Effect of Se on selenoprotein activity and thyroid hormone metabolism in beef and dairy cows and calves


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ABSTRACT: Although Se is essential for antioxidant and thyroid hormone function, factors influencing its requirement are not well understood. A survey and two experiments were conducted to determine the influence of cattle breed and age on selenoprotein activity and the effect of maternal Se supplementation on cow and calf selenoprotein activity and neonatal thyroid hormone production. In our survey, four cowherds of different ages representing three breeds were bled to determine the influence of breed and age on erythrocyte glutathione peroxidase activity (RBC GPX-1). All females were nonlactating, pregnant, and consumed total mixed diets (Holstein) or grazed pasture (Angus and Hereford). In our survey of beef breeds, yearlings had greater average RBC GPX-1 activity than mature cows. In Exp. 1, neonatal Holstein heifers (n = 8) were bled daily from 0 to 6 d of age to determine thyroid hormone profile. An injection of Se and vitamin E (BO-SE) was given after the initial bleeding. Thyroxine (T₄) and triiodothyronine (T₃) concentrations were greatest on d 0 and decreased (P < 0.05) to 0.52 nmol/L by d 5. In Exp. 2, multiparous Hereford cows were drenched weekly with either a placebo containing 10 mL of double-deionized H₂O (n = 14) or 20 mg of Se as sodium selenite (n = 13). After 2 mo of treatment, Se-drenched cows had greater (P < 0.01) plasma concentrations than control cows (84.92 vs. 67.08 ng/mL), and at parturition, they had plasma Se concentrations twofold greater than (P < 0.05) control cows (95.51 vs. 47.14 ng Se/mL). After 4 mo, cows receiving Se had greater (P < 0.05) plasma T₄ concentrations than Se-drenched cows (169.97 vs. 87.00 ng/mL). Calves born to cows drenched with Se had greater (P < 0.05) plasma Se concentration, RBC GPX-1, and plasma glutathione peroxidase activity on d 0 compared with calves born to control cows. By d 7, no differences in plasma glutathione peroxidase activity in calves were observed. Maternal Se supplementation did not influence calf thyroid hormone concentrations. Selenium provided by salt and forages is not adequate for cattle in Se-deficient states.

Key Words: Cows, Glutathione Peroxidase, Selenium, Thyroid Hormones

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Introduction

Selenium is an essential trace mineral for antioxidant and thyroid hormone function. Erythrocyte glutathione peroxidase (RBC GPX-1; EC 1.11.1.9) and plasma glutathione peroxidase (PGPX-3; EC 1.11.1.9) both require Se (Rotruck et al., 1973; Martin-Alonso et al., 1993) and reflect long- and short-term Se status, respectively (Cohen et al., 1985). Thyroxine (T₄) is deiodinated to the more metabolically active triiodothyronine (T₃) by the Se requiring enzyme type 1 deiodinase (EC 3.8.1.4; Beckett et al., 1987).

Michigan forages are Se-deficient, containing 0.1 to 0.2 ppm Se (Kubota et al., 1967; Mortimer et al., 1999). Cow Se status can be further reduced as Se is transferred across the placenta during late pregnancy and during early lactation in colostrum. Consequently, calves born from Se-deficient or marginally deficient dams may have compromised Se status.

Schrama et al. (1993) reported that neonatal calves are susceptible to cold stress at temperatures below 14.6°C. Approximately 70% of Michigan calves are born between January and April, when temperatures range from −6.7 to 7.8°C (Ritchie, 1991). Therefore, calves must make thermogenic responses to cold. A major form
of facultative thermogenesis is through metabolism of brown adipose tissue, which is regulated by T₃.

Arthur et al. (1988) reported impaired T₄ to T₃ conversion in Se-deficient steers; Awadeh et al. (1998b) reported that Se status of the dam influenced neonatal calf thyroid production. Because calves born in Michigan could be prone to a combination of cold stress and Se deficiency, a survey and two experiments were conducted to 1) investigate the influence of breed and age of cows on Se status; 2) determine the normal thyroid profile of neonatal calves; and 3) determine the effect of Se supplementation on maternal and calf selenoprotein activity and Se transfer on neonatal thyroid hormone status.

Materials and Methods

Animal Use and Care

The All-University Committee on Animal Use and Care approved all procedures (AUF No. 12/01-183-00).

Animal Experiments

Survey. The survey was conducted in Fall 2001 to assess the influence of breed and age on RBC GPX-1 activity. Four nonlactating cow herds consisting of yearling heifers (<730 d of age), 2-yr-old cows (730 to 1,095 d of age), and mature cows (>1,095 d of age) were bled via coccygeal venipuncture into evacuated blood tubes (BD Vacutainer, Franklin Lakes, NJ) known not to interfere with Se measurements. These herds were 1) cooperator Angus (CH), n = 49; 2) Michigan State University (MSU) Angus (MA), n = 38; 3) MSU Hereford (MHE), n = 43; and 4) MSU Holstein (MHO), n = 32. The CH was composed of 13 yearlings, 12 2-yr-olds, and 24 mature cows (1,129 to 3,385 d of age). The MA herd comprised eight yearlings, eight 2-yr-olds, and 22 mature cows (1,275 to 6,385 d of age). The MHE herd included 19 yearlings, five 2-yr-olds, and 19 mature cows (1,105 to 3,070 d of age). The MHO herd comprised 10 yearlings, eight 2-yr-olds, and 14 mature cows (1,107 to 4,285 d of age). The CH was located 15 km from MSU and had been assembled between 1997 and 2000 from herds in Montana, Virginia, and Georgia, where forage Se concentration is variable to normal. The yearling heifers in this herd were born in Michigan. The MA herd was composed of 13 yearlings, 12 2-yr-olds, and 24 mature cows (1,129 to 3,385 d of age). The MA herd comprised eight yearlings, eight 2-yr-olds, and 22 mature cows (1,275 to 6,385 d of age). The MHE herd included 19 yearlings, five 2-yr-olds, and 19 mature cows (1,105 to 3,070 d of age). The MHO herd comprised 10 yearlings, eight 2-yr-olds, and 14 mature cows (1,107 to 4,285 d of age). The CH was located 15 km from MSU and had been assembled between 1997 and 2000 from herds in Montana, Virginia, and Georgia, where forage Se concentration is variable to normal. The yearling heifers in this herd were born in Michigan. The MSU herds were located approximately 1 km from campus. All 2-yr-old and mature cows had calved the previous year. The CH, MA, and MHE herds grazed a mixture of alfalfa (Medicago sativa L.), Kentucky blue grass (Poa pratensis L.), and orchardgrass (Dactylis glomerata L.) ad libitum and were supplied a free choice trace-mineral salt containing 60 ppm Se as sodium selenite. The MHO yearlings were housed in a solid-floor, partially sheltered pole-barn and fed a haylage-based total mixed diet balanced to contain 0.3 ppm Se as sodium selenite. The MHO 2-yr-old and mature cows were housed in a slatted, enclosed tie-stall barn and consumed a predominately silage and haylage total mixed diet with 0.3 ppm Se. Because different pastures were not used within herds, statistical analysis was not applied.

Experiment 1. The first experiment was conducted to determine the normal thyroid hormone status profile of newborn calves born in Se-deficient areas in the Midwest. Jugular blood samples were collected from Holstein heifer calves (n = 8) born to cows with an adequate Se status at <12 h of age and daily thereafter for 7 d. Following the initial bleeding, calves were injected (i.m.) with 1 mg of Se as sodium selenite and 68 IU vitamin E as d-alpha tocopheryl acetate (BO-SE; Schering-Plough, Kenilworth, NJ). This is a standard management practice with newborn ruminant animals where Se deficiency is a problem. All blood samples were obtained via jugular venipuncture in heparinized evacuated tubes for plasma Se and RBC GPX-1 enzyme activity. An additional 5 mL of blood was collected into clot-activated evacuated tubes (Vacutainer plus SST) for determination of T₄, T₃, free T₄ (fT₄), free triiodothyronine (fT₃), and reverse triiodothyronine (rT₃). On d 0, before initial bleeding, calves consumed 3 L of pooled colostrum and 12 h later were offered an additional 3 L of pooled colostrum. Thereafter, calves were offered 2 L of a commercial milk replacer (Calvita Supreme, Milk Specialties, Dundee, IL) containing 0.4 ppm Se on a DM basis twice daily. On d 2, calves were placed in individual hutches located in an open-front pole-barn for the remainder of the trial.

Experiment 2. The second experiment was conducted to investigate the influence of maternal Se supplementation on cow and calf plasma Se concentration, PGPX-3 activity, and RBC GPX-1 activity, and to determine thyroid hormone status through the first week of life. Twenty-seven multiparous Hereford cows were assigned to one of two treatment groups: 1) weekly placebo drench of 10 mL of double-deionized H₂O (n = 14), or 2) weekly drench with 20 mg Se from sodium selenite (n = 13). The Se drench was prepared by dissolving 4.38 g of sodium selenite in 1 L of double-deionized water. Cattle were allotted to treatments by initial RBC GPX-1 activity, parity, and date of last calving. Cows were provided with free access to a trace-mineralized salt (Kalmbach Feeds, Upper Sandusky, OH) that contained no added Se. In April, before initiation of the trial, cows were artificially inseminated and then pastured with a bull until mid-August. When drenching began in mid-July, cows were from 0 to 3 mo of gestation and continued on their respective treatments to within 1 wk of parturition. Monthly, cows were bled using heparinized, evacuated tubes via coccygeal venipuncture. As is typical in the Midwest, all ages of females were grazed together on a mixture of alfalfa, blue grass, and orchardgrass ad libitum until the end of October, and were then offered locally harvested cornstalk round bales ad libitum and corn silage (3.4 kg/d, DM basis) for the remainder of the trial. Beginning in January 2003, locally harvested grass hay was supplied every third day until calving. Feedstuffs were sampled
monthly and analyzed for mineral content (Table 1). Hay feeder and bunk space were adequate to accommodate the various ages. Approximately 1 mo before parturition, cows were removed from pasture and relocated to a pole-barn enclosure until calving.

Within 12 h postpartum, environmental temperature was recorded and cows were separated from calves for initial sample collection. Calf rectal temperature and weight were recorded. Colostrum was taken from the left rear teat for determination of colostrum Se concentration and colostrum glutathione peroxidase activity (C GPX-3), and 5 mL of blood was collected from cows and calves for analysis of plasma Se concentration, RBC GPX-1, and P GPX-3 activities. An additional 5 mL of blood was collected from calves for determination of serum thyroid hormone. Calves were tattooed, ear-tagged, vaccinated, and returned to their dam. Vaccinations included a corona and Escherichia coli-K99 bolus (First Defense, ImmuCell, Portland, ME) and infectious bovine rhinotracheitis and para influenza-3 intranasal (First Defense, ImmuCell, Portland, ME) and infectious Escherichia coli-serum thyroid hormone. Calves were tattooed, ear-tagged, vaccinated, and returned to their dam. Vaccinations included a corona and Escherichia coli-K99 bolus (First Defense, ImmuCell, Portland, ME) and infectious bovine rhinotracheitis and para influenza-3 intranasal (TSV-2, Pfizer, Exton, PA). In addition, a vitamin A and D injection (500,000 and 75,000 IU, respectively; Veterinary Laboratories, Lenexa, KS) was administered in the platysma muscle. All sample and data collections from calves, except weight, were repeated on d 3 and 7.

Laboratory Analyses

Blood was centrifuged (2,000 × g, 15 min, 4°C) to separate plasma or serum from RBC. After initial centrifugation, plasma was frozen (−80°C) in aliquots for determination of P GPX-3 activity and Se concentration. Red blood cells were washed and hemoglobin was determined for expression of GPX-1 activity (Hill et al., 1999). Plasma protein concentrations were analyzed by least squares ANOVA in a repeated-measures design using PROC MIXED of SAS (SAS Inst., Inc., Cary, NC). The model contained calf and time as random and fixed effects, respectively. In Exp. 2, time of supplementation and air temperature were used as covariates for Se status indicators and thyroid hormone analysis. The model contained cow as a random effect and treatment, time, and time × treatment interaction as fixed effects. Monthly cow plasma Se concentration and RBC GPX-1 activity were analyzed using repeated measures over time with SAS PROC MIXED. Following parturition, cows were removed from the study. Therefore, Satterwaiite’s degree of freedom adjustment (Gill, 1978) was used to

### Table 1. Mineral composition of feedstuffs offered to cows in Exp. 2 (DM basis)

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>Ca</th>
<th>Mg</th>
<th>P</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Se</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazed forage</td>
<td>0.17</td>
<td>0.25</td>
<td>0.20</td>
<td>5.55</td>
<td>157</td>
<td>62</td>
<td>0.18</td>
<td>24</td>
</tr>
<tr>
<td>Hay (mixed)</td>
<td>0.30</td>
<td>0.17</td>
<td>0.14</td>
<td>4.03</td>
<td>161</td>
<td>54</td>
<td>0.19</td>
<td>15</td>
</tr>
<tr>
<td>Corn silage</td>
<td>0.15</td>
<td>0.13</td>
<td>0.16</td>
<td>3.22</td>
<td>32</td>
<td>23</td>
<td>0.05</td>
<td>22</td>
</tr>
<tr>
<td>Corn stalks</td>
<td>0.22</td>
<td>0.13</td>
<td>0.04</td>
<td>6.24</td>
<td>216</td>
<td>65</td>
<td>0.08</td>
<td>15</td>
</tr>
<tr>
<td>Trace mineral salta</td>
<td>15.20</td>
<td>16.40</td>
<td>8.00</td>
<td>2,508</td>
<td>4,482</td>
<td>614</td>
<td>0.43</td>
<td>2,309</td>
</tr>
</tbody>
</table>

*aTrace mineral salt contained no added Se.*
Survey fT4, fT3, and rT3) were performed. For consistency, all status had RBC GPX-1 activity of 11.5 EU/g of hemoglobin, whereas cows with marginal ng/mL had whole-blood GPX-1 activity between 27 to 105 EU/g of hemoglobin. Based on these values, it seems that 2-yr-old and mature cows in the beef herds we surveyed may be losing Se with advancing parity and may have decreased Se status.

Age, however, did not seem to influence RBC GPX-1 activity in the MHO herd (Table 2). Supplementation of sodium selenite in total mixed diets provided 0.3 ppm Se, the requirement for dairy cattle (NRC, 2001). The dairy diets contained a greater proportion of grain compared with the beef cow diets. Ruminal pH is responsive to type of diet and drops rapidly as NDF level decreases (Allen, 1997). In vitro studies suggest that ruminal bacteria can influence Se absorption. Hudman and Glenn (1984, 1985) reported greater Se absorption by Selenu- monas ruminantium and Butyvibrio fibrisolvens, bacteria more prevalent in acidic ruminal environments, compared with Prevotella ruminicola, a bacterium associated with more basic ruminal pH. Additionally, Koe- nig et al. (1997) reported that Se absorption from labeled selenite was greater for wethers consuming concentrate- vs. forage-based diets. Counotte and Hart- mans (1989) reported that yearling Holstein heifers fed high-roughage diets adequate in Se had less (P < 0.01) RBC GPX-1 activity compared with calves and mature cows, supporting the hypothesis that diet type might influence Se status. In addition to diet differences between beef and dairy herds in our survey, MHO females received semiannual Se injections (50 mg of Se as sele- nite; MU-SE, Schering-Plough, Kenilworth, NJ), whereas beef cows did not, which could further influence the RBC GPX-1 activity. Consequently, because of diet, Se injections, and perhaps other facets of management, age seems to not influence MHO RBC GPX-1 activity.

The CH yearling females had greater RBC GPX-1 activity than the MA, MHE, and MHO herd yearling females. The activity of CH, MHE, and MHO 2-yr-olds was greater than that for MA 2-yr-olds. However, it is of interest that the MHE 2-yr-olds grazed the same pastures and consumed the same preserved feedstuffs as the MA 2-yr-olds. The CH and MHO mature cows also seemed to have greater RBC GPX-1 activity than the MA and MHE mature cows.

Between the two Angus herds, all CH age group fe- males had greater RBC GPX-1 activity than those in the MA herd. The cattle grazed comparable forages, were managed similarly and were offered a similar trace-mineralized salt containing 60 ppm Se as sodium selenite. Possible reasons for the apparent within-breed differences could be genetics or area of origin. The CH 2-yr-old and mature cows were assembled from areas (Georgia, Montana, and Virginia) known to be variable to normal for forage Se concentrations (Kubota et al., 1967). The CH yearling females received in utero Se from cows brought into Michigan; theoretically, their stores were greater than the Michigan-born cows that

Table 2. Mean erythrocyte glutathione peroxidase activity in cooperator Angus, Michigan State University Angus, Hereford, and Holstein herds in the survey

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CH</td>
<td>28.89</td>
<td>13</td>
<td>20.92</td>
<td>12</td>
<td>18.53</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>MA</td>
<td>23.20</td>
<td>8</td>
<td>15.45</td>
<td>8</td>
<td>15.82</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>MHE</td>
<td>20.36</td>
<td>19</td>
<td>19.52</td>
<td>5</td>
<td>16.44</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>MHO</td>
<td>23.00</td>
<td>10</td>
<td>19.14</td>
<td>6</td>
<td>20.79</td>
<td>14</td>
</tr>
</tbody>
</table>

aErythrocyte glutathione peroxidase activity (RBC GPX-1) expressed as enzyme units per gram of hemoglobin (EU/g of hemoglobin). One enzyme unit is the activity needed to oxidize 1 μmol of NADPH/min.

bYearlings = <730 d of age, 2-yr-olds = 730 to 1,095 d of age, mature cows = >1,095 d of age.

Account for decreasing sample size over time. Correlations between dependent variables were analyzed by Pearson’s correlation procedure in SAS. When necessary to meet ANOVA heterogeneous variability requirements, loge transformation on response variables (cow P GPX-3 and C GPX-3 activity, calf P GPX-3 activity, fT4, fT3, and rT3) were performed. For consistency, all loge-transformed least squares means and confidence intervals as indices of variability.

Results and Discussion

Survey

In all beef herds (CH, MA, MHE), mature cows had less RBC GPX-1 activity than yearlings (Table 2). Within the Angus herds, RBC GPX-1 activity decreased in yearlings compared with 2-yr-olds, whereas the decrease in activity for Herefords from yearlings to 2-yr-olds was not as great. To meet the Se needs of the neonatal calf, Se is primarily transferred across the placenta during late pregnancy (VanSaun et al., 1989), and colostrum and milk Se concentrations are reflective of the cow’s Se status (Stowe et al., 1988; Knowles et al., 1999). Even when cows have reduced RBC GPX-1 activity, reports have indicated that RBC GPX-1 activity of the calf is often adequate (Koller et al., 1984). Hence, the dam will decrease her stores to provide Se for the calf. All beef cows in this survey were provided free choice trace-mineral salt containing 60 ppm Se as sodium selenite. Dargatz and Ross (1996) reported that decreased Se status could occur in beef herds even when trace-mineral salt containing Se was provided. Backall and Scholz (1981) reported that Holstein and Angus cows with adequate whole-blood Se status (90 to 105 ng/mL) had whole-blood GPX-1 activity between 27 to 35 EU/g of hemoglobin, whereas cows with marginal status had RBC GPX-1 activity of 11.5 EU/g of hemoglo-
were dams to MA yearlings. Stevens et al. (1985) reported that Holstein cattle residing on Se variable soils had greater RBC GPX-1 activity compared with cattle residing on Se-deficient soil. Further, the amount of nutrients transferred from dam to offspring is based on nutritional status of the dam (VanSaun et al., 1989). Consequently, the greater RBC GPX-1 activity in the CH vs. MA herd could be because cattle originating from higher Se areas had higher Se status in late gestation and transferred more Se to the fetus. Thus, it seems from our survey data, if one assumes that trace-mineral salt consumption was similar, that the RBC GPX-1 activities were influenced by breed and age as well as nutrition and management.

**Experiment 1**

On d 0, the mean neonatal calf plasma Se concentration was similar (Table 3) to that of Stowe and Herdt (1992), who reported that newborn Holstein calves had serum Se concentrations ranging from 50 to 70 ng/mL. Following Se injection (postbleeding on d 0), plasma Se concentrations increased 39% (Table 3) to that of Stowe and Herdt (1992), who reported that newborn Holstein calves had serum Se concentrations ranging from 50 to 70 ng/mL. However, Awadeh et al. (1998b; Hammon et al., 2002) reported consideration greater d-0 T4 and T3 concentrations than we observed in our calves when blood samples from Holstein calves were taken within 6 h of birth; however, by d 6, calf T4 and T3 concentrations were comparable to our observations. In our trial, blood was collected within 12 h of birth which could explain the difference in initial thyroid hormone concentration.

Serum T4 concentrations decreased (P < 0.05) from d 0 to d 5 (Table 3). Although T3 concentration was not different between d 0 and 1, decreases (P < 0.05) were observed from d 2 to 5. The rT4 and fT3 concentrations follow the same trend as T4 and T3, respectively. In young calves, T4 and T3 concentrations decrease with lower energy intake (Kinsbergen et al., 1994). Colostrum is high in lipids and protein and more energy dense than milk (Rauprich et al., 2000); thus, concentrations of T4 and T3 are high at birth and decrease until d 6, which is comparable to other reports (Haidorn et al., 1997; Nussbaum et al., 2002). However, Hadorn et al. (1997) and Nussbaum et al. (2002) reported considerably greater d-0 T4 and T3 concentrations than we observed in our calves when blood samples from Holstein calves were taken within 6 h of birth; however, by d 6, calf T4 and T3 concentrations were comparable to our observations. In our trial, blood was collected within 12 h of birth which could explain the difference in initial thyroid hormone concentration.

Serum rT3 concentrations were greatest (P < 0.05) on d 0 and decreased by d 5 (Table 3). Type III deiodinase is induced by high levels of T3, and it inactivates T4 to the inactive metabolite, rT3 (Kohrle, 2000). Because T3 concentrations are high on d 0, corresponding rT3 concentrations were greatest on d 0 and both continued to decrease until d 5. The T3:T4 ratios were greatest on d 0, 1, and 2 but decreased (P < 0.05) by d 5. The conversion of T4 to T3 is catalyzed by the selenoprotein type 1 deiodinase (Beckett et al., 1989), and its activity is reflected by the T3:T4 ratio. The observed T3:T4 ratios on d 0 are consistent with other reports (Awadeh et al., 1998b; Hammon et al., 2002) and seem to stabilize on

<table>
<thead>
<tr>
<th>Variable</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>P-value</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma Se, ng/mL</td>
<td>72.93u</td>
<td>118.91w</td>
<td>100.36v</td>
<td>100.92v</td>
<td>98.52v</td>
<td>99.44v</td>
<td>89.00uv</td>
<td>0.001</td>
<td>7.04</td>
</tr>
<tr>
<td>T3, nmol/L</td>
<td>156.13z</td>
<td>141.63y</td>
<td>121.75z</td>
<td>100.75x</td>
<td>84.13x</td>
<td>65.88a</td>
<td>71.50x</td>
<td>0.001</td>
<td>5.81</td>
</tr>
<tr>
<td>T4, nmol/L</td>
<td>6.69z</td>
<td>6.31y</td>
<td>5.10x</td>
<td>3.98w</td>
<td>2.88w</td>
<td>1.95v</td>
<td>2.25u</td>
<td>0.001</td>
<td>0.27</td>
</tr>
<tr>
<td>fT3, pmol/L</td>
<td>64.50x</td>
<td>48.75y</td>
<td>37.50x</td>
<td>30.63w</td>
<td>24.25v</td>
<td>18.50u</td>
<td>22.38uv</td>
<td>0.001</td>
<td>2.39</td>
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<tr>
<td>fT4, pmol/L</td>
<td>31.58z</td>
<td>23.64y</td>
<td>17.23x</td>
<td>11.94w</td>
<td>9.08v</td>
<td>5.50u</td>
<td>6.68uv</td>
<td>0.001</td>
<td>1.30</td>
</tr>
<tr>
<td>rT3, nmol/L</td>
<td>3.10y</td>
<td>2.25x</td>
<td>1.15w</td>
<td>0.91v</td>
<td>0.71uv</td>
<td>0.52u</td>
<td>0.59v</td>
<td>0.001</td>
<td>0.11</td>
</tr>
<tr>
<td>T3:T4 ratio</td>
<td>0.043uv</td>
<td>0.045z</td>
<td>0.042xx</td>
<td>0.039w</td>
<td>0.034v</td>
<td>0.029x</td>
<td>0.032uv</td>
<td>0.001</td>
<td>0.002</td>
</tr>
</tbody>
</table>

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Table 3. Neonatal Holstein heifer plasma selenium and thyroid hormone concentrations during the first week of life following a Se and vitamin E injection in Exp.1

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Note: Data are least squares means.

* Eight calves were bled for seven consecutive days.

* T3 = triiodothyronine.

* fT3 = free triiodothyronine.

* rT3 = reverse triiodothyronine.

**Within a row, means that do not have a common superscript letter differ.**
were greater (4). However, after 2 mo, the plasma Se concentrations did not differ between treatment groups (Table 4). The delay in difference for the remainder of the trial. The delay in

However, after 4 mo, Se-drenched cows had greater plasma Se status for the entire trial (Table 4). The RBC

Twenty milligrams of Se per week, supplemented as a sodium selenite drench, adequately maintained cow

 assured by the plasma Se concentrations in control cows. Concentrations in adult cattle range from 70 to 100 ng/mL (Stowe and Herdt, 1992). According to these values, by the eighth month, control cow plasma Se concentrations were decreased to 41.08 ng/mL, which is almost deficient. Removal of the sodium selenite from the trace-mineral salt and Se transfer from dam to fetus in the last trimester of pregnancy (VanSaun et al., 1989) both likely contributed to the decreasing plasma Se concentrations observed over time. Further, Se concentrations in Michigan grown feedstuffs (Table 1) were not sufficient to maintain adequate Se status as measured by the plasma Se concentrations in control cows. Twenty milligrams of Se per week, supplemented as a sodium selenite drench, adequately maintained cow plasma Se status for the entire trial (Table 4). The RBC GPX-1 activity of cows in both treatment groups did not differ during the first 3 mo of the study (Table 4). However, after 4 mo, Se-drenched cows had greater (P < 0.01) RBC GPX-1 activity and maintained this difference for the remainder of the trial. The delay in activity of RBC GPX-1 in response to Se was likely due to the 90- to 120-d RBC life expectancy, resulting in only limited monthly incorporation of GPX-1 enzyme into RBC during erythropoesis (Stowe and Herdt, 1992). However, Enjalbert et al. (1999) reported 35-fold increases in RBC GPX-1 activity after 15 d of supplementing large amounts of Se (45 mg) as sodium selenite in Se-deficient Salers cows. Thus, Se concentration could also influence response time of RBC GPX-1 activity to Se supplementation. Peak RBC GPX-1 activities in our trial agree with Stevens et al. (1985), who reported whole-blood RBC GPX-1 activities between 27 and 35 EU/g of hemoglobin for Se-adequate Holstein and Angus cows. However, more recently, Gunter et al. (2003) reported British crossbred and Simmental cows in Arkansas consuming trace-mineralized salt with 26 ppm Se as sodium selenite or Se yeast for 4 mo had RBC GPX-1 activities of 101 or 106 EU/g of hemoglobin, respectively. These activities are considerably greater than those observed in our trial, but differences could also be attributed to laboratory variation in assessing enzyme activity.

At parturition, Se-supplemented cows had twofold greater plasma Se concentrations than control cows, and this increase was also seen in RBC GPX-1 activity (Table 5). The two variables were highly correlated (r = 0.75, P < 0.001). The plasma Se concentrations in our cows were greater than those of Weiss et al. (1984), who reported parturition serum Se concentrations of 32 and 58 ng/mL in cows supplemented with 1 or 5 mg of Se/d as sodium selenite beginning 60 d prepartum. Counotte and Hartmans (1989) reported a high correlation between RBC GPX-1 activity and whole-blood Se concentration (r = 0.933, P < 0.001) in dairy cattle. More recently, Knowles et al. (1999) reported whole-blood

<table>
<thead>
<tr>
<th>Month</th>
<th>Control</th>
<th>Se</th>
<th>P-value</th>
<th>SEM</th>
<th>Control</th>
<th>Se</th>
<th>P-value</th>
<th>SEM</th>
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<td>5.17</td>
<td>15.08</td>
<td>15.78</td>
</tr>
<tr>
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<td>13</td>
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<td>61.98</td>
<td>0.01</td>
<td>4.61</td>
<td>15.95</td>
<td>16.34</td>
</tr>
<tr>
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<td>52.12</td>
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<td>0.01</td>
<td>4.26</td>
<td>18.47</td>
<td>21.63</td>
</tr>
<tr>
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<td>17.14</td>
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<td>63.58</td>
<td>89.15</td>
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<td>4.53</td>
<td>18.09</td>
<td>22.90</td>
</tr>
<tr>
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<td>14</td>
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<td>0.01</td>
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</tr>
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<td>17.02</td>
<td>27.44</td>
</tr>
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<td>84.86</td>
<td>0.01</td>
<td>8.17</td>
<td>17.14</td>
<td>26.86</td>
</tr>
<tr>
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<td>3</td>
<td>31.28</td>
<td>77.59</td>
<td>0.01</td>
<td>10.66</td>
<td>14.39</td>
<td>26.20</td>
</tr>
<tr>
<td>May</td>
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<td>1</td>
<td>53.83</td>
<td>97.81</td>
<td>—</td>
<td>—</td>
<td>14.74</td>
<td>23.28</td>
</tr>
</tbody>
</table>

aSelenium drench (20 mg of Se as Na2SeO3) or a placebo (water) was administered weekly to treatment and control cows respectively, beginning July 16, 2002, and ending at parturition.

bData are least square means. Treatment × time interaction for plasma Se concentration and RBC GPX-1, P < 0.01.

Experiment 2

After 1 mo of Se supplementation, plasma Se concentrations did not differ between treatment groups (Table 4). However, after 2 mo, the plasma Se concentrations were greater (P < 0.01) for cows in the Se-supplemented group compared with control cows, and this difference continued until the conclusion of the trial. Diagnostic laboratories assume that normal serum Se concentrations in adult cattle range from 70 to 100 ng/mL (Stowe and Herdt, 1992). Marginally Se-deficient adult cattle have serum Se concentrations between 40 to 70 ng/mL, whereas cattle deficient in Se have serum concentrations below 40 ng/mL (Gerloff, 1992). According to these values, by the eighth month, control cow plasma Se concentrations were decreased to 41.08 ng/mL, which is almost deficient. Removal of the sodium selenite from the trace-mineral salt and Se transfer from dam to fetus in the last trimester of pregnancy (VanSaun et al., 1989) both likely contributed to the decreasing plasma Se concentrations observed over time. Further, Se concentrations in Michigan grown feedstuffs (Table 1) were not sufficient to maintain adequate Se status as measured by the plasma Se concentrations in control cows. Twenty milligrams of Se per week, supplemented as a sodium selenite drench, adequately maintained cow plasma Se status for the entire trial (Table 4). The RBC GPX-1 activity of cows in both treatment groups did not differ during the first 3 mo of the study (Table 4). However, after 4 mo, Se-drenched cows had greater (P < 0.01) RBC GPX-1 activity and maintained this difference for the remainder of the trial. The delay in
d 5 and 6, which is consistent with ratios reported by Arthur et al. (1988) in Holstein calves 3 mo of age.

Table 4. Effect of weekly selenium drench on monthly prepartum Hereford cow plasma Se concentrations and erythrocyte glutathione peroxidase activity in Exp. 2ab
GPX-1 and Se correlations of 0.85 \( (P < 0.001) \) in Holstein cows receiving 2 or 4 mg of Se as sodium selenite or selenium yeast drenches administered three times weekly for 19 wk. However, Awadeh et al. (1998a,b) reported no differences in whole-blood GPX activity in beef cows offered differing amounts of supplemental Se as sodium selenite or yeast in free choice trace-mineralized salt.

Plasma GPX-3 activity (Table 5) tended \( (P = 0.09) \) to be greater at parturition for cows receiving Se supplementation. However, because this is a short-term index, and the time interval from drench until blood sampling was up to 6 d, differences may be obscured. Cows in this trial received Se supplementation weekly; thus, a 6-d difference between drench and blood collection at parturition could exist. In nonruminants, serum GPX-3 is used as a short-term Se status indicator (Mahan and Parrett, 1996; Mahan et al., 1999); however in the ruminant, few trials have examined P GPX-3 activity and Se status. Podoll et al. (1992) reported that supplemental Se increased Holstein serum Se, but serum GPX-3 was not affected. Likewise, Enjalbert et al. (1999) reported no influence of beef cow Se intake on P GPX-3 activity. Only a small portion of Se found in blood is associated with P GPX-3 in the rat (Deagen et al., 1993) and bovine (Awadeh et al., 1998a). Importantly, 98% of GPX activity is associated with erythrocytes (Scholz and Hutchinson, 1979) and P GPX-3 represents only a very small portion of Se and total GPX activity.

Colostrum Se concentration at parturition was almost 50% greater in cows drenched with Se than in control cows (Table 5). Schingoethe et al. (1982) reported that dietary Se concentrations (0.1 or 2 ppm Se) or selenite injection (5 mg of Se/45.4 kg BW) did not influence dairy cow colostrum Se concentrations in Se adequate cows. Additionally, deToledo and Perry (1985) reported that colostrum Se concentrations were not different between Se adequate and Se-deficient Holstein cows receiving 1 or 2 mg of Se in feed as sodium selenite for 60 d prepartum. Alternatively, Koller et al. (1984) reported that Hereford cows consuming high-Se soybean meal (0.3 ppm Se) and Se-supplemented trace-mineralized salt (90 ppm Se as sodium selenite) had greater Se concentrations in colostrum than cows consuming only low-Se hay. Intraruminal boluses (3 mg of Se/d as selenite) given 120 d prepartum also increased colostrum Se concentrations in Holstein cows (Abdelrahman and Kincaid, 1995).

Although our supplemented cows had 39% greater C GPX-3 activity compared with control cows, they did not differ \( (P = 0.17) \). To our knowledge, GPX-3 activity has never been assayed in bovine colostrum. Hojo (1982) was the first to detect GPX-3 activity in raw bovine milk. However, only 12% of the milk Se was bound to GPX-3 and only 0.003% of the protein found in milk was GPX. Thus, the small percentage of Se associated with milk GPX-3 could explain why differences were not detected.

Treatment did not influence calf birth weights \( (41.60 \pm 0.79 \text{ kg}; \text{ data not shown}) \). Awadeh et al. (1998b) and, most recently, Gunter et al. (2003) reported no influence of maternal Se supplementation on calf birth weights. Relative to BW changes, Castellan et al. (1999) reported Se injections \( (0.05 \text{ mg of Se/kg BW as selenite}) \) improved gain in Hereford × Angus calves from birth to 70 d of age.

In our study, calves born to dams receiving drenches containing Se had greater \( (P < 0.05) \) plasma Se concentrations at d 0, 3, and 7 compared with calves born to control cows (Figure 1A). However, since plasma Se concentrations decreased 10 ng/mL between d 3 and 7 in calves born to Se-supplemented cows, there was a time × treatment interaction \( (P = 0.02) \). No decrease was observed in calves born to control cows. Stowe and Herdt (1992) reported that serum Se concentrations in

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**Table 5. Effect of selenium drench on Hereford cow selenium status indicators at parturition in Exp. 2a,b**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control</th>
<th>Confidence interval</th>
<th>Se</th>
<th>Confidence interval</th>
<th>P-value</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma Se, ng/mL</td>
<td>47.14</td>
<td>—</td>
<td>95.51</td>
<td>—</td>
<td>0.001</td>
<td>3.33</td>
</tr>
<tr>
<td>RBC GPX-1, EU/g of hemoglobin</td>
<td>14.94</td>
<td>—</td>
<td>24.61</td>
<td>—</td>
<td>0.001</td>
<td>0.93</td>
</tr>
<tr>
<td>P GPX-3, EU/g of protein</td>
<td>0.92</td>
<td>0.69 to 1.24</td>
<td>1.34</td>
<td>0.99 to 1.83</td>
<td>0.09</td>
<td>—</td>
</tr>
<tr>
<td>Colostrum Se, ng/mL</td>
<td>87.00</td>
<td>—</td>
<td>169.97</td>
<td>—</td>
<td>0.01</td>
<td>20.49</td>
</tr>
<tr>
<td>C GPX-3, EU/mL</td>
<td>2.38</td>
<td>1.44 to 3.90</td>
<td>3.90</td>
<td>2.30 to 6.55</td>
<td>0.17</td>
<td>—</td>
</tr>
</tbody>
</table>

*Se selenium drench (20 mg of Se as Na2SeO3) or a placebo (water) was administered weekly to treatment \((n = 13)\) and control \((n = 14)\) cows respectively, beginning July 16, 2002, and ending at parturition.

*Data are least squares means.

*The statistical analysis of plasma glutathione peroxidase activity (P GPX-3) and colostrum glutathione peroxidase activity (C GPX-3) were performed on loge-transformed data. The back-transformed least squares means are presented together with the 95% confidence intervals of the least squares means for these variables.

*Erythrocyte glutathione peroxidase activity (RBC GPX-1) expressed as enzyme units per gram of hemoglobin (EU/g of hemoglobin). One enzyme unit is the activity needed to oxidize 1 μmol of NADPH/min.

*P GPX-3 = plasma glutathione peroxidase activity.

*C GPX-3 = colostrum glutathione peroxidase activity.
newborn Holstein calves range from 50 to 70 ng/mL. Based on these values, calves born from cows receiving weekly 20-mg Se drenches had adequate plasma Se, whereas calves born to control cows had plasma Se concentrations approaching less than adequate Se status. However, calves born to cows receiving the placebo were numerically greater for plasma Se concentrations than their dam. This observation agrees with that of Koller et al. (1984), who reported calves born to Se-deficient Hereford cows had greater whole-blood Se concentrations than their dam.

Calves born to Se-drenched cows had a twofold greater ($P < 0.05$) RBC GPX-1 activity compared with calves born to control cows at birth, d 3 and 7 (Figure 1B). Scholz et al. (1981) reported Angus × Holstein calves with low plasma Se concentrations (24 ng/mL) had whole-blood GPX-1 activity of 14.0 EU/g of hemoglobin. Awadeh et al. (1998b) observed that neonatal calves born to cows offered free choice trace-mineral salt containing 60 or 120 ppm Se as selenite or 60 ppm Se as yeast had greater whole-blood GPX activity compared with calves born from cows receiving 20 ppm Se as selenite when supplied for 90 d prepartum. However when supplementation continued through the next parity, the amount or source of Se supplemented to cows did not influence newborn calf whole-blood GPX activity. Gunter et al. (2003) reported no differences in neonatal calf whole-blood GPX activity when their dams were offered either no Se or a trace-mineral salt containing 26 ppm Se as selenite or yeast.

Although cow P GPX-3 activity did not differ between treatments, a treatment × time interaction ($P = 0.05$) for calf P GPX-3 activity was observed (Figure 1C). Calves born from Se supplemented cows had greater P GPX-3 activity compared with control calves at d 0 and 3 ($P < 0.05$). However, by d 7, maternal Se supplementation had no influence on P GPX-3 activity. Koller et al. (1984) reported that colostrum/milk Se concentrations decrease rapidly from d 0 to 7, postpartum. Because P GPX-3 responds to immediate Se intake (Cohen et al., 1985), the greater colostrum Se intake of calves born to Se-supplemented dams could have influenced d-0 and -3 calf P GPX-3 activity.

Mean environmental temperature at initial bleeding was $-2 \pm 1.1 ^\circ$C, well below temperatures reported to induce cold stress in neonatal calves (Schrama et al.,

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**Figure 1.** Effect of maternal weekly drench (20 mg of Se as sodium selenite or placebo) and time on A) calf plasma Se concentration postpartum during wk 1 (treatment × time, $P < 0.05$); B) calf erythrocyte glutathione peroxidase activity (RBC GPX-1) (treatment, $P < 0.05$; one enzyme unit [EU] is the activity needed to oxidize 1 μmol of NADPH/min); C) plasma glutathione peroxidase activity (P GPX-3) (treatment × time, $P < 0.05$). Data for plasma Se concentration (panel A) and RBC GPX-1 activity (panel B) are least squares means ± SEM. Statistical analysis of P GPX-3 activity was performed on loge-transformed least squares means; therefore, data for P GPX-3 activity (panel C) are back-transformed means with error bars for corresponding 95% confidence intervals (Exp. 2).
Table 6. Neonatal Hereford calf thyroid hormone concentrations during the first week of life in Exp. 2a

<table>
<thead>
<tr>
<th>Variable</th>
<th>d 0</th>
<th>Confidence interval</th>
<th>d 3</th>
<th>Confidence interval</th>
<th>d 7</th>
<th>Confidence interval</th>
<th>P-value</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>T4, nmol/Lb</td>
<td>166.70a</td>
<td>122.46a</td>
<td>112.49a</td>
<td>0.001</td>
<td>2.83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T3, nmol/Lc</td>
<td>5.19a</td>
<td>112.49a</td>
<td>0.001</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T3:T4 ratio</td>
<td>0.031a</td>
<td>0.042a</td>
<td>0.035a</td>
<td>0.001</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSH, mU/Ld</td>
<td>18.05a</td>
<td>5.04a</td>
<td>5.31a</td>
<td>0.001</td>
<td>2.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fT4, pmol/Le</td>
<td>49.72a</td>
<td>31.33a</td>
<td>28.83a</td>
<td>0.001</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fT3, pmol/Lf</td>
<td>15.33a</td>
<td>10.78a</td>
<td>9.70a</td>
<td>0.001</td>
<td>—</td>
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<tr>
<td>rT3, nmol/Lg</td>
<td>3.50a</td>
<td>0.70a</td>
<td>0.60a</td>
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</table>

a,b,c,d,e,f,gThe statistical analysis of free thyroxine (fT4), free triiodothyronine (fT3), and reverse triiodothyronine (rT3) were performed on log(e)-transformed data. The back-transformed least squares means for each variable are presented together with 95% confidence intervals. 

Implications

Calves from cows consuming exclusively Michigan-grown feedstuffs may be at risk for selenium deficiency, even when selenium is provided as a free-choice trace-mineral salt. Survey results indicated that older cows had decreased selenium status compared with yearling females. In the young calf, red blood cell glutathione peroxidase 1 activity was more reflective of long-term selenium status than plasma glutathione peroxidase 3 activity. Producers should be cognizant of replenishing nutrients that are transferred to the calf. Additionally, more research is needed to fully understand the influence of breed and management on selenium status and thyroid hormone concentrations.

Literature Cited


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hormones and immunoglobulins in beef cows and calves. J. Anim. Sci. 76:1204–1215.


