg·kg^{-1} d.m. There were no statistical differences between hair samplings (Table 2). Similar values were presented in the work by Bis-Wencel [2001]. As the physiological standard figure is 2000 mg·kg^{-1} d.m, the aforementioned value can be accepted as appropriate.

4. CONCLUSIONS

Soils belonging to the farm studied contained low sodium and potassium levels. The concentrations of the above elements in feeds fluctuated and depended on type of the feeds. Feeds produced on-farm contained sodium and potassium concentrations which were sufficient to meet the animals' needs. Sodium content in cow's hair was very close to the physiological standard and potassium level was appropriate when referred to the referential values.

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