Assessment of Manganese Levels in the Soil and Feeds, and in the Bodies of Milk Cows from Central-Eastern Poland Administered a Mineral Compound Feed

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ABSTRACT

Background: Highly productive animals are characterised by particularly high requirement of minerals and the tendency to mineral deficiency in the period of intensive lactation. Appropriate mineral nutrition of ruminants is largely determinate by soil and plant availability of minerals. The missing elements could be supplied directly in water, mineral licks, mixtures and drenches, and intramuscular injections. Study was aimed at assessing the manganese supply to cows, on the basis of analyses of the soils, feeds and body tissues in the herd in which fertility problems were observed and determining the dietary value of a mineral compound feed (Bovifosfomag®).

Materials, Methods & Results: Three year studies were conducted in central-eastern Poland on selected dairy farm to evaluate the manganese status in cows based on soil, feed and body tissue (hair) analyses. Moreover, alkaline phosphatase activity was determined in animal blood serum. Twenty two cows with symptoms of reproductive system pathologies were selected from farm. Dairy cows were used to determine feeding usefulness of the mineral mixture Bovifosfomag® composed taking into account the biogeochemical conditions of the area. Soil samples were collected once from pastures and cultivated fields at the peak of the vegetation season. Manganese content was determined using the atomic absorption spectrophotometer. Feed samples were obtained in all the periods when the feeds were introduced as diet components. Mn content in the feeds was determined by the AAS method. Samples of hair were taken from the back part of the body after first month of lactation. Hair contents of manganese were determined by the ICP method. Determinations of alkaline phosphatase activity were made by the kinetic method using Cormay monotests. It was found that manganese level in the analysed soils were within the range of typical values reported for this type of soils in Poland. Mn concentration in feeds were sufficient in terms of dietary requirements of animals. Manganese concentration in cow hair exceeded the threshold value of 8 mg/kg⁻¹ d.m. An application of the mineral mixture Bovifosfomag® as a supplement to alleviate the manganese deficiency effects favourably influenced the mineral metabolism of the cows, which was reflected in increased hair levels of Mn and reduced alkaline phosphatase activity in experimental group. The percentage of cows with symptoms of reproductive system pathologies was much lower in the experimental group than in the control group.

Discussion: Concentration of manganese in the soil examined was adequate for plants. Plants concentration of manganese is the most positively correlated with the Mn soil concentration. The feed concentrations of manganese recorded in the present study posed no threat to the animals as they indicated neither manganese deficiency nor excess. The usefulness of hair for diagnosing animal demand for macro- and microelements results from the specific structure of hair tissue that lends it resistance to biological modification and a constant chemical composition. Manganese deficiency is associated with a fall in alkaline phosphatase activity in cow serum. This activity can thus be an indirect index of manganese deficiency. There is a connection between perinatal diseases and macro- and microelement levels in the body. Animal fertility and performance are affected by a number of factors. A particular role was played here by the diet. Mistakes made in feeding the cows led to digestive and metabolic disorders. The applied Bovifosfomag® mineral compound feed positively influenced the mineral metabolism of the cows, which was manifested in correct manganese levels in the hair and reduced alkaline phosphatase activities in the animals, as well as in lower percentages of cows showing symptoms of reproductive system disorders in the experimental group.

Keywords: cows, minerals, manganese, soil, feed, hair.

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INTRODUCTION

The correct provision of ruminants with minerals is largely affected by how rich the soil and the plants growing on it are in minerals [3,17]. This gives rise to the necessity of analysing the biogeochemical conditions each time, as well as the interactions between the elements in the soil-plant-animal system [23].

Incorrect feeding is frequent causes of health problems of milk cows [2,7,18]. The correct course of many vital processes depends on the availability of macroelements [1,24]. An essential role for the course of these processes is also played by microelements, such as: iron, selenium, cobalt, zinc, copper and manganese [20,21,29,30,34,36]. With manganese deficiency, animals undergo fertility disorders manifested in higher numbers of miscarriages, lower values of reproductive indices and higher incidence of ovary cysts [11,22,32,33]. The fertility deterioration associated with manganese deficiency is an after-effect of disordered synthesis of cholesterol and cholesterol-related compounds indispensable for the synthesis of sex hormones and other steroids [16].

Supplementation of deficient minerals in ruminants can be achieved through the use of multicomponent mineral feeds [20]. In the case of manganese deficiency, supplementation is also availed of when there is only an unconfirmed suspicion of this shortage [27].

Study was aimed at assessing the manganese supply to cows, on the basis of analyses of the soils, feeds and body tissues in the herd in which fertility problems were observed and determining the dietary value of a mineral compound feed (Bovifosfomag®).

MATERIALS AND METHODS

Animals and diets

A three-year study was performed in the region of central-eastern Poland on selected dairy farm. The animals raised on the farm were Polish Holstein-Friesian breed, Black and White variety, aged between 4 and 7 years with an average lactational milk performance of around 4300 kg. Twenty two cows with symptoms of reproductive system pathologies were selected from farm. The animals had similar rearing parameters. The study was carried out over the period of summer and winter feeding. In winter the animals were housed in barns where they were maintained appropriate zootechnical parameters required for dairy cows. Feeding regimes of cows were based on rations including corn silage, meadow hay, barley straw and a concentrated mixture. In summer, the rations included green forage from meadows and cultivated fields supplemented by hay and barley straw. Nutritional requirements of the cows were established on the basis of NRC [26].

The study was divided into two stages. During the first one-year stage the evaluation of the characteristics of mineral metabolism in cows was made. The evaluation took into account the local biogeochemical conditions and was based on examination of manganese content in the soil, feeds and hair. In the second stage, the balanced mineral mixture Bovifosfomag®1 was introduced to the diet in the amount of 150 g per cow per day (Table 1).

Over the period of 14 days, the eleven cows from the treatment group was offered the mixture together with the concentrated feed in the morning to let the animals get used to the new regime. The control cows did not receive an addition of the mineral mixture. The effect of mineral supplement on manganese status in dairy cows’ hair was determined after two years of supplementation.

Sample collection

Soil samples were collected once from pastures and cultivated fields at the peak of the vegetation season by means of a soil sampling stick from the surface layer (0-15 cm). Manganese content was determined in the samples by soil mineralization in a mixture of concentrated acids HNO₃ + HCLO₄. The determination was performed using the atomic absorption spectrophotometer ASA Solaar 939 (Unicam)². Feed samples were collected in all the periods when the feeds were introduced as diet components. Manganese content in feed was determined by atomic absorption spectrometry ASA by means of the apparatus Solaar 939 (Unicam)². As recommended by Brochart [5], samples were taken of white hair (which had just grown back following shaving) from the back. The sampling date was after the first month of lactation. The hair was cleansed and degreased using detergents and alcohol. Dried and weighed hair samples were placed in Teflon® containers which were filled with spectrally clean, concentrated nitric acid and hydrogen peroxide (Merck)³. Following microwave mineralization, the samples were subjected to spectrometric analysis. Manganese content in hair was determined by the ICP (Inductively Coupled Plasma) method using the plasma spectrometer ICP Philips
SC-PU 7000 attached to the Ultrasonic-Nebulizer\textsuperscript{4} [14]. Blood was collected after one month of lactation. Alkaline phosphatase activities were identified by kinetic method [6] in blood serum, using ACCENT 200 automated chemistry analyzer (Cormay)\textsuperscript{5} and commercial Cormay diagnostic kits\textsuperscript{6}.

**Statistical analysis**

Data are reported as mean ± standard deviation. Analyses of the data were performed using Statistica for Windows\textsuperscript{7}. Differences between group means were investigated using Student t-test. The level of significance was set at $P < 0.05$.

### Table 1. Material composition of experimental Bovifosfomag\textsuperscript{®} mixture.

<table>
<thead>
<tr>
<th>Source compound (macrolelement)</th>
<th>Content of pure element (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca</td>
</tr>
<tr>
<td>Calcium phosphate Ca(H\textsubscript{2}PO\textsubscript{4})\textsubscript{2}</td>
<td>350</td>
</tr>
<tr>
<td>Tricalcium phosphate Ca\textsubscript{3}(PO\textsubscript{4})\textsubscript{2}</td>
<td>100</td>
</tr>
<tr>
<td>Magnesium oxide MgO</td>
<td>175</td>
</tr>
<tr>
<td>Ground limestone CaCO\textsubscript{3}</td>
<td>200</td>
</tr>
<tr>
<td>Forage salt NaCl</td>
<td>175</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source compound (microelement)</th>
<th>Content of pure element (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zn</td>
</tr>
<tr>
<td>Zinc sulfate ZnSO\textsubscript{4}7H\textsubscript{2}O</td>
<td>22,000</td>
</tr>
<tr>
<td>Cupric sulfate CuSO\textsubscript{4}5H\textsubscript{2}O</td>
<td>4,000</td>
</tr>
<tr>
<td>Ferrous sulfate FeSO\textsubscript{4}7H\textsubscript{2}O</td>
<td>5,000</td>
</tr>
<tr>
<td>Manganese carbonate MnCO\textsubscript{3}</td>
<td>0.020</td>
</tr>
<tr>
<td>Sodium selenate Na\textsubscript{2}SeO\textsubscript{4}</td>
<td>0.050</td>
</tr>
<tr>
<td>Potassium iodide KI</td>
<td>0.040</td>
</tr>
<tr>
<td>Cobalt sulfate CoSO\textsubscript{4}7H\textsubscript{2}O</td>
<td>0.015</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>31,125</td>
</tr>
</tbody>
</table>

#### RESULTS

The mean manganese level in the analysed soils was found to be 269.62 mg/kg\textsuperscript{-1} d.m. (Table 2). Manganese levels in maize silage, pasture green forage and meadow hay oscillated around the value of 50 mg/kg\textsuperscript{-1} d.m.

Lower manganese levels were, in turn, identified in concentrated mixtures and barley straw from the analysed farms. In the study, manganese concentration in cow hair exceeded the threshold value of 8 mg/kg\textsuperscript{-1} d.m. The applied mineral compound feed led to an insignificant rise of Mn levels in cow hair. In the study, alkaline phosphatase activity in bovine blood did not exceed 70 U/L. It can be regarded as normal. The administration of the mineral compound feed contributed to a reduction in alkaline phosphatase activity form 69.38 U/L to 66.00 U/L ($P < 0.05$) [Table 2].

Among the 11 cows which were not administered the mineral compound feed, three were found to develop pathological symptoms concerning the hypofunction and afunction of ovaries, there were two cases of ovarian cysts, and two cows were diagnosed with placenta retention (Table 3).

The number of the above pathological cases was relatively lower in the treatment group. As regards purulent inflammation of uterus, two cases were recorded in the control group, and only one in the experimental one. It should be noted that the percentage of cows with symptoms of reproductive system pathologies was lower in the treatment group than in the control group.
Table 2. Manganese content in soil, each feedstuff, coat hair and AP levels in the serum of studied cows.

<table>
<thead>
<tr>
<th>Material</th>
<th>Soil mg·kg⁻¹ d-m</th>
<th>Feedstuff type mg·kg⁻¹ d-m</th>
<th>Hair mg·kg⁻¹ d-m</th>
<th>AP U/l</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maize silage</td>
<td>Pasture forage</td>
<td>Concentrate</td>
<td>Meadow hay</td>
</tr>
<tr>
<td>UTES</td>
<td>269.62</td>
<td>47.89</td>
<td>52.07</td>
<td>31.68</td>
</tr>
<tr>
<td>SE</td>
<td>19.67</td>
<td>7.40</td>
<td>7.29</td>
<td>2.83</td>
</tr>
</tbody>
</table>

*ab significant differences between groups at *P* < 0.05; (1) alkaline phosphatase; (2) C - control group; (3) T - treatment group; (4) Standard deviation.

Table 3. Incidence of reproduction clinical disturbances in cows from the studied farm prior and after the mineral mixture supply.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FARM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control group</td>
</tr>
<tr>
<td>Sexual cycles observed</td>
<td>11</td>
</tr>
<tr>
<td>Hypofunction and dysfunction of ovaries</td>
<td>3</td>
</tr>
<tr>
<td>Ovary cysts</td>
<td>2</td>
</tr>
<tr>
<td>Placenta retention</td>
<td>2</td>
</tr>
<tr>
<td>Purulent inflammation of uterus</td>
<td>2</td>
</tr>
</tbody>
</table>

DISCUSSION

Polish soils are generally quite rich in manganese. Increasing soil acidification, however, leads to manganese depletion. Apart from the soil pH, the presence of assimilable forms of manganese is affected by the moisture content and organic fertilisation. Sandy soils have a lower manganese content than clayey ones, and mineral soils are poorer than organic ones [25]. Concentration of manganese in the soil examined was adequate for plants. Plants concentration of manganese is the most positively correlated with the Mn soil concentration. According to recommendations [26], the cow demand for manganese is covered by feeds that contain approximately 40 mg/kg⁻¹ d.m. of this trace element. The feed concentrations of manganese recorded in the present study posed no threat to the animals as they indicated neither manganese deficiency nor excess.

It is commonly believed the hair is a good index of the body content of manganese [31]. Hair is an easily collectible analytical material. The usefulness of hair for diagnosing animal demand for macro- and microelements results from the specific structure of hair tissue that lends it resistance to biological modification and a constant chemical composition [10]. This helps determine manganese deficiency or excess when due to a factor that acts over a long period of time, e.g. manganese-deficient feeds [9,12]. The level of Mn in the hair of control and experimental cows on the studied farm was within the physiological value [19].

Manganese deficiency is associated with a fall in alkaline phosphatase activity in cow serum. This activity can thus be an indirect index of manganese deficiency [28]. The level of AP activity in the serum of cows assumed values within the physiological limits, considering the reference range of up to 200 U/L [4]. Manganese levels in animal bodies depend, among others, on the type of compounds in which this element is present in plants and the antagonistic action of some elements, including Ca, P and Fe [13,37]. What is important in the soil-plant system is the relation of iron to manganese. Mn deficiency in plants is connected with excessive iron content. Elevated Ca and P levels in the feed reduce manganese assimilation [17].

In connection with high numbers of reproductive system ailments at the analysed farm, we started a study to identify manganese levels in the bodies of the...
cows, as manganese deficiency can result in fertility disorders in animals. As reported by Machado et al. [22], there is a connection between perinatal diseases and macro- and microelement levels in the body, affected by incorrect mineral provision. Such ailments as: pre- and postnatal retention, placenta retention or obstetrical paraplegia were observed in the perinatal period. Such changes and symptoms as: hypofunction and afunction of ovaries, ovary cysts or purulent inflammation of uterus were also often identified. In the light of the above findings, the conclusion comes up that there is a correlation between improved diet and the reduction in cases of reproductive system diseases and perinatal disorders. The presented results correspond with data published by Griffiths et al. [15] who observed a containment of reproduction pathologies under the influence of mineral supplementation.

CONCLUSIONS

Animal fertility and performance are affected by a number of factors. A particular role was played here by the diet. Mistakes made in feeding the cows led to digestive and metabolic disorders, reflected in the incidence of sex organ malfunctions. We confirmed the importance of adjusting the mineral compound feed composition to the needs of the animals in order to improve their health and metabolism. The polyetiological conditions of fertility show that it was not possible to entirely eliminate all reproductive system pathologies. However, by removing one of the principal factors impinging on reproduction, we managed to improve the general state of health at the analysed farm.

MANUFACTURERS

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Declaration of interest. The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

REFERENCES


