Effect of selenium supplementation and plane of nutrition on mares and their foals: Selenium concentrations and glutathione peroxidase

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ABSTRACT: To investigate the maternal plane of nutrition and role of Se yeast on muscle Se concentration, plasma glutathione peroxidase (Gsh-Px) activity, and colostrum Se concentration in mares and their foals, 28 Quarter Horse mares (465 to 612 kg of BW, and 6 to 19 yr of age) were used in a study with a randomized complete block design. Mares were blocked by expected foaling date and randomly assigned to dietary treatments within blocks. Dietary treatments were arranged as a 2 × 2 factorial with 2 planes of nutrition, pasture or pasture + grain mix (fed at 0.75% of BW on an as-fed basis) and 2 concentrations of Se yeast supplementation (0 or 0.3 mg/kg of DMI), resulting in 4 treatments: pasture, pasture + grain mix, pasture + grain mix + Se, or pasture + Se. Mares fed diets of pasture and pasture + Se received approximately 100% of the calculated NRC (2007) DE requirements, whereas mares fed diets of pasture + grain mix and pasture + grain mix + Se received 120%. Selenium supplementation began 110 d before the estimated foaling date and treatments were terminated at parturition. Blood and muscle (biopsy) samples were collected on d 0 and then every 14 or 28 d, respectively, thereafter until parturition. Additionally, BW, BCS, and rump fat (RF) were recorded every 14 d. At parturition, colostrum, foal plasma, and foal muscle samples were collected and sampling continued every 14 d for plasma and every 28 d for muscle until d 56. Mare BW, BCS, and RF were affected by plane of nutrition (P ≤ 0.02), but not by Se supplementation. Mares fed the grain mix had greater (P < 0.05) BW, BCS, and RF measurements throughout the experiment. Mare plasma, muscle, and colostrum Se concentrations were greater (P < 0.01) in mares fed Se. Mares fed the grain mix had greater plasma Se (P = 0.02) than mares on pasture alone. Mare and foal plasma Gsh-Px concentrations were not affected by treatment. Foal plasma and muscle Se concentrations were greater when dams were fed the supplemental grain mix (P = 0.04 and 0.02, respectively) and supplemental Se (P < 0.001). Results indicated that maternal plane of nutrition and Se supplementation affected mare and foal plasma, muscle, and colostrum Se concentrations, but not Gsh-Px activity.

Key words: digestible energy, equine, glutathione peroxidase, selenium

INTRODUCTION

Selenium deficiency in animals may lead to white muscle disease or nutritional muscular dystrophy (Muth et al., 1958; Lofstedt, 1997) and suppression of the immune system (Boyne and Arthur, 1979; Stabel et al., 1989; Knight and Tynik, 1990). Selenium is an antioxidant, and supplementation has been shown to increase serum Se and glutathione peroxidase (Gsh-Px) activity and enhance humoral immune function (Knight and Tynik, 1990; Pagan et al., 1999; Kamada et al., 2007). Maternal Se status during gestation plays an integral role in the Se status of offspring (Hostetler and Kincaid, 2004; Ghany-Hefnawy et al., 2007); so too does the maternal plane of nutrition.

Selenium, as a component of Gsh-Px, is a required nutrient and an antioxidant, and the current recommendation is that horses of all classes receive 0.10 mg/kg of DM, with a maximum tolerance level of 5 mg/kg of DM (NRC, 2007). However, the US Food and Drug Administration has recently recommended that 0.3 mg of Se, regardless of source, can be safely supplemented in the diets of all livestock species [FDA 2004, Code of Federal Regulations, Title 21, Part 573.920(h)]. When Se is added to the diet in the form of selenomethionine
(SeMet), it is incorporated into body tissue in place of methionine (Schrauzer, 2000). When SeMet was compared with NaSeO3 supplementation in yearling horses, SeMet increased plasma Se to a greater extent during the first 28 d of the experiment (Richardson et al., 2006). However, there is little data evaluating the use of SeMet in the pregnant mare. Therefore, the purpose of this study was to investigate the maternal plane of nutrition and the role of Se yeast on muscle Se concentration, plasma Gsh-Px activity, and colostrum Se concentration in mares and their foals. The current paper focuses on plasma and muscle Se and GSH-Px in both mares and foals, whereas a companion paper (Thorson et al., 2010) reports the results of colostrum components, passive transfer of IgG, foaling variables (e.g., time to stand, nurse), and placental DNA and RNA.

MATERIALS AND METHODS

Care, handling, and sampling of animals were approved by the Texas A&M University Animal Care and Use Committee.

Horses and Treatments

Twenty-eight Quarter Horse mares from the Texas A&M University Horse Center (College Station) were used in a randomized complete block design. Mares were housed at the Texas A&M University Horse Center and maintained according to the farm protocol. Horses ranged from 6 to 19 yr of age and had BW between 465 and 612 kg.

Mares were blocked by expected foaling date and assigned randomly within block to dietary treatments. Dietary treatments were arranged as a 2 × 2 factorial with 2 planes of nutrition (pasture or pasture + grain mix) and 2 concentrations of SeMet supplementation (0 or 0.3 mg of SeMet/kg of DMI). This resulted in 4 treatment groups: pasture (PA; n = 7), pasture + Se (PS; n = 8), pasture + grain mix (PG; n = 5), and pasture + grain mix + Se (PGS; n = 8). Pasture diets (PA and PS) provided approximately 100% of NRC (2007) DE requirements, whereas grain mix (or grain)-supplemented diets (PG and PGS) provided approximately 120%. Dietary energy intake was 2.17 Mcal/kg of DM for diets PA and PS, whereas diets PG and PGS provided 2.53 Mcal/kg of DM [calculated using equations from NRC (2007)]. Selenium content of dietary treatments was calculated based on Se concentrations of dietary components (Table 1) and resulted in 0.19, 0.49, 0.35, and 0.65 mg/kg of DM for diets PA, PS, PG, and PGS, respectively. Because pasture intake was not measured, total dietary intake was assumed to be 2% of BW (DM basis; Aiken et al., 1989). Plane of nutrition treatments were initiated 45 d before the last one-third of pregnancy, whereas SeMet supplementation (0 or 0.3 mg/kg of DM) was initiated at the beginning of the last one-third of pregnancy (approximately 110 d before the estimated foaling date). Plane of nutrition treatments were initiated earlier to induce changes in BW and BCS between groups by the beginning of the last one-third of pregnancy. All dietary treatments were terminated at parturition. After parturition, all mares returned to pasture, where they were group fed grain mix at approximately 1% of BW (as-fed) twice daily. The composition of the lactation grain mix was similar to that used before parturition (Table 1).

All mares had continual access to coastal bermudagrass (Cynodon dactylon) pastures (Table 1), water, and trace mineralized salt (containing no added Se) throughout the study. Multiple adjacent pastures were used at the facility; however, blocks were maintained on the same pasture and were rotated among pastures as part of farm protocols.

The nutrient composition of pasture, grain mix and SeMet is presented in Table 1. Mares on treatments PG and PGS received a supplemental grain mix composed of sorghum, wheat middlings, soybean meal, soybean hulls, and a vitamin and mineral premix. Selenium content of dietary treatments was calculated based on Se concentrations of dietary components (Table 1) and resulted in 0.19, 0.49, 0.35, and 0.65 mg/kg of DM for diets PA, PS, PG, and PGS, respectively. Because pasture intake was not measured, total dietary intake was assumed to be 2% of BW (DM basis; Aiken et al., 1989). Plane of nutrition treatments were initiated 45 d before the last one-third of pregnancy, whereas SeMet supplementation (0 or 0.3 mg/kg of DM) was initiated at the beginning of the last one-third of pregnancy (approximately 110 d before the estimated foaling date). Plane of nutrition treatments were initiated earlier to induce changes in BW and BCS between groups by the beginning of the last one-third of pregnancy. All dietary treatments were terminated at parturition. After parturition, all mares returned to pasture, where they were group fed grain mix at approximately 1% of BW (as-fed) twice daily. The composition of the lactation grain mix was similar to that used before parturition (Table 1).

For all mares, the composition of the lactation grain mix was similar to that used before parturition (Table 1). Mares on treatments PG and PGS received a supplemental grain mix composed of sorghum, wheat middlings, soybean meal, soybean hulls, and a vitamin and mineral premix at 0.75% of BW (as-fed). Mares on treatments PS and PGS received supplemental Se yeast in the form of SeMet (Selenosource, Diamond V Mills Inc., Cedar Rapids, IA) at 0.3 mg/kg of DMI. Grain and SeMet treatments (PG, PS, and PGS) were fed in individual 3.0 × 2.9 m stalls twice daily. Selenomethionine was mixed with a small amount of sweet feed (12% of CP sweet feed, Producers Co-op) and was offered to mares before additional grain mix to ensure ingestion of the SeMet supplement. Body weight was recorded every 2 wk and diets were adjusted accordingly. Mares on treatment PA were housed in individual stalls during the same time period but were not fed any supplemental grain.

Forage and Concentrate Samples

Forage samples were randomly obtained from all pastures and on a monthly basis throughout the experiment. Pasture samples were taken from multiple

Table 1. Energy and nutrient composition of coastal bermudagrass (Cynodon dactylon) pasture, grain mix, and supplemental selenium (DM basis)

<table>
<thead>
<tr>
<th>Item</th>
<th>Pasture</th>
<th>Grain mix</th>
<th>SeMet</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP, %</td>
<td>14.30</td>
<td>15.37</td>
<td>25.00</td>
</tr>
<tr>
<td>Fat (ether extract), %</td>
<td>2.60</td>
<td>2.45</td>
<td>3.00</td>
</tr>
<tr>
<td>ADF, %</td>
<td>36.41</td>
<td>16.77</td>
<td>—</td>
</tr>
<tr>
<td>Crude fiber, %</td>
<td>—</td>
<td>—</td>
<td>5.50</td>
</tr>
<tr>
<td>TDN, %</td>
<td>60.14</td>
<td>72.27</td>
<td>—</td>
</tr>
<tr>
<td>Ca, %</td>
<td>0.48</td>
<td>0.98</td>
<td>0.20</td>
</tr>
<tr>
<td>P, %</td>
<td>0.41</td>
<td>0.56</td>
<td>0.90</td>
</tr>
<tr>
<td>Se, mg/kg</td>
<td>0.19</td>
<td>0.63</td>
<td>600.00</td>
</tr>
<tr>
<td>Organic Se, mg/kg</td>
<td>—</td>
<td>588.00</td>
<td></td>
</tr>
<tr>
<td>DE, Mcal/kg</td>
<td>2.17</td>
<td>3.14</td>
<td>1.40</td>
</tr>
</tbody>
</table>

1Grain mix contained sorghum, wheat middlings, soybean meal, soybean hulls, and a vitamin and mineral premix.
2Selenomethionine (Selenosource, Diamond V Mills Inc., Cedar Rapids, IA). Analysis provided by the manufacturer (Diamond V Mills Inc.).
3Calculated according to NRC (2007).
locations and plant heights. All forage and concentrate samples collected throughout the experiment were dried in a forced-air oven (Lindberg/Blue M, Asheville, NC) at 60°C for 96 h. Samples were then ground using a 2-mm screen (Wiley Mill, Thomas Scientific, Swedesboro, NJ). Ground samples were analyzed by a commercial laboratory (SDK Laboratories, Hutchinson, KS) for DM, CP, ADF, TDN, ether extract, and mineral (Ca, P, and Se) contents (Table 1). Gross energy analysis was performed via bomb calorimetry (Parr 6300 Calorimeter, Parr Instrument Company, Moline, IL).

**Mare Measurements**

Mare BW, BCS, and rump fat (RF) measurements were collected every 14 d for the duration of the experiment and diets were adjusted accordingly. Body weight was determined by a digital scale (CAS Corp., Seoul, Korea) and BCS was determined by 4 individuals (2 constant, and 2 rotating) on a scale of 1 to 9 (with 1 being described as poor and 9 as extremely fat) as described by Henneke et al. (1983). Rump fat was measured via ultrasonic images on the left hip at a point 5 cm dorsal of halfway between the first coccygeal vertebra and the ischium (Westervelt et al., 1976), using an ultrasound instrument (Aloka SSD-500V, Aloka Inc., Tokyo, Japan).

**Blood and Colostrum Samples and Analysis**

Mare blood samples were collected every 14 d and were terminated at parturition. Foal blood samples began at birth (before nursing) and continued every 14 d until 56 d of age. Blood samples (10 mL) were collected before the morning feeding. All blood samples were collected via jugular venipuncture into evacuated tubes containing sodium heparin (143 USP units; Becton Dickinson, Franklin Lakes, NJ) and placed on ice until centrifugation. Samples were centrifuged at 2,700 × g and 10°C for 20 min, and plasma was harvested and stored at −20°C until further analysis for Se and Gsh-Px. Colostrum samples were obtained after parturition and before nursing. Approximately 20 mL of colostrum was collected into a conical vial (VWR Int., West Chester, PA) and stored at −20°C until further analysis for Se.

Plasma Gsh-Px activity was determined spectrophotometrically by a commercially available colorimetric assay kit (Bioxytech, Foster City, CA). The assay was validated for Gsh-Px in equine by Richardson et al. (2006). Within and between CV for this assay were less than 15%. Mare plasma was diluted 1:10 (vol/vol) in assay buffer to measure values within the range recommended by the manufacturer (0.035 to 0.15 A340/min), whereas foal plasma required no dilution. This assay provides an indirect measure of plasma Gsh-Px activity and therefore must be expressed per unit of plasma protein. Plasma protein concentrations were determined using a commercial kit (Sigma-Aldrich Co., Saint Louis, MO). Plasma and colostrum Se concentrations were determined by atomic absorption spectrophotometry with a hydride generator (A Analyst 800, PerkinElmer, Waltham, MA) as described by Finley et al. (1996).

**Muscle Biopsies and Analysis**

Mare muscle biopsies (approximately 100 mg wet weight) were collected every 28 d and terminated at parturition. Foal muscle biopsies (approximately 100 mg wet weight) were collected at birth (12 h of age) and on d 28 and 56. Muscle biopsies were collected from the right-middle gluteal muscle via percutaneous needle biopsy (5-mm biopsy needle, Popper and Sons Inc., New Hyde Park, NY) as described by Snow and Guy (1976). Muscle samples were placed in cryogenic vials (VWR Int.), immediately snap-frozen in liquid N, and stored at −60°C until analysis for Se. Muscle Se concentrations were determined using atomic absorption spectrophotometry with a hydride generator (A Analyst 800, PerkinElmer) as described previously by Finley et al. (1996).

**Statistical Analysis**

Data were analyzed as a randomized complete block design. Colostrum Se concentrations were analyzed using GLM procedures (SAS Inst. Inc., Cary, NC), whereas repeated measures, such as plasma and muscle Se and plasma Gsh-Px, were analyzed using the MIXED procedure. The model contained effects for block (early, mid-1, mid-2, and late), nutrition (pasture vs. grain), and plasma Gsh-Px, were analyzed using the MIXED procedure. The model contained effects for block (early, mid-1, mid-2, and late), nutrition (pasture vs. grain), level of Se supplementation (none vs. supplement), and the nutrition × SeMet interaction. Main effects were considered significant when \( P < 0.05 \).

**RESULTS**

Mare BW, BCS, RF, and changes in BW, BCS, and RF (final minus initial values) were all affected by dietary treatment (Table 2). Dietary energy intake (nutrition) affected mare BW, BCS, and RF, with mares in the PG and PGS treatments having greater values (\( P = 0.002, P < 0.001, \) and \( P = 0.02, \) respectively) than mares in the PA or PS treatment. However, nutrition did not affect BW gain or ADG. Mares fed PA and PS had a negative change in BCS and RF compared with mares fed PG and PGS (\( P < 0.01 \)). There was no effect of SeMet supplementation or the interaction between nutrition and SeMet on mare BW, BCS, RF, ADG, or the changes in those values. These measurements expressed over time are reported in the companion paper (Thorson et al., 2010).

Mare plasma Se concentrations (Table 3) were greater (\( P = 0.02 \)) in mares fed PG and PGS than in mares fed PA and PS. Selenomethionine supplementation likewise affected plasma Se concentrations, with mares in the PS and PGS treatments having greater (\( P < 0.01 \))
values than mares in the PA or PG treatment. Mare muscle and colostrum Se concentrations were greater (P < 0.01) in mares fed PGS and PS than in mares fed PA and PG. There was no effect of nutrition on mare muscle or colostrum Se concentrations (P = 0.64 and P = 0.89, respectively). Despite changes in mare plasma Se concentrations, mare plasma Gsh-Px activities were not affected by nutrition or SeMet supplementation (P = 0.89 and 0.55, respectively). There was no interaction (P > 0.25) effect between nutrition and SeMet on mare plasma, muscle, or colostrum Se concentration and plasma Gsh-Px.

Foal plasma and muscle Se concentrations differed with maternal dietary treatment (Table 4). Maternal plane of nutrition affected foal plasma and muscle Se concentrations (P = 0.04 and 0.02, respectively), with foals of mares fed PG and PGS having greater plasma and muscle Se concentrations than foals of mares fed PA and PS. Similarly, maternal SeMet supplementation affected foal plasma and muscle Se concentrations (P < 0.01), with foals from mares fed PS and PGS having greater values than foals of mares fed PA and PG. Furthermore, foal plasma Gsh-Px activities were not affected by maternal plane of nutrition or SeMet supplementation of the dam (P = 0.37 and P = 0.12, respectively).

**DISCUSSION**

Mare body measurements changed as a result of the maternal diet, with mares fed the grain mix (PG and PGS) having greater mean BW, BCS, and RF than mares not fed grain (PA and PS). Although mares on only pasture (PA and PS) were estimated to receive approximately 100% of NRC (2007) recommended allowances for mares in the last one-third of gestation, they did have negative changes in BCS and RF. However, all mares gained BW similarly (40.0 to 53.3 kg) and had similar ADG (0.36 to 0.50 kg/d). In addition, voluntary DMI was estimated as a percentage of mare BW in this study. There is little previous work describing voluntary DMI in the pregnant mare, particularly when the diet of the mare includes both forage and grain (NRC, 2007). The current recommendation indi-

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**Table 2.** Effect of dietary energy manipulation and selenomethionine1 (SeMet) supplementation on mare BW, BCS, rump fat (RF), and ADG2

<table>
<thead>
<tr>
<th>Measurement</th>
<th>PA (n = 7)</th>
<th>PS (n = 8)</th>
<th>PG (n = 5)</th>
<th>PGS (n = 8)</th>
<th>Nutrition</th>
<th>Se</th>
<th>Nutrition × Se</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW, kg</td>
<td>572 ± 13.8</td>
<td>554 ± 12.9</td>
<td>603 ± 16.4</td>
<td>624 ± 13.0</td>
<td>0.002</td>
<td>0.88</td>
<td>0.18</td>
</tr>
<tr>
<td>Change in BW, kg</td>
<td>40.0 ± 9.4</td>
<td>44.2 ± 8.8</td>
<td>53.3 ± 11.3</td>
<td>51.0 ± 8.8</td>
<td>0.31</td>
<td>0.92</td>
<td>0.74</td>
</tr>
<tr>
<td>ADG, kg</td>
<td>0.36 ± 0.09</td>
<td>0.40 ± 0.08</td>
<td>0.50 ± 0.10</td>
<td>0.48 ± 0.08</td>
<td>0.24</td>
<td>0.88</td>
<td>0.77</td>
</tr>
<tr>
<td>BCS</td>
<td>4.9 ± 0.3</td>
<td>4.6 ± 0.3</td>
<td>5.8 ± 0.3</td>
<td>6.6 ± 0.3</td>
<td>&lt;0.001</td>
<td>0.44</td>
<td>0.06</td>
</tr>
<tr>
<td>Change in BCS</td>
<td>−0.9 ± 0.3</td>
<td>−0.9 ± 0.2</td>
<td>−0.1 ± 0.3</td>
<td>0.2 ± 0.2</td>
<td>0.002</td>
<td>0.57</td>
<td>0.52</td>
</tr>
<tr>
<td>RF, cm</td>
<td>1.01 ± 0.12</td>
<td>0.78 ± 0.12</td>
<td>1.11 ± 0.14</td>
<td>1.33 ± 0.12</td>
<td>0.02</td>
<td>0.98</td>
<td>0.08</td>
</tr>
<tr>
<td>Change in RF, cm</td>
<td>−0.09 ± 0.09</td>
<td>−0.17 ± 0.09</td>
<td>0.34 ± 0.11</td>
<td>0.22 ± 0.09</td>
<td>0.002</td>
<td>0.29</td>
<td>0.81</td>
</tr>
</tbody>
</table>

1Selenosource (Diamond V Mills Inc., Cedar Rapids, IA).
2Values are least squares means.
3Grain mix was supplemented at 0.75% of BW on an as-fed basis and Se was supplemented at 0.3 mg/kg of DM, resulting in 4 dietary treatments: PA = pasture only (coastal bermudagrass), PS = pasture + Se, PG = pasture + grain mix, and PGS = pasture + grain mix + Se.
4Nutrition = effect of nutrition, Se = effect of Se, and nutrition × Se = interaction between nutrition and Se.

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**Table 3.** Effect of dietary energy manipulation and selenomethionine1 (SeMet) supplementation on mare plasma, muscle, and colostrum Se concentrations and plasma glutathione peroxidase (Gsh-Px) activities2

<table>
<thead>
<tr>
<th>Measurement</th>
<th>PA (n = 7)</th>
<th>PS (n = 8)</th>
<th>PG (n = 5)</th>
<th>PGS (n = 8)</th>
<th>Nutrition</th>
<th>Se</th>
<th>Nutrition × Se</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma Se, µg/mL</td>
<td>0.224 ± 0.006</td>
<td>0.255 ± 0.005</td>
<td>0.253 ± 0.007</td>
<td>0.260 ± 0.006</td>
<td>0.02</td>
<td>0.01</td>
<td>0.08</td>
</tr>
<tr>
<td>Muscle Se, µg/mg</td>
<td>0.317 ± 0.023</td>
<td>0.362 ± 0.021</td>
<td>0.282 ± 0.028</td>
<td>0.419 ± 0.023</td>
<td>0.64</td>
<td>0.01</td>
<td>0.07</td>
</tr>
<tr>
<td>Colostrum Se, µg/mL</td>
<td>0.179 ± 0.029</td>
<td>0.255 ± 0.030</td>
<td>0.203 ± 0.035</td>
<td>0.319 ± 0.027</td>
<td>0.16</td>
<td>0.01</td>
<td>0.51</td>
</tr>
<tr>
<td>Plasma Gsh-Px, mU/mg of protein</td>
<td>6.85 ± 0.39</td>
<td>7.56 ± 0.37</td>
<td>7.37 ± 0.47</td>
<td>7.14 ± 0.38</td>
<td>0.89</td>
<td>0.55</td>
<td>0.25</td>
</tr>
</tbody>
</table>

1Selenosource (Diamond V Mills Inc., Cedar Rapids, IA).
2Values are least squares means.
3Grain mix was supplemented at 0.75% of BW on an as-fed basis and Se was supplemented at 0.3 mg/kg of DM, resulting in 4 dietary treatments: PA = pasture only (coastal bermudagrass), PS = pasture + Se, PG = pasture + grain mix, and PGS = pasture + grain mix + Se.
4Nutrition = effect of nutrition, Se = effect of Se, and nutrition × Se = interaction between nutrition and Se.
cates pregnant mares consume 2% of their nonpregnant BW in DM per day. Therefore, these values were used to estimate intake, determine SeMet supplementation, and compare DE intake with recommendations (NRC, 2007). The loss in BCS of mares not fed grain indicates that pasture alone was not sufficient to maintain late-gestation mares in this management setting, and further study is required to determine the voluntary DMI of pregnant mares more accurately.

Previous work investigating Se supplementation in horses agrees with the present study that dietary Se supplementation does affect plasma or serum and muscle Se status regardless of source (Shellow et al., 1985; Wichtel et al. 1998; Janicki et al., 2001; Richardson et al., 2006; Calamari et al., 2009). As expected, mare plasma Se concentrations in the current study were affected by SeMet supplementation. Plasma Se concentrations are indicative of short-term Se status and are therefore more sensitive to changes in dietary Se concentrations (Shellow et al., 1985). These values are greater than those reported by Richardson et al. (2006; 0.096 to 0.169 µg/mL) in 18-mo-old horses, but are in agreement with values reported by Calamari et al. (2009; 0.17 to 0.21 µg/g) when mature horses were fed Se yeast at 0.29 mg/kg of DM.

The difference among these results may be due in part to the length of SeMet supplementation, the source of SeMet, and the physiological state of the animal. Although the current study and that by Calamari et al. (2009) provided supplemental SeMet for longer than 112 d, Richardson et al. (2006) supplemented horses for only 56 d. Plasma Se concentrations seemed to plateau by 28 to 90 d in previous studies (Shellow et al., 1985; Richardson et al., 2006; Calamari et al., 2009), but Se concentrations in the current study continued to increase until d 112. We observed this increase in plasma Se in mature, pregnant mares, whereas previous studies have used 18-mo-old geldings and nonpregnant females (Richardson et al., 2006) and mature, nonpregnant horses (Calamari et al., 2009) fed different sources of SeMet. Sunde et al. (2005) noted that the dietary Se requirement was less for gestating rats than for growing rats; however, Se requirements for growth or pregnancy in horses have not been determined (NRC, 2007), and further research is needed to provide definitive requirements for horses.

Additionally, the amount of Se provided may be a source of variation between the current and previous work in horses (Janicki et al., 2001; Richardson et al., 2006; Calamari et al., 2009). Janicki et al. (2001) provided supplemental Se at 1 or 3 mg of Se/d to pregnant mares, Richardson et al. (2006) supplemented Se at a rate of 0.45 mg of Se/kg of DM, and Calamari et al. (2009) fed Se at 0.77, 1.62, and 2.47 mg of Se/animal per day. It is important to note that forage intake was estimated in the current study; therefore, total dietary intake of Se is a reflection of that estimate. Furthermore, DE intake was manipulated in the current study, and this aspect was not investigated in the previous studies (Janicki et al., 2001; Richardson et al., 2006; Calamari et al., 2009).

In the current study, we observed that SeMet supplementation did not affect plasma Gsh-Px activity. This is in agreement with other studies in which SeMet was fed to horses (Richardson et al., 2006; Calamari et al., 2009). Richardson et al. (2006) reported plasma Gsh-Px activities ranging from 10.0 to 12.3 mU/mg of protein, whereas in the current study, we observed smaller values (6.8 to 7.5 mU/mg of protein). The lack of increased Gsh-Px activity observed by others (Richardson et al., 2006; Calamari et al., 2009) and in the current study may be partially due to prestudy Se status. Shellow et al. (1985) reported that a plateau in Gsh-Px activity, via an adequate prestudy Se status of horses, may have been the reason they did not observe an increase in Gsh-Px activities with Se supplementation. Therefore, the horses used in the current study may have reached a plasma Gsh-Px plateau before the beginning of the study because of adequate Se in their environment.

Mare muscle Se concentrations in the current study were affected by SeMet supplementation. Conversely, Richardson et al. (2006) reported that Se supplementation, regardless of source, did not affect muscle Se concentrations. Mean final muscle Se concentrations in the current study were greater than those reported by Richardson et al. (2006; 0.079 to 0.101 µg/g). The amount and source of Se provided may explain the differences observed between these studies.

### Table 4: Effect of maternal dietary energy manipulation and selenomethionine (SeMet) supplementation on foal plasma and muscle selenium (Se) concentrations and plasma glutathione peroxidase (Gsh-Px) activities

<table>
<thead>
<tr>
<th>Measurement</th>
<th>PA (n = 7)</th>
<th>PS (n = 8)</th>
<th>PG (n = 5)</th>
<th>PGS (n = 8)</th>
<th>Treatment</th>
<th>F-value 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma Se, µg/mL</td>
<td>0.118 ± 0.006</td>
<td>0.149 ± 0.006</td>
<td>0.138 ± 0.007</td>
<td>0.158 ± 0.005</td>
<td>Nutrition</td>
<td>0.04 &lt;0.001 0.34</td>
</tr>
<tr>
<td>Muscle Se, µg/mg</td>
<td>0.382 ± 0.022</td>
<td>0.425 ± 0.021</td>
<td>0.353 ± 0.026</td>
<td>0.573 ± 0.021</td>
<td>Se</td>
<td>0.02 &lt;0.001 &lt;0.001</td>
</tr>
<tr>
<td>Plasma Gsh-Px, mU/mg of protein</td>
<td>8.33 ± 0.48</td>
<td>7.72 ± 0.46</td>
<td>8.06 ± 0.57</td>
<td>7.10 ± 0.45</td>
<td>Nutrition × Se</td>
<td>0.37 0.12 0.73</td>
</tr>
</tbody>
</table>

1Selenosource (Diamond V Mills Inc., Cedar Rapids, IA).
2Values are least squares means.
3Grain was supplemented at 0.75% of BW on an as-fed basis and Se was supplemented at 0.3 mg/kg of DM, resulting in 4 dietary treatments: PA = pasture only (coastal bermudagrass), PS = pasture + Se, PG = pasture + grain mix, and PGS = pasture + grain mix + Se.
4Nutrition = effect of nutrition, Se = effect of Se, and nutrition × Se = interaction between nutrition and Se.
Similar to mare muscle Se concentrations, colostrum Se concentrations in the current study were affected by SeMet supplementation. This agrees with the study by Janicki et al. (2001), which likewise reported increased colostrum Se concentrations with SeMet supplementation and stated that Se from an organic source was more effective in increasing colostrum Se concentrations than inorganic sources. Although the current study did not investigate the difference between organic and inorganic Se, it was concluded that Se supplementation was effective in increasing colostrum Se concentrations.

Maternal SeMet supplementation and DE manipulation can affect the Se status of mares, but also the Se status of foals. Previous studies have reported that the Se status of offspring is correlated with the maternal Se status during gestation (Lee et al., 1995; Mahan and Kim, 1996). Foal plasma Se concentrations in the current study were affected by the maternal plane of nutrition and SeMet supplementation. Samples of both foal muscle and plasma were taken at 12 h after birth; therefore, it is possible that colostrum Se concentrations affected these initial values. This agrees with the study by Janicki et al. (2001), who reported that foals from mares supplemented with SeMet had greater serum Se concentrations. This relationship has also been noted in cattle (Ortman and Pehrson, 1999; Guyot et al., 2007), sheep (Rock et al., 2001; Reed et al., 2007), and pigs (Loudenslager et al. 1986; Mahan and Kim, 1996). Previous investigations of SeMet supplementation and its effect on foal plasma Gsh-Px activity are somewhat limited. Janicki et al. (2001) reported that foals from mares supplemented with 3 mg of Se/d had greater whole blood Gsh-Px activities than those supplemented with 1 mg of Se/d as NaSe. Mares in the current study exhibited no increase in plasma Gsh-Px activity, and foal plasma Gsh-Px activity was not affected by maternal treatment. Although Janicki et al. (2001) investigated Gsh-Px activity in whole blood and the current study used plasma, Richardson et al. (2006) reported no appreciable difference between methods. However, a review of other studies concluded that serum Se concentrations are a reflection of long-term Se status, whereas plasma Se concentrations are more indicative of short-term Se status (Thomson, 2004). The presudy maternal Se status and the effect of dietary Se concentrations may be possible explanations for the differences observed, and additional research is needed to clarify this relationship further.

Although the relationship of maternal SeMet supplementation and foal plasma or serum Se concentrations has been investigated previously, literature regarding foal muscle Se concentrations is limited. To our knowledge, this is the first study to report the effect of maternal DE manipulation and SeMet supplementation on foal muscle Se status. Foal muscle Se concentrations were affected by maternal SeMet supplementation and nutrition. These results indicate that supplemental SeMet provided to mares in the last one-third of pregnancy can improve the tissue Se status of foals. These findings are in agreement with work in pigs (Mahan and Kim, 1996; Kim and Mahan, 2001; Mahan and Peters, 2004). The ability to improve tissue Se status prenatally is of particular importance because it is doubtful that foals receive sufficient Se through milk alone because of the relatively small concentration of Se (Breedveld et al., 1988). Therefore, if foals have increased Se stores at birth, it is likely that they will be able to utilize body stores to meet Se needs in the first few months of life.

In summary, SeMet supplementation seems to be effective in increasing the Se status of mares in the last one-third of pregnancy and in their foals. The maternal plane of nutrition and SeMet supplementation affect mare and foal plasma, muscle, and colostrum Se concentrations, but not Gsh-Px activity. Further research is needed in this area to determine the Se requirements of mares in the third trimester of pregnancy.

LITERATURE CITED


Effect of maternal nutrition on selenium status


