Effect of Level and Source of Dietary Selenium on Concentrations of Thyroid Hormones and Immunoglobulins in Beef Cows and Calves

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ABSTRACT: Our objective was to determine the effect of level and chemical form of dietary selenium on productivity of beef cows, concentrations of triiodothyronine (T₃), and thyroxine (T₄) in plasma, and immunoglobulins (IgG and IgM) in plasma and colostrum of cows. Pregnant cows (n = 60) were randomly allocated among four dietary treatments of 20, 60, or 120 ppm Se as selenite and 60 ppm as selenomethionine from selenized yeast (SeY) in salts offered free-choice. Treatments began 90 d prepartum and continued through the second parturition. Treatments did not affect the final body weights of cows or birth weights or weaning weights of calves. At parturition, cows given salt with 20 ppm Se as selenite had lower (P < .05) concentrations of Se in blood than cows with access to higher-Se salts. Treatments affected (P < .01) the concentration of T₃ and the ratio of T₃:T₄ in plasma of cows. The concentration of T₃ in plasma of cows with access to salt with 20 ppm Se was 14% lower than that in cows supplemented with 60 ppm Se as selenite or SeY. Plasma IgG in cows and calves, colostrum, and Se concentrations in colostrum, casein, and whey were lowest (P < .01) for cows given salts with only 20 ppm Se. Thus, salts with concentrations of 60 and 120 ppm Se improved measures of Se status in cows and calves. Consideration should be given to the concentrations of T₃ and IgG when determining the nutritional requirements for Se in cattle.

Key Words: Cattle, Selenium, Thyroid Hormones, Glutathione Peroxidase, Immunoglobulins


Introduction

Nutritional deficiencies of Se result in white muscle disease (Muth et al., 1958) and suppression of immunity (Yamini and Mullaney, 1985). Selenium is needed for glutathione peroxidase (GPX) activity, which decomposes hydrogen peroxide and lipid peroxides. Control of the free radicals produced in phagocytic and thyrocyte cells is required for normal immune activity (Corvilain et al., 1993; Larsen, 1993). Dietary deficiencies of Se decreases immunoglobulin (Ig) G and IgM in plasma (Larsen, 1993). Calves failing to absorb enough IgG have higher risk of morbidity (McGuire et al., 1976).

Thyroid hormone is important for metabolism, development, and regulation of heat production (Danforth and Burger, 1984; McNabb and King, 1993). Beckett et al. (1987) found that Se is required for conversion of thyroxine (T₄) into the more active triiodothyronine (T₃) via the enzyme type 1 deiodinase (IDI).

The chemical form of dietary Se affects its metabolism. In nonruminants, Se from selenomethionine is incorporated more into tissue proteins, and selenite is more available for GPX synthesis (Butler et al., 1991). The objective of this study was to determine the effect of level and chemical form of dietary Se on concentrations of T₃, T₄, and passive transfer of immunoglobulins in newborn calves.

Materials and Methods

The experimental protocol used in this study was approved by the Washington State University Institutional Animal Care and Use Committee. Sixty mature Angus and crossbred beef cows were randomly assigned to one of four dietary treatments consisting of free-choice access to salt mixes containing 20, 60, or 120 ppm Se as sodium selenite (Table 1). The fourth treatment was 60 ppm Se as selenized yeast (SeY; Alltech, Nicholasville, KY). Cows were fed their experimental diets (Table 2) from 90 prepartum and were maintained on their respective treatments for two calving and breeding seasons. The cows were separated by treatment and rotationally grazed grass pastures during the summers and in winter were fed...
Table 1. Ingredient composition of salt mixes

<table>
<thead>
<tr>
<th>Item</th>
<th>20 ppm Se</th>
<th>60 ppm Se</th>
<th>120 ppm Se</th>
<th>SeY,</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na-Selenite</td>
<td>100</td>
<td>78</td>
<td>44</td>
<td>95.9</td>
</tr>
<tr>
<td>Se premix</td>
<td>22</td>
<td>56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selenized yeast</td>
<td></td>
<td></td>
<td></td>
<td>4.1</td>
</tr>
</tbody>
</table>

aConsisted of 97% NaCl, .2% Mn, .35% Zn, .20% Fe, .15% Mg, .03% Ca, .007% I, .005% Co, and .002% Se.
bConsisted of .02% Se as sodium selenite.
cSelplex-50. Contained .1% Se. Alltech Biotechnology Center, Nicholasville, KY.

Haylage, a concentrate, and ryegrass seed screening pellets in the 1st yr and cereal grain screenings in the 2nd yr. Intakes of the salt mixes were recorded for each group. Body weights for cows and calves were recorded monthly. Pregnancy was determined by rectal palpation at 45 d after breeding. Blood samples were obtained from cows at −3, 0, 3, and 9 mo from the first parturition and 0 and 7 mo from the second parturition. Blood samples were taken from calves at 24 to 36 h and at 2 mo of age. Needle (The Deseret Company, Sandy, UT) biopsies of liver were taken from calves at birth and at 2 mo of age in the 1st yr and 2 mo of age in the 2nd yr. At biopsy, calves were injected subcutaneously and intercostally with flunixin meglumine (Banamine®; Schering Plough Animal Health, Kenilworth, NJ) at 1.1 mg/kg of BW to control pain and with 3 to 5 mL of lidocaine (2%; Abbott Laboratories, Chicago, IL) to provide local anesthesia for the biopsy procedure. Feeds and pasture samples (2nd yr) were taken at monthly intervals, dried at 60°C overnight, and stored at −20°C until they were analyzed. Blood samples were centrifuged (1,500 x g for 15 min) to obtain plasma, which was stored at −20°C until analysis. Samples of whole blood and liver were freeze-dried and analyzed for Se by neutron activation analysis (NAA; Liu et al., 1990). Selenium-dependent GPX activity (as unit per milligram of hemoglobin) in blood was assayed with the method of Paglia and Valentine (1967). Hemoglobin was determined with the cyan-methemoglobin method (Sigma, procedure No. 5250). Plasma concentrations of T4 and T3 were determined with radioimmunoassay kits (Coat-A-Count procedure; Diagnostic Products, Los Angeles, CA).

Samples of colostrum taken within 16 h after parturition and milk taken approximately 42 d later were separated into casein and whey fractions by ultracentrifugation (150,000 x g for 2 h). Concentrations of Se in colostrum, casein, and whey were measured by NAA. Concentrations of IgG and IgM in plasma (cows and calves) and colostrum were measured by radial immunodiffusion (VMRD Inc., Pullman, WA). Feed samples were analyzed for Ca by atomic absorption spectrophotometry (AAS; Perkin-Elmer, 1981), P by colorimetry (AOAC), total N with the Kjeldahl method (AOAC, 1990), and ADF and NDF according to Goering and Van Soest (1970).

Statistical Analysis. Data for concentrations of Se, GSH-PX activities in whole blood, and T3 and T4 in plasma were analyzed according to a completely randomized design with repeated measures using the General Linear Models procedure of SAS (1989). The model included treatment (level of Se demonstrated in the salt mix), cows (or calves) within treatment, time of measurements, and the treatment x time interaction. Dependent variables were Se concentration, GSH-PX activity, T3, T4, and body weight. Cows (or calves) within treatment were used as error terms to test the effect of treatment. Effects of treatments on pregnancy rates were evaluated by chi-square analysis (Steel and Torrie, 1980), and the number of services per cow was analyzed with SAS (1989). Concentrations of immunoglobulins were analyzed as a com-

Table 2. Ingredient and chemical composition of feedstuffs

<table>
<thead>
<tr>
<th>Item</th>
<th>Haylage</th>
<th>Ryegrass</th>
<th>Pasture</th>
<th>Concentratea</th>
<th>Hay</th>
<th>Cereal grain screenings</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>20.2</td>
<td>13.7</td>
<td>10.2</td>
<td>16.2</td>
<td>13.5</td>
<td>9.5</td>
</tr>
<tr>
<td>ADF</td>
<td>33.4</td>
<td>31.3</td>
<td>31.5</td>
<td>8.5</td>
<td>36.8</td>
<td>8.9</td>
</tr>
<tr>
<td>NDF</td>
<td>42.1</td>
<td>49.8</td>
<td>52.3</td>
<td>15.5</td>
<td>48.6</td>
<td>16.4</td>
</tr>
<tr>
<td>Ash</td>
<td>11.7</td>
<td>11.4</td>
<td>9.5</td>
<td>16.2</td>
<td>8.1</td>
<td>6.8</td>
</tr>
<tr>
<td>Ca</td>
<td>1.0</td>
<td>2.4</td>
<td>.24</td>
<td>1.2</td>
<td>1.1</td>
<td>.12</td>
</tr>
<tr>
<td>P</td>
<td>.31</td>
<td>.22</td>
<td>.3</td>
<td>1.07</td>
<td>.24</td>
<td>.21</td>
</tr>
<tr>
<td>Se</td>
<td>.15</td>
<td>.12</td>
<td>.07</td>
<td>.30</td>
<td>.08</td>
<td>.1</td>
</tr>
</tbody>
</table>

aIngredient composition: 50% peas, 32.31% barley, 1% animal fat, .32% vitamin A, 6.37% Bovatec®, 5% magnesium oxide, and 5% dicalcium phosphate.
Results and Discussion

Treatments did not affect (P > .05) the final body weights of cows (X = 659.1 ± 2.1 kg). Supplementation of cows with Se did not affect calf birth weights in either yr 1 (X = 39.2 ± 1.4 kg) or yr 2 (X = 39.5 ± 2.1 kg), or weight gains of calves in either yr 1 or yr 2 (Table 3). Neither Ammerman et al. (1980) nor Hidiroglou et al. (1987) found that Se supplementation of dams affected calf birth weights. Recently, Wichtel et al. (1996) conducted two trials on Se supplementation of grazing calves (5 mo of age) and found a positive response in one herd but not the other. Ullrey et al. (1977), Swecker et al. (1989), and Lacetera et al. (1996) all have reported no significant impact of Se supplementation on body weight gain.

Treatment did not affect (P > .05) the pregnancy rate of cows. Mean pregnancy rates were 84.5 ± 2.6% in yr 1 and 80.0 ± 7.7% in yr 2. A similar lack of effect on pregnancy rates was reported by Kott et al. (1983), Spears et al. (1986), and Wichtel et al. (1994). Although Harrison et al. (1984) reported that Se supplementation reduced the incidences of cystic ovaries and metritis in cows, no differences were detected in the current trial on days to first breeding or services per conception.

The concentrations of Se and activity of GPX in blood of cows differed significantly (P < .01) among treatment groups for the 2 yr of the trial (Figures 1 and 2). Cows fed the 20 ppm Se salt mixture had lower (P < .05) concentrations of Se in blood than cows fed the 120 ppm Se mixture throughout the study. With the exception of samples collected at first parturition, blood Se concentrations of cows supplemented with 60 ppm Se salt were intermediate to blood Se concentrations of cows supplemented with 20 or 120 ppm. Cows supplemented with 60 ppm SeY salt had higher (P < .01) blood Se concentrations than cows supplemented with 60 ppm Se as selenite in salt only at 7 mo postpartum of the 2nd yr. The level of Se supplementation did not affect GPX activity of cows.

Nicholson et al. (1991) reported that organic Se was more effective than inorganic Se in raising blood Se concentrations in calves at 4 mo of age. Similar results were reported by Chavez (1989). Suomi and Alaviuhkola (1992) found that pigs supplemented with organic and inorganic Se did not differ significantly in Se concentrations in liver and serum. In the present study, in which cows were grazing pastures that had forages with 0.07 ppm Se DM, SeY was more effective (P < .01) than selenite in raising blood Se concentrations and GPX activities after 22 mo of supplementation. Differences between this and other studies may be due to the age of the animals, Se intakes, and duration of supplementation. Selenomethionine is thought to be randomly substituted for methionine in protein and to accumulate mainly in liver and muscle (Chavez, 1989). Thus, level of dietary Se and the duration that animals are fed added Se may affect expected results.

Selenium concentrations in blood of newborn calves were different (P < .01) in yr 1 and 2 but GPX differed only in yr 1 (Figures 3 and 4). Blood Se and GPX were highest at birth for calves of cows given salt with 60 ppm Se as SeY in yr 1, but by 2 mo of age, only calves allowed access to salt with 120 ppm Se had elevated Se and GPX activities. Concentrations of Se and GPX activities in blood of dams and their calves were correlated (P < .01; r = .41 for Se; r = .61 for GSH-PX). Similar results were reported by Hidiroglou et al. (1987). There were no significant differences among treatments in Se concentrations in liver of calves (Figure 5).
Two routes exist for transfer of Se from the dam to the calf: placental transfer and milk. In the present study, the concentrations of Se in milk at 42 d postpartum in yr 1 were similar among cows (.03 to .04 μg Se/mL). Thus, treatment differences in maternal transfer of Se would have had to occur in either placental transport or colostrum. The amount of Se consumed by cows during the nonlactating period has been shown to affect Se concentrations in serum of their newborn calves. Abdelrahman and Kincaid (1995) reported that nonlactating cows with daily intakes of approximately 1 mg Se/d were unable to maintain Se concentrations in blood during late gestation. Weiss et al. (1984) found that cows supplemented with 5 mg Se/d during the nonlactating period and their subsequent calves had higher Se concentrations in serum at parturition than cows supplemented with 0 or 1 mg Se/d. In the present study, cows given access to salts with 20, 60, and 120 ppm Se as selenite and 60 ppm Se as SeY consumed an estimated .98, 3.3, 7.3, and 3.4 mg Se/d, respectively, from the salt mixes. Peripartum concentrations of Se in whole blood ranged from .13 to .17 μg/mL (Figure 1). Cows supplemented with salt containing 120 ppm Se had the highest concentrations of Se in blood during the first lactation.

Most of the Se in colostrum was found in the casein fraction (66 to 71%), and this is similar to that reported for ewes (63 to 68%; Jenkins and Hidiroglou, 1971). Concentrations of Se in colostrum at the first parturition and in milk at 42 d postpartum were similar for all cows (Figure 6), but in yr 2 (Figure 7) Se concentrations in colostrum, casein, and whey were higher (P < .01) for cows given salt with 60 ppm Se as SeY than for control cows (Figure 7). Previously, Jenkins and Hidiroglou (1971) reported that ewes fed Se as selenite (.1 ppm) had higher Se concentrations in colostrum than ewes supplemented with selenomethionine (.1 ppm). Abdelrahman and Kincaid (1995) reported lower values in dairy cows for Se in colostrum (.04 to .06 μg/mL), casein (.07 to .09 μg/mL), and whey (.036 to .04 μg/mL). Hidiroglou et al. (1987) found significantly increased Se concentrations in milk of cows supplemented with two 120-g glass boluses (containing .31% Se) compared to concentrations in milk of unsupplemented cows. Conrad and Moxon (1979) earlier concluded that the response of Se concentrations in milk was nonlinear in relation to total Se consumption. They found that 4.8
and .9% of added dietary Se was transferred to milk of cows given deficient or adequate Se diets, respectively. However, Perry et al. (1977) reported that cows supplemented with 0, 1, 2, or 5 mg of Se as selenite from 3 mo prepartum to 6 mo postpartum had similar Se concentrations in milk (.016 to .021 mg/mL).

Treatments affected (P < .01) the concentrations of T3, but not of T4, in plasma of cows (Table 4). Because of the large quantitative differences between concentrations of T3 and T4 in blood, significant decreases can occur in T3 without detectable changes in T4. Concentrations of T3 in plasma of cows given salt with only 20 ppm Se averaged 86% of those of cows supplemented with 60 ppm Se as selenite or SeY.

Conversion of T4 to T3 and subsequently to T2 (5′-deiodinase) is controlled by three isoenzymes: type IDI (liver, kidney, and thyroid), type IDII (brain, brown adipose tissue, and pituitary), and type IDIII (brain and placenta). About 80% of T3 in plasma is produced in the liver, kidney, and muscle, and all these tissues contain the Se-dependent enzyme type IDI (Beckett et al., 1992). A study with guinea pigs showed similar results (Cammack et al., 1995); concentrations of T3 in plasma of Se-deficient guinea pigs were 69% of those in guinea pigs fed Se-adequate diets. Similarly, Se-deficient rats had T3 concentrations in plasma that were reduced 23% (Thompson et al., 1995). Calves fed Se-deficient diets had lower T3 and higher T4 concentrations in plasma at 20 and 23 wk compared to Se-supplemented calves (Arthur et al., 1988). Recently, Wichtel et al. (1996) found that plasma of calves that received intraruminal Se pellets (estimated release of 3 mg of Se/d) had significantly higher T3 and lower T4 in 6 wk compared to calves fed a basal diet (.03 mg Se/kg DM).

Calves born to cows supplemented with 60 ppm Se as SeY had higher T3 concentrations at birth than calves from cows supplemented with 20 and 60 ppm Se as selenite. The ratio of T3:T4 in calves of cows supplemented with 120 ppm Se in the salt mix was higher than that in calves of cows fed salt with 20 and 60 ppm Se (Table 5). Concentrations of T3 and T4

Figure 2. Effect of level and chemical form of selenium in salt mixes offered to cows on the activity of glutathione peroxidase (GPX) in blood (n = 40, yr 1; and n = 32, yr 2). EU = nmoles of NADPH oxidized·min⁻¹·mg⁻¹ hemoglobin.
were lower in plasma of all calves at 2 mo of age than at birth. The T<sub>3</sub> and T<sub>4</sub> concentrations in calves of this trial are lower than those reported by Carstens et al. (1997) due to differences in age at sampling. This observation is consistent with a reduction in concentrations of T<sub>3</sub> and T<sub>4</sub> in plasma as the calf matures. The physiological events of pregnancy and days in milk also may have affected concentrations of T<sub>3</sub> and T<sub>4</sub>. At parturition cows had concentrations of T<sub>3</sub> in plasma that were higher (P < .01) than at 3 and 9 mo postpartum, concentrations of T<sub>4</sub> that were lower (P < .01), and higher ratios of T<sub>3</sub>:T<sub>4</sub> (P < .05) at 3 mo (Table 6). The higher levels of T<sub>3</sub> at parturition also may be related to the high Se concentrations in blood at parturition.

Concurrent deficiencies of Se can modulate the severity of hypothyroidism in cases of iodine deficiency. Beckett et al. (1993) found that a nutritional deficiency of Se in rats causes a significant decrease in plasma T<sub>3</sub>, an increase in plasma T<sub>4</sub>, and inhibition of type IDI activity in liver. In another trial, a Se deficiency caused a 23% decrease in T<sub>3</sub> concentrations in plasma of rats, the ratio of T<sub>3</sub>:T<sub>4</sub> was reduced by 35%, and growth rates were depressed (Thompson et al., 1995). The activity of IDI decreased in pituitary of rats fed Se and iodine-deficient diets (Beckett et al., 1993). However, calves supplemented with 3 mg Se/d had significantly higher T<sub>3</sub> and lower T<sub>4</sub> in plasma compared to calves fed basal diet (.03 ppm Se DM; Wichtel et al., 1996). Results from these studies support the interpretation that calves of cows fed salt with only 20 ppm Se had lower (P < .05) T<sub>3</sub> levels, numerically higher T<sub>4</sub> levels, and higher (P < .05) T<sub>3</sub>:T<sub>4</sub> ratios compared to calves of cows fed salt with 120 ppm Se. The concentrations of T<sub>3</sub> in calves is important because T<sub>3</sub> enhances the synthesis of uncoupling protein, necessary for brown adipose tissue thermogenesis (Carstens, 1994).

The observations that low dietary Se caused reduced T<sub>3</sub> and elevated T<sub>4</sub> levels (i.e., reduced T<sub>3</sub>:T<sub>4</sub> ratios) suggest that low dietary Se reduced IDI enzyme activity in peripheral tissues. The strong correlation (r = .75) between GPX and T<sub>4</sub> in cows fed salt with only 20 ppm Se supports this theory.
Figure 4. Effect of level and chemical form of selenium in salt mixes on glutathione peroxidase (GPX) activity in blood of calves during the trial. EU = nmoles of NADPH oxidized·min⁻¹·mg⁻¹ hemoglobin (n = 40, yr 1; n = 32, yr 2).

Concentrations of IgG and IgM were significantly lower in plasma of cows and their calves when given salt with 20 ppm Se as selenite compared to higher Se levels (Figures 8 and 9). The chemical form of supplemented Se had no effect on cow or calf plasma IgG concentrations, whereas plasma IgM concentrations were higher (P < .05) in cows given salt with 60 ppm Se as SeY compared to those supplemented with 60 ppm Se as selenite. Calves from cows given salt with 60 ppm Se as either selenite or SeY had similar (P > .05) IgM concentrations in plasma. Cows supplemented with 120 ppm Se in salt mineral mix

Table 4. Effect of level and chemical form of Se in salt mixes on mean concentrations of triiodothyronine (T₃) and thyroxine (T₄) in plasma of cows for the 2 years of the trial

<table>
<thead>
<tr>
<th>Item</th>
<th>Na-selenite</th>
<th>SeY, 60 ppm Se</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₃, ng/mL</td>
<td>20 ppm Se</td>
<td>60 ppm Se</td>
<td>120 ppm Se</td>
</tr>
<tr>
<td>1.00a</td>
<td>1.00a</td>
<td>1.00a</td>
<td>.04</td>
</tr>
<tr>
<td>T₄, ng/mL</td>
<td>32.6</td>
<td>33.9</td>
<td>34.1</td>
</tr>
<tr>
<td>.03b</td>
<td>.031b</td>
<td>.031b</td>
<td>.003</td>
</tr>
</tbody>
</table>

a,b,cMeans in the same rows with different superscripts differ (P < .05).
Figure 5. Effect of level and chemical form of selenium in salt mixes on selenium concentrations of liver in calves during the trial (n = 40; n = 32, yr 2).

Figure 6. Effect of level and chemical form of selenium in salt mixes offered to cows on concentrations of selenium in colostrum and milk in yr 1 of the study (n = 40).
**Figure 7.** Effect of level and chemical form of selenium in salt mixes offered to cows on concentrations of selenium in colostrum, casein, and whey in yr 2 of the study (n = 32).

had higher (P < .05) levels of IgG in colostrum, and as a consequence their calves had higher concentrations of IgG in plasma. Similarly, Larsen (1988) reported no significant differences in IgG concentrations in serum of lambs supplemented with 0.1, 0.5, or 1.0 ppm Se as selenite or selenomethionine. However, ewes supplemented with Se as selenite or selenomethionine had higher antibody titers compared to unsupplemented ewes (Larsen, 1988).

Previous work showed that mineral mixes containing 120 ppm Se resulted in significant increased concentrations of IgG in colostrum and calf serum.

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**Table 5.** Effects of level and chemical form of Se in salt mixes offered to cows on concentrations of triiodothyronine (T₃) and thyroxine (T₄) in plasma of calves (year 2)

<table>
<thead>
<tr>
<th>Item</th>
<th>Na-selenite</th>
<th>SeY, 60 ppm Se</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 ppm Se 60 ppm Se 120 ppm Se</td>
<td>60 ppm Se</td>
<td></td>
</tr>
<tr>
<td><strong>T₃ ng/mL</strong></td>
<td>3.4&lt;sup&gt;b&lt;/sup&gt; 3.0&lt;sup&gt;b&lt;/sup&gt; 4.3&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>5.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.4</td>
</tr>
<tr>
<td><strong>T₄ ng/mL</strong></td>
<td>85.3&lt;sup&gt;ab&lt;/sup&gt; 99.2&lt;sup&gt;ab&lt;/sup&gt; 70.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>116.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>33.9</td>
</tr>
<tr>
<td>Ratio of T₃/T₄</td>
<td>.032&lt;sup&gt;b&lt;/sup&gt; .033&lt;sup&gt;b&lt;/sup&gt; .053&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.04&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.023</td>
</tr>
<tr>
<td><strong>T₃ ng/mL</strong></td>
<td>2.6 2.5 2.7</td>
<td>3.0</td>
<td>.07</td>
</tr>
<tr>
<td><strong>T₄ ng/mL</strong></td>
<td>80.1 70.7 67.8</td>
<td>74.0</td>
<td>34.5</td>
</tr>
<tr>
<td>Ratio of T₃/T₄</td>
<td>.032 .035 .04</td>
<td>.041</td>
<td>.004</td>
</tr>
</tbody>
</table>

<sup>a,b</sup>Means in the same rows with different superscripts differ (P < .05).
Table 6. Changes during the trial in concentrations of Se and glutathione peroxidase (GPX) in blood and on concentrations of triiodothyronine (T₃) and thyroxine (T₄) in plasma of cows

<table>
<thead>
<tr>
<th>Item</th>
<th>Month relative to calvings</th>
<th>1st Calving</th>
<th>3</th>
<th>9</th>
<th>2nd Calving</th>
<th>7</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Se, µg/mL</td>
<td>−3</td>
<td>.08d</td>
<td>.15b</td>
<td>.15b</td>
<td>.14c</td>
<td>.16b</td>
<td>.11e</td>
</tr>
<tr>
<td>GPX, EU</td>
<td>aEU = nmoles of NADPH oxidized·min⁻¹·mg⁻¹ hemoglobin.</td>
<td>.4d</td>
<td>.7b</td>
<td>.7b</td>
<td>.5c</td>
<td>.6e</td>
<td>.34d</td>
</tr>
<tr>
<td>T₃, ng/mL</td>
<td>−</td>
<td>1.03b</td>
<td>.85c</td>
<td>.87c</td>
<td>1.02b</td>
<td>1.1b</td>
<td>0.34</td>
</tr>
<tr>
<td>T₄, ng/mL</td>
<td>−</td>
<td>38.4b</td>
<td>22.3d</td>
<td>36.5bc</td>
<td>32.6c</td>
<td>45.4e</td>
<td>1.04</td>
</tr>
<tr>
<td>Ratio of T₃:T₄</td>
<td>−</td>
<td>.025d</td>
<td>.04b</td>
<td>.024d</td>
<td>.03c</td>
<td>.02d</td>
<td>.003</td>
</tr>
</tbody>
</table>

Means in the same rows with different superscripts differ (P < .05).

Figure 8. The effect of level and chemical form of selenium in salt mixes offered to cows on the concentrations of immunoglobulin G in serum of cows and calves, and in the colostrum (n = 40, yr 1; n = 32, yr 2).

compared to those in unsupplemented cows, but IgM concentrations did not differ significantly (Swecker et al., 1995). Administration of 5 mg of Se as sodium selenite and 25 IU of vitamin E/100 kg of body weight of cows did not affect plasma Ig concentrations in cows, their calves, or in colostrum. However, cows given Se and vitamin E produced more colostrum, and this meant that more Ig was produced in those cows than in untreated cows (Lacetera et al., 1996). In the present study, total colostrum production was not measured.

Immunoglobulin concentrations in colostrum of cows ranges from 50 to 150 g/L; 85 to 90% is IgG, 7% IgM, and 5% IgA (Larson et al., 1980). In the present study, salts with 60 or 120 ppm Se enhanced transfer of IgG from cow serum to colostrum but did not affect synthesis of IgM in the mammary gland. Calves naturally suckled their dams, so total Ig intake is unknown.

There was a positive correlation between IgG concentrations in serum and colostrum of cows (P < .01; r = .42). Concentrations of Se in blood of cows were correlated (P < .05) with concentrations of IgG in cow plasma (r = .36). A positive correlation (P < .05; r = .31) existed between Se and IgG concentrations in colostrum.

In summary, the chemical form of dietary Se affected the concentrations of T₃ and the ratio of T₃:T₄ in plasma of cattle. After 22 mo of supplementation, SeY was more effective than selenite in maintaining Se concentrations and GPX activities in blood.
given salts with 60 or 120 ppm Se had increased Se, IgG, and IgM in blood and increased Se and IgG in colostrum. Conversely, cows given salt with 20 ppm Se generally had poorer synthesis and transfer of Ig to their calves. Thus, Se intake recommendations for pregnant cows should consider effects on synthesis of T₃ and transfer of Ig to their calves.

**Implications**

The finding that low, but not deficient, intakes of selenium by pregnant cows affect immunoglobulin and triiodothyronine levels has large significance for the health and survival of newborn calves. Passive immunity and heat production from brown adipose are required for calf survival, and both events may be influenced by maternal selenium intakes. Thus, selenium intakes of pregnant cows may be an important factor in weak calf disorders.

**Literature Cited**


