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Selenium-fertilized forage as a way to supplement lactating dairy cows

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ABSTRACT

Fertilization with Se improves forage organic Se concentration, but comparisons with other forms of Se supplementation in feeding lactating dairy cows are scarce. Our objective was to compare the effect of Se-enriched forages to dietary sources of inorganic and organic Se. Digestibility, retention, and balance were assessed by measuring Se concentrations in feces, urine, milk, and blood. The resulting effect on antioxidant status and lactation performance of dairy cows was also determined. High-Se silages (1.72 mg of Se/kg of DM) were produced following a spring application of 2.5 kg/ha of Selcote Ultra, whereas low-Se silages (0.05 mg of Se/kg of DM) were produced in the Se-unfertilized portion of the same fields. After a 77 ± 17 d period of Se depletion, 33 late-lactation primiparous Holstein cows were blocked and randomly assigned for 43 d to 1 of 4 experimental total mixed rations fed for ad libitum intake in an unbalanced randomized block design. Treatments consisted of 4 diets: control with low-Se silages, without Se supplement (0.12 ± 0.04 mg of Se/kg of DM); ISe with low-Se silages and inorganic Se (0.80 ± 0.14 mg of Se/kg of DM); YSe with low-Se silages and organic Se from yeast (0.70 ± 0.11 mg of Se/kg of DM); and FSe with high-Se silages, without Se supplement (0.79 ± 0.14 mg of Se/kg of DM). Organic Se, either as YSe or FSe, was more available and more effective to increase blood and milk Se concentrations than ISe. Moreover, FSe was more available than YSe, as cows fed FSe excreted 16 and 22% less Se (as percentage of intake) in feces and urine, respectively, had higher Se apparent absorption (17%), retention (37%), and balance (45%), and had greater concentration of Se in serum (16%) and milk (11%) than cows fed YSe. Antioxidant status (whole blood and plasma glutathione peroxidase, and milk thioredoxin reductase and malondialdehyde) was not affected by treatments. Dry matter intake, yield of actual, energy-corrected, and fat-corrected milk, as well as milk fat and lactose concentrations, were not affected by the dietary treatments. Cows fed ISe had lower milk protein concentration (3.44%) than cows fed YSe (3.58%) or FSe (3.51%). Cows fed Se-supplemented diets had a lower milk somatic cell count than cows fed the control diet. Results from the current study showed that the production of Se-enriched forages is an effective method to supplement dairy cows in Se as it was more available than YSe, and did not alter antioxidant status and performances of lactating dairy cows.
Key words: dairy cow, forage, selenium

INTRODUCTION

Selenium is an essential micronutrient for both livestock and humans (Schwarz and Foltz, 1957). It is an integral component of several functional selenoenzymes, including glutathione peroxidase (**GSH-Px**), which plays a key role in cellular antioxidant systems (Rotruck et al., 1973). Selenium also regulates redox (McKenzie et al., 2002) and immune functions (Salman et al., 2009), and supports thyroid hormone metabolism (Spears, 2000; Ibeagha et al., 2007). In dairy cows, an adequate level of Se intake is known to minimize the incidence of mastitis (Smith et al., 1984), improve immune functions (Gerloff, 1992; Weiss, 2003; Ibeagha et al., 2009), reduce the prevalence of retained fetal membranes (Allison and Laven, 2000; Spears and Weiss, 2008), and prevent calf mortalities (Maas, 1983).

In numerous areas of the world, feeds have low Se concentrations because of low soil Se contents (Filley et al., 2007). Therefore, it is a common practice in the dairy industry to supplement dairy cows to provide adequate levels of Se and avoid deficiencies. Additionally, supplementation of dairy cows enhances milk Se concentration, which could be a way of increasing human intake for this mineral and subsequently benefit human health (Combs et al., 2001; Givens et al., 2004).

Two forms of supplemental Se are commonly used: inorganic Se such as sodium selenite or selenate, and organic forms such as selenized yeast, in which selenomethionine (**SeMet**) is the predominant form. Regardless of the forms, Se can be added in concentrations up

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to 0.3 mg/kg of DM in dairy cow rations in Canada (Canadian Food Inspection Agency, 2015) and the United States (Food and Drug Administration, 2003). In recent years, the utilization of organic Se supplements has gained considerable interest because several studies have demonstrated a greater bioavailability to dairy cows than in inorganic forms, making it interesting considering the functional effect of this trace element on physiological mechanisms (Juniper et al., 2006; Calamari et al., 2010; Cun et al., 2015). In his review, Weiss (2005) showed that cows fed organic Se have greater concentrations of this mineral in whole blood (+20%) and milk (+90%), and a greater whole blood GSH-Px activity (+16%) than cows fed inorganic supplement.

The enrichment of forages is an alternative way to supply Se to dairy cows. Enriched forages can be harvested after a spring application of an inorganic slow-release Se fertilizer (Tremblay et al., 2015). When inorganic Se is applied to field crops, plants have the capacity to incorporate this mineral to organic compounds (Filley et al., 2007). As a result, Se in fertilized forages is more bioavailable to cows than the inorganic supplement commonly used (sodium selenite), as recently demonstrated by Cun et al. (2015). Forage Se-enrichment by fertilization has been studied in several countries for many years (Gupta and MacLeod, 1994; Filley et al., 2007; Tremblay et al., 2015). To our knowledge, however, the bioavailability of Se-enriched forages, and their effect on the performance and the antioxidant status of lactating cows have not been compared with other forms of organic Se. We hypothesized that (1) supplementing dairy cows with Se increases Se in blood and milk, (2) organic sources of Se are more digestible and result in a better Se balance than inorganic sources, and (3) Se-enriched forages are as digestible as other organic sources of Se in dairy cows. The objective of this study was to compare the effect of Se-enriched forages to inorganic and organic dietary supplementation on the Se digestibility, retention, and balance, and the resulting effect on antioxidant status and performances of lactating dairy cows.

MATERIALS AND METHODS

Silage Production

Five silages were produced at the Centre de Recherche en Sciences Animales de Deschambault, QC, Canada (46°40′N, 71°55′W). Two low-Se, and 2 high-Se silages were produced in June of 2011 on a 9.8-ha field of pure timothy (*Phleum pratense* L.) and an 8.9-ha field of mixed alfalfa (*Medicago sativa* L.):timothy (75:25). A low-Se silage was also produced in June of 2012 on the mixed alfalfa/timothy field (Table 1). This forage was used solely in blocks 3 and 4, because not enough good quality silage of the mixed alfalfa/timothy was produced in 2011. Diets were adjusted to account for this modification (Table 2). Before the start of spring growth in early May, both fields received 75.6 kg of N/ha, 9.4 kg of P/ha, and 68.7 kg of K/ha. The Se-enriched forages were produced by fertilizing 25% of each field with a slow-release Se fertilizer (Selcote Ultra, Terralink, Vancouver, BC, Canada) containing 10 g of Se/kg as Na_2SeO_4 and $BaSeO_4$ (90% minimum), and Na_2SeO_3 and $BaSeO_3$ (10% maximum). The slow-release Se fertilizer was mixed with the N fertilizer (ammonium nitrate), and applied at a rate of 25 g of Se/ha in early May. The remaining part of each field was used to produce the low-Se silages. Timothy and alfalfa from the spring growth were respectively at the early-heading and early-bloom stages of development when they were cut using a disc mower equipped with a roller-type conditioner (New Holland Discbine, model 1432, New Holland, PA). The forages were wilted in the field until they reached 35% DM. They were then chopped and stored in plastic bag silos (Bag All, Klerk's Plastic Products Manufacturing Inc., Richburg, SC) with a silage compactor (Roto Press, Sioux Automation, Sioux City, IA).

Cows, Diet, and Experimental Design

The experiment was conducted at the Centre de Recherche en Sciences Animales de Deschambault (Deschambault, QC, Canada) throughout the year of 2012. All procedures involving dairy cows followed the regulations of the Canadian Council on Animal Care (1993), and were approved by the Université Laval Animal Care Committee. Thirty-three primiparous Holstein cows (average ± SD; 187 ± 54 DIM; 585 ± 45 kg of BW; 27.2 ± 4.2 kg of milk/d) housed in a tie stall barn were used in an unbalanced randomized block design (3 blocks of 8 cows and 1 block of 9 cows). Each block of cows entered the experiment when enough animals with similar DIM were available. Before the start of each experimental block, cows underwent a period of 77 ± 17 d of Se depletion when each animal received the same basal diet not supplemented with Se. Our target for the depletion period was a Se level in serum considered in the zone of marginal deficiencies (40–70 μg/L; Gerloff, 1992). Blood samples were taken on d 60 of the depletion period, and cows were kept on the depletion diet until blood serum analyses confirmed that the target value had been reached. This target value was reached for all blocks except one, for which the group of cows started the experiment at an average of 86.3 ± 8.5 μg/L after extending the length of the