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The status of essential elements and associations with milk yield and the occurrence of mastitis in organic and conventional dairy herds

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ABSTRACT

There is a lack of detailed information on the impact of organic feeding regulation on the health and well-being of cows. This has become especially important since January 2008 when the EU required 100% organic ration for organic dairy herds. The aim of this investigation was to determine and compare the levels of essential elements in organic and conventional dairy herds, and to associate them with milk yield and the occurrence of mastitis. The field study was carried out in 10 organic and 10 conventional herds from 2005 to 2010. This period included the point in time when the ration became 100% organic in organic dairy herds. Essential element concentrations (Cu, Co, Se, Zn, Mn, Mo, I and Fe) were determined by inductively coupled plasma–mass spectrometry in 158 serum samples. Associations between concentrations of elements and milk yield and mastitis were determined with mixed linear and logistic regression models, respectively. No significant differences in metal levels between organic and conventional herds were found. No severely deficient concentrations of essential elements were observed in organic herds, either before or after the change in regulation. Cows with low serum concentrations of Se had lower somatic cell counts. Daily milk yield was significantly influenced by deficient concentrations of Cu. For the evaluation of clinical mastitis occurrence, herds were classified for each element, based on the individual values of the sampled cows. Low levels of some elements (Se, I) were associated with a reduced risk of mastitis occurrence. However, other elements indicated a protective effect against mastitis.

1. Introduction

Regulation of organic dairy production results in general in different feeding regimens compared to conventional systems (Fall and Emanuelson, 2009). There is a lack of detailed information on the impact of organic feeding practices on the health and well-being of cows. Since January 2008 the responsible body of the EU has required the ration for organic herds to be 100% organic (EEC 889/2008). While in conventional dairy production mineral deficiencies can be corrected through the inclusion of mineral diet supplements, organic production can only give organic feed; 60% of the food ration must consist of on-farm-produced roughage, and the use of mineral supplements is restricted (EEC 889/2008). Organic herds require strict management of the feed ration to avoid mineral imbalances. Organic management claims to improve animal health and welfare (Sundrum, 2012), but if the diet does not contain sufficient essential elements it

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may actually have the opposite effect (Mitchell and Gray, 2003; Thamsborg et al., 2004; Zollitsch et al., 2004), and it has been reported that organic cows could be prone to some mineral deficiencies (Govasmark, 2005; Govasmark et al., 2005; Kupiainen et al., 2004).

Essential elements are important for a well-functioning immune system (Suttle and Jones, 1989). Their biological function has been underestimated in the past, but has recently been emphasised, clearly showing how necessary they are to stimulate immune response and thereby maintain animals in good health (National Research Council, 2001; Suttle, 2010). Numerous studies have confirmed that the appropriate inclusion of, for example, Se, Mn, Cu, Zn and Co in diets is important for optimising the cows' health, particularly for prevention of mastitis and high somatic cell counts (SCCs) (Ali-Vehmas et al., 1997; Smith et al., 1997; Allison and Laven, 2000; Cebra et al., 2003).

The overall aim of the present study was to determine and compare the levels of essential elements in organic and conventional dairy herds and to evaluate the potential associations between low levels of essential elements and milk yield and the occurrence of mastitis. The study also focused on different conditions that may affect the levels of essential elements, such as feeding regulations for organic herds and cow physiological state.

2. Material and methods

2.1. Study design

This study is one part of an extensive longitudinal survey performed during 2005 to 2010 with the goal of investigating the metabolic status and general health of Swedish organic and conventional dairy herds (Blanco-Penedo et al., 2012; Fall et al., 2008; Fall and Emanuelson, 2009). Originally, 40 farms, half of them organic, with >40 lactating cows and participating in the Swedish Official Milk Recording Scheme, were selected (see Fall et al., 2009, for details about the selection process). For this part of the study the original 40 farms were contacted again by letter and asked to participate. Of these, 13 conventional and 13 organic farms agreed to participate; four declined and one was excluded for technical or time-limiting reasons. Of the 26 farms that were visited, we finally analysed 20 farms to fit the number of samples to the analytical kits. The 26 herds were all visited twice to collect samples during the barn periods November 2005 to March 2006 (first visit) and October 2009 to February 2010 (second visit), with Regulation No 889/2008 *in vigour* during the last period. All herd visits were carried out by a veterinarian. The study was approved by the Ethics Committee for Animal Experimentation in Uppsala, Sweden (C240/9).

All organic farms were managed according to the standards of the Swedish organisation for organic production (www.krav.se) and had been certified for at least three years when the study started. All the components of the diet were in accordance with the practices and legislation associated with each farming system at the time of the visits (CEC, 2005; EEC 889/2008).

Concerning the feeding at the selected herds, there was a large variation in feeding management for lactating cows, from individual feeding of roughage and concentrate to total mixed rations. For dry cows, most farms presented two different feeding regimens: they typically fed roughage *ad lib* with the minerals supplied in a mineral bucket, or in some cases with the minerals spread on top of the roughage once daily.

2.2. Sampling and analyses

Blood samples were taken from approximately 8 randomly chosen healthy cows in each farm to obtain serum from early-lactating (0–6 weeks in lactation) ($n \approx 5$) and dry cows (from dry-off until parturition) ($n \approx 3$). The total number of samples corresponded to 60 cows at the first visit and 100 cows at the second visit, resulting in 160 serum samples of which two were rejected due to haemolysis (Supplementary material 1). Blood from the coccygeal vein or artery of each cow was collected in evacuated test tubes with gel for serum (tube of 8 ml Z Serum Sep Clot Activator, Vacuette®; Greiner Bio-One, Germany). Blood samples were refrigerated and transported to the laboratory of the Department of Clinical Sciences at Swedish University of Agricultural Sciences or to a field station (in the case of far-off farms). Samples were centrifuged at 2000 g for 10 min and serum was frozen within 6 h of sampling. Samples were stored at -20 °C before analysis. Essential (Cu, Co, Fe, I, Mo, Mn, Se and Zn) and non-essential (Cd and Pb) element concentrations were determined in 158 serum samples by inductively coupled plasma–mass spectrometry (ICP-MS; Thermo X7, Thermo Elemental, Winsford, UK). A sample volume of 250 μL was diluted 10 times with an alkaline solution according to Bárány et al. (1997). The analytical accuracy was checked against reference material (SERONORM Trace Elements Serum LOT. 0903106; SERO AS, Billingstad, Norway). The obtained values for the quality samples showed good agreement with the recommended and certified concentrations. All determinations were made in duplicate preparations, and the method imprecision, calculated as the coefficient of variation for the duplicate measurements, were for all elements but Cd and Pb below 10%. The values for Cd and Pb were 22% and 13%, respectively.

Chemical composition of the diets in the organic and conventional herds at the second visit is presented in Supplementary material 2. Detailed information on the diets at the first visit was not available. Briefly, daily feed consumption on each farm was recorded during a 24 h period by weighing individual feed allocations, or, when cows were fed in groups, by weighing the feed allocated to the group and dividing it by the number of animals, as described in Nordqvist et al. (2014). For estimation of nutrient content the samples were analysed using the NIR method, or, for Ca and Mg, the atomic absorption spectrophotometry method (NMKL, 1998; Eurofins, Lidköping, Sweden). Data on the composition of the concentrates were taken from the feed declarations by the manufacturers.

2.3. Data analysis

To calculate mean concentrations, non-detectable concentrations were assigned a value of half the quantification