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Selenium concentration in soil, and in the feed and hair coat of Polish Holstein-Friesian cows administered a mineral mixture

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Selenium is an essential component of animal organisms, ensuring their proper function (De *et al*. 2017). Long-term selenium deficiency in animals may cause nutritional muscular dystrophy (Kim and Mahan 2003). In all animal species, selenium deficiency leads to impaired fertility in males and females (Palmieri and Szarek 2011). In areas with a deficiency of this element, an increase was observed in perinatal disorders, such as retained placenta, abortion and stillbirth (Sattar *et al*. 2007). Selenium deficiency leads to increased incidence of ovarian cyst formation (Jukola *et al*. 1996). The main source of selenium in the diet of cattle is plant-based feed, and its content in feed is affected by its content in the soil and the ability of the plant species to up take it . Feed with about 0.1 mg/kg DM, covers the selenium requirement for cows (Ammerman and Goodrich 1983). If selenium content falls below 0.01 mg/kg DM, symptoms of deficiency may occur (Kabata-Pendias and Pendias 2001). Selenium status in animal organism can be expressed as its concentration in the hair coat (Batariova *et al*. 2005). The gradual and slow deposition of minerals in the hair is widely viewed as a reflection of their actual concentration in the animal organism (Puls 1994). Selenium concentrations in hair appear to be correlated with dietary intake (Combs 1987). Selenium deficiencies with varying degrees of severity have been reported in cattle (Krzyżewski *et al*. 2014) and horses (Wyganowska *et al*. 2017) in many parts of Poland. Both the low selenium status of cattle in Poland and its low content in feed indicate that proper nutrition requires the introduction of selenium supplements to the feed ration. In cattle diets, selenium is most often included in mineral mixtures (Koh and Judson 1987). The aim of the study was to determine the nutritional suitability of the Bovifosfomag® mineral mixture, whose composition took into account the biogeochemical conditions of the location of farms in eastern Poland.

A two-year study was conducted on four dairy cattle farms, viz. A, B, C and D, located in eastern Poland. Herds with an average of 12 Polish Black-and-White Holstein-Friesian cows, were divided into two groups, i.e. control and treament. The control cows did not receive the mineral supplement. The animals in the treatment group received the Bovifosfomag® mineral mixture (Table 1). The mixture was administered with concentrate feed @ 150 g/cow. It was introduced into the diet gradually over a period of two weeks. The animals were clinically healthy. The study was conducted during the summer and winter feeding periods. The animals were fed maize silage, meadow hay, barley straw and compound concentrate feed. In the summer, the feed rations included pasture forage and field crops. The nutritional needs of cows were established on the basis of feeding recommendations (NRC 2001). Soil samples were collected once from the soil surface layer in the middle of the growing season. On each farm, 15 pooled soil samples were collected. The soil samples were collected at a depth of 0–30 cm. Soil pH was measured using a glass electrode in a saturated paste. Feeds were regularly sampled during the time they were fed to the cows. The selenium content in soils and feeds was analysed by hydride generation-atomic absorption spectrometry (Perkin Elmer). Hair samples were taken from cows twice (10–14 days before parturition and after the first month of lactation) . The material for the tests was acquired in the second year of administration of the mineral mixture, following a thorough veterinary examination. Hair of uniform colour (white), newly grown in (after shaving), was taken from the dorsal area, according to recommendations by Brochart (1971).

The hair was thoroughly cleaned and degreased with detergents and alcohol. Dried and weighed samples were placed in Teflon crucibles and concentrated Suprapur® nitric acid and hydrogen peroxide (Merck, Germany) were poured over them. Selenium in the digested hair samples was analysed by hydride generation-atomic absorption spectrometry. Hair mineral concentrations were reported as mg/kg DM.

Data were reported as mean±standard deviation. Statistical analysis of the results was performed in Excel 2010 and Statistica® 10 PL software. The significance of differences between means for groups of animals was

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Table 1. Composition of modificated material of mineral mixture Bovifosfomag®

Specification	Content of pure element											
	(g)	Ca (g)	P (g)	Mg (g)	Na (g)	Zn (g)	Cu (g)	Fe (g)	Mn (mg)	Se (mg)	I (mg)	Co (mg)
$Ca(H_2PO_4)_2$ (Calcium phosphate)	350	60	95	–	–	–	–	–	–	–	–	–
$Ca_3(PO_4)_2$ (Tricalcium phosphate)	100	39	20	–	–	–	–	–	–	–	–	–
MgO (Magnesium oxide)	175	–	–	105	–	–	–	–	–	–	–	–
$CaCO_3$ (Ground limestone)	200	80	–	–	–	–	–	–	–	–	–	–
NaCl (Forage salt)	175	–	–	–	70	–	–	–	–	–	–	–
$ZnSO_4.7H_2O$ (Zinc sulfate)	22.000	–	–	–	–	5.0	–	–	–	–	–	–
$CuSO_4.5H_2O$ (Cupric sulfate)	4.000	–	–	–	–	–	1.0	–	–	–	–	–
$FeSO_4.7H_2O$ (Ferrous sulfate)	5.000	–	–	–	–	–	–	1.2	–	–	–	–
$MnCO_3$ (Manganese carbonate)	0.020	–	–	–	–	–	–	–	10.0	–	–	–
Na_2SeO_4 (Sodium selenate)	0.050	–	–	–	–	–	–	–	–	20.0	–	–
KI (Potassium iodide)	0.040	–	–	–	–	–	–	–	–	–	30.0	–
$CoSO_4.7H_2O$ (Cobalt sulfate)	0.015	–	–	–	–	–	–	–	–	–	–	3.0
Total microelements	1000	179	115	105	70	5.0	1.0	1.2	10.0	20.0	30.0	3.0

verified by Student's t-test. The level of significance was set at P≤0.05.

The average selenium content in the soil ranged from 0.01 µg/g DM (farms B, C and D) to 0.02 µg/g DM (farm A). The pH of the soils ranged from 6.0 to 6.1 (Table 2).

The data presented in Table 2 indicate that the selenium level in the feed for cows varied according to the kind of feed. The lowest selenium content was found in the concentrate (0.06–0.07 mg/kg DM). The selenium concentration in the remaining feeds ranged from 0.15 mg/kg DM (farm C) to 0.28 mg/kg DM (farm A).

Selenium levels in the hair of the dairy cows from farms A, B, C and D are presented in Table 2. The data show that the average level of selenium in the hair of cows fed on-farm feed without a selenium supplement ranged from 0.22 mg/kg DM (farm B) to 0.43 mg/kg DM (farm D). The Bovifosfomag® mineral blend containing selenium resulted in a significant increase (P≤0.05) in the concentration of this element in the cow hair, to a level indicating sufficient supply of selenium to cows (Table 2).

The calving interval and gestation interval were shortest for the cows from farm A receiving the Bovifosfomag$^{\beta}$ mineral supplement (379.5 and 103.8 days respectively), and longest for the cows from farms C and D whose diet contained no additives (431.1 and 155.0 days respectively) (Table 3).

This means that the use of the mixture significantly reduced the length of these periods (P≤0.05). The insemination index was also lower for the cows receiving the supplement.

The selenium concentrations indicate very low soil content of this element. Most soils worldwide have showed low content of selenium (Cartes *et al*. 2005). The natural Se concentration in soils ranges from 0.1 to 2.0 µg/g DM, and the mean selenium concentration in the surface layers of soil worldwide is less than 0.5 µg/g DM (Combs 2001). According to Kabata-Pendias and Pendias (2001), the mean selenium content in Polish soils is 0.27 µg/g DM. Biernacka and Maluszyñski (2006) reported that the selenium concentration was 0.06–0.81 µg/g DM in the soils of southern Poland and ranged from 0.11 to 1.57 µg/g DM in north-eastern Poland. Sandy soils typically have low quantities of selenium, while soils originating from rocks material rich in selenium may contain significantly higher quantities of element (Cartes *et al*. 2005). In acidic soils, selenium occurs in the form of selenides, which are characterized by low bioavailability (Mehdi *et al*. 2013).

The selenium level in feeds should be between 0.1 and 2 mg/kg DM (Ammerman and Goodrich 1983). According to the recommended values, the feeds tested had a sufficient quantity of this element. The bioavailability of selenium for plants depends on soil pH, the redox conditions in the

Table 2. Selenium content in soil, each feedstuff and hair of studied cows in farms A, B, C and D

Farms	Soil (µg/g DM)	Soil pH	Feedstuff type (mg/kg DM)					Hair (mg/kg DM)			
								Sampling I		Sampling II	
			Corn silage	Pasture forage	Concentrate	Meadow Hay	Barley straw	Control group	Treated group	Control group	Treated group
A	0.02±0.01	6.0	0.28±5.84	0.20±0.01	0.07±0.01	0.21±0.02	0.25±8.25	0.30^{a}±0.37	1.35^{b}±0.32	0.27^{a}±1.47	1.25^{b}±1.17
B	0.01±0.01	6.0	0.25±7.99	0.21±0.01	0.07±0.01	0.21±0.02	0.22±6.80	0.22^{a}±2.37	1.37^{b}±2.43	0.25^{a}±1.87	1.24^{b}±3.31
C	0.01±0.01	6.1	0.15±8.43	0.20±0.02	0.06±0.01	0.23±0.01	0.22±5.94	0.31^{a}±1.94	1.40^{b}±2.32	0.29^{a}±1.63	1.36^{b}±3.36
D	0.01±0.01	6.1	0.20±10.12	0.21±0.02	0.06±0.01	0.20±0.01	0.23±7.00	0.43^{a}±1.22	1.28^{b}±2.26	0.39^{a}±1.42	1.29^{b}±2.53

Mean±SD. Values with same letter differ nonsignificantly (P≤0.05).

Table 3. Selected fertility rates in examined cows.

Reproductive parameter	Farm	Control group	Treatment group
Calving interval (days)	A	429.8^{b}±79.00	379.5^{a}±36.51
	B	428.3^{b}±65.33	381.6^{a}±43.47
	C	431.1^{b}±75.64	406.2^{a}±46.17
	D	424.7±69.01	402.4^{a}±36.93
Gestation interval (days)	A	149.7^{b}±65.50	103.8^{a}±35.63
	B	139.1^{b}±75.10	105.4^{a}±41.20
	C	151.2^{b}±64.39	107.6^{a}±38.67
	D	155.0^{b}±69.01	109.3^{a}±35.80
Insemination index	A	2.3^{a}±1.6	2.1^{a}±1.25
	B	2.4^{a}±1.5	2.2^{a}±1.30
	C	2.3^{a}±1.7	2.0^{a}±1.40
	D	2.1^{a}±1.8	1.9^{a}±1.35

Mean±SD. Values with same letter differ nonsignificantly (P≤0.05).

soil, the degree of selenium oxidation, climate factors, and the activity of soil microbes (Krzyżewski *et al*. 2014). The concentration of selenium in plants may be reduced by contamination of the soil with heavy metals and sulphur and by the use of phosphorous and nitrogen fertilizers (Mikkelsen and Wan 1990).

According to the reference range for selenium concentrations in the hair coat (0.5–1.32 mg/kg DM), this suggests an insufficient supply of this element to the animals (Puls 1994). Markedly lower content of selenium was noted in sheep wool by Antunovic *et al*. (2010), who also demonstrated a link between selenium level in the body of sheep and its content in their feed. Monitoring of selenium concentration in cow hair may be the basis for the use of dietary supplements containing selenium to avoid the risk of many diseases caused by deficiency of this element. The presence of selenium deficiency in animals despite a proper Se concentration in feed can be explained by insufficient intake of vitamin E or the inhibitory effect of sulphur compounds (Netto *et al*. 2014). Secondary selenium deficiency is also likely, due to factors interfering with the assimilation of the element from the food ration (the chemical form of selenium in the feed, heavy metals in the feed interfering with selenium absorption, or low rumen pH) (Awadeh *et al*. 1998). Increasing the sulphur and calcium content in the feed ration reduces absorption of selenium (Pavlata *et al*. 2005).

Reproductive indices in cows depend on fulfilment of requirements for nutrients, which are not always sufficiently supplied in feed. Selenium deficiency causes fertility disorders, which are the main reason for culling cows and affect the profitability of dairy farming (Kruze *et al*. 2007). Administration of selenium has been shown to result in improved fertility rates as compared to control cows (Sattar *et al*. 2007). Prepartum supplementation with selenium increases conception rates, and thereby reduces the gestation interval in lactating dairy cows (Arechiga *et al*. 1994). Hemingway (2003) also showed that the application of selenium resulted in an improved fertility index.

SUMMARY

The aim of the study was to determine the nutritional suitability of the Bovifosfomag® mineral mixture, whose composition took into account the biogeochemical conditions of the location of farms. The criterion for the supplement's nutritional suitability was the selenium level in the hair coat of Polish Black-and-White Holstein-Friesian dairy cows. Hair from animals in control and experimental groups was collected twice (10–14 days before parturition and after the first month of lactation). Selenium content in the hair coat was determined by hydride generation-atomic absorption spectrometry. The mean selenium concentration in the hair of cows from the control group ranged from 0.22 to 0.43 mg/kg DM, which was insufficient to meet the production requirement. The mineral mixture containing selenium caused a significant increase (P≤0.05) in the Se concentration in the hair, to a level indicating a sufficient supply of selenium. The mineral supplement also improved the fertility rates in the experimental group.

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