Supplemental Selenium Source in Holstein Steers Challenged with Intranasal Bovine Infectious Rhinotracheitis Virus and in Newly Received Beef Heifers: Performance, Morbidity, Antibody Titers, and Blood Cell Counts

T. L. Covey, N. E. Elam, J. A. Carroll, D. B. Wester, and M. L. Galyean

*Department of Animal and Food Sciences, Texas Tech University, Lubbock 79409; †Clayton Livestock Research Center, New Mexico State University, Clayton 88415; §Department of Natural Resources Management, Texas Tech University, Lubbock 79409; and ‡Livestock Issues Research Unit, USDA-ARS, Lubbock, TX 79403

ABSTRACT

Viral infection in newly received feedlot cattle can lead to oxidative stress. As a constituent of glutathione peroxidase, Se plays a vital antioxidant role. Our objective was to evaluate effects of Se source on the performance and health of calves challenged with infectious bovine rhinotracheitis virus (IBRV; Exp. 1) or in field conditions (Exp. 2). In Exp. 1, twenty-four Holstein steers (initial BW = 170 ± 6 kg) were given either 1) no supplemental Se (control), 2) 1 mg/steer daily of Se from Se-yeast, or 3) 5 mg/steer daily of Se from sodium selenite. Treatments were fed for 28 d before steers were inoculated with IBRV (d 0) and were continued 21 d after the challenge. Treatments did not affect BW or DMI (P > 0.20) from 7 d before through 21 d after the challenge. Supplemental Se (P = 0.02) increased IBRV titer values on d 21. The IBRV challenge induced a febrile response; however, there were no treatment differences (P > 0.10) in rectal temperature. Total red and white blood cell counts, percentage of white blood cell types, and hemoglobin concentrations did not differ (P > 0.11) among the 3 treatments.

In Exp. 2, newly received, crossbred heifers (4 pens/treatment) were fed the same treatments as in Exp. 1, except selenite was supplied at 1 mg/heifer daily for 28 d. No treatment differences (P > 0.10) were observed for performance or health during Exp. 2. Results help to define the effects of Se supplementation and source on the immune response to viral infections in cattle.

INTRODUCTION

Bovine respiratory disease (BRD) is considered to have the most significant negative economic effects of any disease in cattle feeding production systems in the United States (Edwards, 1996; Gardner et al., 1999; Schmidt et al., 2006). Stressors that commonly occur during transport and receiving decrease disease resistance in young cattle (Chirase et al.,...
than 75% of the morbidity in North America contributes to the detriment of production, as well as the cost of treating BED, as well as the economic impact (McNeil et al., 2001). The economic impact of BED, as well as the cost of treatment, contributes to the detriment of this disease, which accounts for more than 50% of the mortality and more than 75% of the morbidity in North American feedlots (Gardner et al., 1999). In addition to backgrounding procedures that emphasize vaccination against viral and bacterial agents that contribute to BED, nutritional manipulation of the immune system to improve resistance, response time, and pathogen clearance holds promise for decreasing the negative effects of BED on the cattle feeding industry (Galyean et al., 1999; Duff and Galyean, 2007).

Our objective was to evaluate the potential roles that supplemental Se and the source of supplemental Se play in the viral component of the BRD complex. Because infectious bovine rhinotracheitis virus (IBRV) is acknowledged as an important agent in the development of BRD, our experimental model involved evaluation of metabolic and immune system responses to an IBRV challenge in Holstein calves, as well as measurement of health and production responses of beef heifers in a field-trial setting.

**MATERIALS AND METHODS**

**Experiment 1**

Animals. Thirty Holstein steers were received at the Texas Tech University Burnett Center research feedlot on March 30, 2007, after a 2-h transit from Clovis, New Mexico. On arrival, calves were given 5 mL (s.c.) of Micotil (Elanco Animal Health, Indianapolis, IN) and 2 mL (s.c.) of Triangle 4 + Type II BVD vaccine (Fort Dodge Animal Health, Fort Dodge, IA); a booster was given 14 d later. All calves were placed in a single, covered concrete-floor pen that provided shade and shelter.

Feed (basal diet; composition shown in Table 1) and sudangrass hay were delivered daily to provide 3.18 kg and 0.45 kg/animal, respectively. After 5 d, all calves were removed from the pen before feed delivery and taken to the working facility. Individual BW was recorded (149.7 ± 3.42 kg), a uniquely numbered tag was placed in the ear of each steer, and blood was collected by jugular venipuncture. Steers were stratified by BW, and the 4 heaviest and 2 lightest steers were excluded to decrease variation in BW, leaving 24 steers for the experiment (BW = 148.2 ± 2.79 kg). The steers were then assigned randomly to 1 of 3 treatments: 1) no supplemental Se (control); 2) supplemental Se supplied in the form of a Se-yeast product (0.2% Se premix; Sel-Plex, Alltech Biotechnology Inc., Nicholasville, KY); or 3) supplemental Se supplied in the form of sodium selenite (0.2% Se premix; Animal Science Products Inc., Nacogdoches, TX). Within treatment, steers were assigned randomly to 1 of 6 soil-surfaced pens (4 steers/pen with 2 pens/treatment; 0.9 x 3.05 m; 4.9 m of linear feed bunk space).

Steers were housed by treatment group in soil-surfaced pens and remained on the basal diet with no added Se for 21 d, after which dietary treatments were initiated. Initial (d −35) BW for the experiment was 170 ± 0.6 kg. Every 7 d (d −35, −28, −21, −14, −7, 7, 14, and 21 relative to an IBRV challenge), steers were taken to the working facilities, where an individual BW measurement was recorded and blood was collected via jugular venipuncture (blood collection procedures, equipment, and sample handling are described in a subsequent section). After receiving their assigned treatments for 21 d, steers were moved to individual stanchions (0.8 x 2.1 m) inside an enclosed barn. The barn was ventilated by fans and opened doors and was illuminated 24 h daily. Steers were assigned randomly to stanchions in the enclosed barn by first assigning steers within treatment to either the east or west side of the barn, and then within a side of the barn, assigning steers to stanchions (12 stanchions/side; 4 steers/treatment on each side of the barn). Stanchions were equipped with individual feeders and automatic water

**Table 1. Formulated ingredient and analyzed chemical composition (DM basis) of the diet in Exp. 1**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam-flaked corn</td>
<td>44.00</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>20.00</td>
</tr>
<tr>
<td>Cottonseed meal</td>
<td>17.00</td>
</tr>
<tr>
<td>Cottonseed hulls</td>
<td>10.00</td>
</tr>
<tr>
<td>Canola meal</td>
<td>4.00</td>
</tr>
<tr>
<td>Premix†</td>
<td>2.50</td>
</tr>
<tr>
<td>Fat (animal-vegetable blend)</td>
<td>2.00</td>
</tr>
<tr>
<td>Urea</td>
<td>0.50</td>
</tr>
<tr>
<td>Analyzed composition</td>
<td></td>
</tr>
<tr>
<td>DM, %</td>
<td>94.9</td>
</tr>
<tr>
<td>CP, %</td>
<td>16.6</td>
</tr>
<tr>
<td>ADF, %</td>
<td>21.3</td>
</tr>
<tr>
<td>Ca, %</td>
<td>0.71</td>
</tr>
<tr>
<td>P, %</td>
<td>0.33</td>
</tr>
<tr>
<td>K, %</td>
<td>1.30</td>
</tr>
<tr>
<td>Se, mg/kg</td>
<td>0.41</td>
</tr>
</tbody>
</table>

†Fed to all steers during pen feeding (d −35 through −8) and individual feeding (d −7 through −21) periods. Individual experimental treatment applied daily as ground corn-based top dress.

†Premix composition (DM basis): limestone = 42.1053%; cottonseed meal = 23.4676%; sodium chloride = 12.0000%; potassium chloride = 8.0000%; ammonium sulfate = 6.6667%; magnesium oxide = 3.5587%; dicalcium phosphate = 1.0363%; zinc sulfate = 0.8450%; Endox = 0.5008% (Kemin Industries, Des Moines, IA); Rumensin-80 = 0.6750% (17.4 mg/kg; Elanco Animal Health, Indianapolis, IN); Tylan-40 = 0.4500% (88.2 mg/kg; Elanco Animal Health); manganous oxide = 0.2667%; copper sulfate = 0.1572%; iron sulfate = 0.1333%; vitamin E (500 IU/g) = 0.1260%; vitamin A (1,000 kIU/g) = 0.0079%; ethylenediamine dithiodicarbamate (79.5%) = 0.0026%; cobalt carbonate = 0.0017%.
Table 2. Analyzed DM and Se concentration of treatment top dress fed to steers in Exp. 1

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Sel-Plex</th>
<th>Selenite</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM, %</td>
<td>86.8 ± 0.30</td>
<td>86.4 ± 0.65</td>
<td>86.3 ± 0.49</td>
</tr>
<tr>
<td>Se, mg/kg</td>
<td>0.16 ± 0.02</td>
<td>15.25 ± 1.75</td>
<td>67.35 ± 2.85</td>
</tr>
</tbody>
</table>

1 Fed at a rate of 50 g/steer (DM basis) daily.
2 Control = no supplemental Se; Sel-Plex = 1 mg/steer daily of Se from Sel-Plex (Alltech Inc., Nicholasville, KY); selenite = 5 mg/steer daily of Se from sodium selenite.

after feed delivery and gently combined in the feed bunk with the top layer of the basal diet. The feeding regimen was such that the steers were fed at slightly less than ad libitum, which facilitated complete consumption of the top dress. Equal quantities of feed were delivered to all pens daily during this period, and the average DMI from d -28 through -8 while steers were pen-fed (4 steers/pen; 2 pens/treatment) was 6.7 kg/d per steer. While in the enclosed barn, top dress treatments were delivered at approximately 0700 h, and complete consumption was enticed by mixing approximately 20 g (as-fed basis) of dark brown sugar into each dose. Treatments were the same as described above, but were delivered on an individual basis rather than a pen basis (50 g of ground-corn-based top dress DM/steer). Once the top dress was completely consumed, the basal diet was delivered in quantities sufficient to allow ad libitum consumption. Orts were minimized by basing the quantity of feed delivered on the actual individual intake from the previous day. After the challenge period, when steers were removed from the stanchions and placed in individual pens (described in a subsequent section), the treatment top dress was delivered similarly into concrete bunkers (individually fed) daily before feed delivery. A representative sample of each treatment top dress was taken from each batch and stored in a freezer for Se analysis (SDK Laboratories, Hutchinson, KS). In addition, representative samples of the basal diet were taken weekly for determination of DM and various chemical analyses, including Se (SDK Laboratories).

Performance. Feed bunk were cleaned daily, and orts were weighed and deducted from feed delivery records to determine actual feed intake. Individual BW were recorded on d -28, -21, -14, -7, -3, -1, 7, 14, and 21 relative to the IBRV challenge. A single-animal squeeze chute (C & S, Garden City, KS) set on 4 load cells (Rice Lake Weighing Systems, Rice Lake, WI) was calibrated (453.59 kg; certified by the Texas Department of
Agriculture) within 24 h of each use. Performance data were evaluated on a pen basis from d -35 through -8 because the steers were pen-fed during that time, but data were evaluated on an individual basis thereafter.

**IBRV Challenge.** After receiving their assigned treatments for 28 d, steers were administered a 4-mL dose (2 mL/nostril) of IBRV (Cooper Strain, Lot 00-22; titer value = 10^8.5 tissue culture infected dose_{50} per 2 mL; USDA-Animal and Plant Health Inspection Service Center for Veterinary Biologics, Ames, IA). To prepare the challenge dose, the virus was thawed (stored at -80°C in individual glass ampoules) on the morning of the challenge and diluted with PBS to 4 mL, after which the diluted contents of the ampoules were pooled. Viral doses were administered by use of a metal and glass atomizer (particle size 4 to 5 μm; Model 151, Sunrise Medical, Carlsbad, CA) connected to a nebulizer (207 to 241 kPa; DeVilbiss Plumo-Aide LT, Sunrise Medical) by a bleeder-type cutoff valve attachment (Model 633, Sunrise Medical). It was determined that 4 mL was delivered in less than 30 s; therefore, at the time of the challenge, each steer was restrained by halter, the atomizer was inserted into the nasal cavity, and the cutoff valve was closed to dispense the virus for approximately 15 s, after which the process was repeated in the opposite nostril. The atomizer was sterilized by thoroughly wiping with an isopropyl alcohol swab twice between steers.

**Blood Collection.** Blood was collected via jugular venipuncture (Vacutainer SST and Vacutainer EDTA, BD, Franklin Lakes, NJ) on d -35, -28, -21, -14, -7, -3, 7, 14, and 21 relative to the IBRV challenge. After blood collection, each tube was inverted 5 times and allowed to stand at room temperature for approximately 30 min. Tubes from which serum was to be harvested were stored on ice, and serum was separated by centrifugation (1,500 × g for 20 min) and then poured into plastic, screw-top containers (Fisherbrand 15-mL sterile, disposable centrifuge tubes, No. 05-539-1, Fisher Scientific, Pittsburgh, PA) and stored frozen until further analysis. Whole blood was transported at room temperature to the USDA-ARS Livestock Issues Research Unit located approximately 8 km from the Burnett Center, and each sample was evaluated for differential cell count (Cell-Dyn System 3700, Abbott Laboratories, Abbott Park, IL) within 2 h of collection. Remaining whole blood samples were stored in a freezer until analyzed for Se.

While jugular catheters were in place and patent (d 0; 0 h = immediately before administration of virus, and 4, 8, 12, and 24 h, and 3 d after the challenge), blood was drawn from the catheter line into Monovette blood collection tubes (EDTA and serum tubes, Sarstedt Inc., Newton, NC). At each sampling time, catheter lines were flushed with 2 mL of heparinized saline (20 IU heparin/mL), and approximately 5 mL of blood was drawn and discarded, after which 9 mL of blood was drawn into sample tubes. Finally, the catheters and extension lines were flushed with 5 mL saline and 3 mL heparinized saline. Typically, when catheters became nonpatent because of a collapsed line, they were replaced; however, on d 3, the sample from 1 steer in the sodium selenite treatment was collected by venipuncture because the catheters were to be removed on that day, and it would not have been sensible to replace the catheter at that time. After collection from the catheters, blood was handled as described previously. Steers were removed from the enclosed stanchion barn 7 d after the IBRV challenge and placed in individual concrete slotted-floor pens (2.9 m wide × 5.6 m deep between steers.

### Table 3. Formulated ingredient and analyzed chemical composition (DM basis) of the diets in Exp. 2

<table>
<thead>
<tr>
<th>Item</th>
<th>Diet 68</th>
<th>Diet 75</th>
<th>Diet 82</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredient, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam-flaked corn</td>
<td>40.15</td>
<td>47.10</td>
<td>54.05</td>
</tr>
<tr>
<td>Wheat hay</td>
<td>32.00</td>
<td>25.00</td>
<td>18.00</td>
</tr>
<tr>
<td>Sweet bran&lt;sup&gt;1&lt;/sup&gt;</td>
<td>20.00</td>
<td>20.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Supplement&lt;sup&gt;2&lt;/sup&gt;</td>
<td>3.50</td>
<td>3.50</td>
<td>3.50</td>
</tr>
<tr>
<td>Tallow</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
</tr>
<tr>
<td>Premix&lt;sup&gt;3&lt;/sup&gt;</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
</tr>
<tr>
<td>Urea</td>
<td>0.60</td>
<td>0.65</td>
<td>0.70</td>
</tr>
<tr>
<td>Analyzed composition, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>77.9</td>
<td>76.7</td>
<td>75.8</td>
</tr>
<tr>
<td>CP</td>
<td>14.6</td>
<td>15.8</td>
<td>14.4</td>
</tr>
<tr>
<td>ADF</td>
<td>15.7</td>
<td>15.1</td>
<td>10.8</td>
</tr>
<tr>
<td>Ca</td>
<td>0.73</td>
<td>0.75</td>
<td>0.81</td>
</tr>
<tr>
<td>P</td>
<td>0.52</td>
<td>0.54</td>
<td>0.50</td>
</tr>
<tr>
<td>S</td>
<td>0.22</td>
<td>0.23</td>
<td>0.21</td>
</tr>
</tbody>
</table>

<sup>1</sup>Sweet bran wet corn gluten feed (Cargill Inc., Blair, NE).

<sup>2</sup>Supplement composition (DM basis): limestone = 55.5144%; potassium chloride = 22.8571%; magnesium oxide = 7.6258%; salt = 8.5714%; cobalt carbonate = 0.0031%; copper sulfate = 0.1701%; iron sulfate = 0.4762%; ethylenediamine dihydroiodide (4.4%) = 0.0519; manganese sulfate = 0.5357%; zinc sulfate = 0.8048%; vitamin A (30 kIU/g, 90% DM basis) = 0.3429%; vitamin E (500 IU/g, 90% DM basis) = 0.5143%; mineral oil = 1.500%; sunflower meal = 1.0322%.

<sup>3</sup>Premix composition (DM basis): MGA 200 (441 ppm of melengestrol acetate; Pfizer Animal Health, Exton, PA) = 0.61%; Rumensin-80 = 1.125% (176.4 mg/kg, 90% DM basis; Elanco Animal Health, Indianapolis, IN); Tylan40 = 0.750% (88.2 mg/kg, 90% DM basis; Elanco Animal Health); sunflower meal = 97.52%.

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**Note:** All values are expressed on a DM basis.
with 2.4 m of linear bunk space) for a 21-d period after the challenge.

Rectal Temperature. During the time the steers were restrained for insertion of the jugular catheters, they were fitted with an indwelling, automatic rectal temperature (RT) recording device (Reuter et al., 2007; Reuter et al., 2008). Temperature probes were immersed in a common container of water for 1 h before attaching to the animal, and temperatures collected from the animals were corrected for differences among probes. Rectal temperatures were recorded at 5-min intervals beginning approximately 18 h before the challenge and continuing until 6 d (165 h) after the challenge.

Serum and Blood Analyses. As noted previously, whole blood was transported at room temperature, and each sample was evaluated within 2 h of collection for differential cell counts using the Cell-Dyn System 3700 (Abbott Laboratories). Serum was separated by centrifugation (1,500 × g for 20 min), poured into plastic, screw-top containers described previously, and stored frozen. Serum neutralizing antibody titers to IBRV were measured by a microtiter method using a constant dose of virus and various dilutions of serum (Texas Vet Labs, San Angelo TX).

Statistical Analyses. All data were analyzed as a completely random design with repeated measures in time using the MIXED procedure (SAS Institute Inc., Cary, NC). The appropriate covariance structure for each variable was determined by comparing Akaike's and Schwarz's Bayesian information criteria from the MIXED printout for compound symmetry, autoregressive (type 1), and antedependence covariance structures and selecting the structure that resulted in the minimal values for these criteria. Data collected before steers were placed in the individual stanchions were analyzed with pen (2 pens/treatment) as the experimental unit, whereas all data collected after the steers entered the barn (d -7 relative to challenge) were analyzed with steer (8 steers/treatment) as the experimental unit. For all variables collected on individual animals, the respective baseline value for each steer was included in the model as a covariate and retained in the model regardless of significance. Because of the error associated with the Se concentration of the selenite treatment, the 2 Se treatments were not compared. Thus, comparisons (determined using the PDff option in SAS when the treatment or treatment x sampling time interaction was significant; \( P \leq 0.05 \)) were limited to control versus Sel-Plex and control versus selenite. When the sampling time x treatment interaction was significant (\( P \leq 0.05 \)), orthogonal contrast statements were

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Table 4. Body weights and DMI of Holstein steers given either no supplemental Se or Se from either an organic complex (Sel-Plex) or sodium selenite and challenged intranasally with infectious bovine rhinotracheitis virus (IBRV) on d 0 of the study

<table>
<thead>
<tr>
<th>Item (^1)</th>
<th>Treatment (^2)</th>
<th>Contrast (^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Sel-Plex</td>
</tr>
<tr>
<td>Adaptation BW, (^5) kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d -35</td>
<td>171</td>
<td>170</td>
</tr>
<tr>
<td>d -28</td>
<td>178</td>
<td>180</td>
</tr>
<tr>
<td>d -21</td>
<td>190</td>
<td>195</td>
</tr>
<tr>
<td>d -14</td>
<td>203</td>
<td>204</td>
</tr>
<tr>
<td>d -7</td>
<td>207</td>
<td>210</td>
</tr>
<tr>
<td>BW before and after the IBRV challenge, (^5) kg</td>
<td>218</td>
<td>214</td>
</tr>
<tr>
<td>DMI before and after the IBRV challenge, (^5) kg/d</td>
<td>5.3</td>
<td>5.1</td>
</tr>
</tbody>
</table>

\(^1\) Days are expressed relative to the IBRV challenge.

\(^2\) Control = no supplemental Se; Sel-Plex = 1 mg/steer daily of Se from Sel-Plex (Alltech Inc., Nicholasville, KY); selenite = 5 mg/steer daily of Se from sodium selenite.

\(^3\) Pooled SE of treatment least squares means, \( n = 8 \) steers/treatment. Values for BW before and after the IBRV challenge are adjusted for baseline covariates.

\(^4\) P-value for contrasts. C1 = control versus Sel-Plex; C2 = control versus selenite.

\(^5\) Treatment average BW for the period during which steers were pen-fed (35 d pre-IBRV challenge through 7 d pre-IBRV challenge). For the times indicated, a treatment x day interaction (\( P < 0.001 \)) was detected.

\(^6\) Treatment average BW for the period during which steers were individually fed (7 d pre-IBRV challenge through 21 d after the IBRV challenge); no treatment x day of study interactions were detected for this period of the study, \( P = 0.64 \).

\(^7\) Treatment average of DMI for period during which steers were individually fed (7 d pre-IBRV challenge through 21 d after the IBRV challenge); no treatment x day of study interactions were detected for this period of the study (\( P = 0.88 \)). The average DMI from d -35 through -8 while steers were pen-fed (4 steers/pen; 2 pens/treatment) was 6.7 kg/steer per day. Equal amounts of feed were delivered to all pens to target slightly less than ad libitum intake.
evaluated within sampling days. Differential cell count data were missing for 1 steer in the control treatment at 12 h after challenge, but all other data were available for this steer at this time period. Within 12 h after returning to stanchions with RT probes attached, probes from 2 steers from the control group malfunctioned and were no longer usable. In addition, on d 5 at approximately 0800 h, 1 control steer, 2 Sel-Plex steers, and 1 selenite steer had nonfunctioning RT probes. To ensure that a daily RT measurement was available for analysis on these 6 steers, RT was measured manually and recorded once daily at approximately 1030 h through d 6.

**Experiment 2**

**Animals.** One hundred crossbred heifers (predominately British × Continental breeding; average arrival BW = 214 kg) were received on August 17, 2007, at the New Mexico State University Clayton Livestock Research Center. The heifers were purchased from an order buyer (Justice Farm, Bearden, AR).

On arrival, heifers were treated down the backbone for external and internal parasites with Noromectin (25 mL/heifer; Norbrook Pharmaceuticals, UK), vaccinated (s.c.) with a clostridial bacterin-toxoid (Vision 7 with Spur; Intervet, Millboro, DE) and treated with Micotil (Elanco Animal Health) at a rate of 10 mg/kg of BW (s.c.). Heifers were revaccinated with Titanium 5 (Agri Labs, St. Joseph, MO) and Clostridial 7 (Agri labs) on d 14.

**Diet and Treatments.** After processing, all heifers were fed a diet (Table 3) consisting of 68% concentrate for the first 20 d. Heifers were transitioned to 75% concentrate on d 21 and to 82% concentrate (Table 3) on d 28, with the quantity of NE offered held constant with that of the previous day at each step. Treatments consisted of 1) no supplemental Se (control); 2) 1.0 mg of supplemental Se/heifer daily from Sel-Plex (0.2% Se premix; Alltech Inc.); and 3) 1.0 mg/heifer daily of supplemental Se from sodium selenite (0.2% Se premix; Animal Science Products Inc.). The basal diet did not contain supplemental Se, and the treatments were provided in the form of a sunflower meal-based top dress (50 g of top dress/heifer; as-fed basis). A single batch of each top dress treatment was mixed for the entire experiment. Grab samples were obtained during delivery and stored in an airtight container for future analysis. Weekly diet samples were obtained from randomly selected feed bunk samples that were collected immediately after delivery to the feed bunk, but before the top dress was added. The DM content of these...
samples was determined by drying in a forced-air oven for 24 h at 100°C. Fresh samples were composited and stored frozen, and subsamples were sent to a commercial laboratory for proximate analysis (ServiTech Laboratories, Amarillo, TX).

Performance. Individual BW measurements were obtained without withholding feed or water. All animals were weighed individually before the morning feeding in a single-animal squeeze chute suspended from 2 load cells (Silencer, Moly Manufacturing, Lorraine, KS) on d 0 (initial processing), 7, 14, 21, 28, and 35 of the experiment. The scale was calibrated with 453.6 kg of certified weights before each scheduled weigh day. Daily DMI was calculated by subtracting dry weight of orts on d 7, 14, 21, 28, and 35 from the total quantity of dry feed delivered over the previous 7-d period. Efficiency of gain was calculated as the ADG divided by the average daily DMI over each measurement period.

Morbidity. Daily clinical monitoring of the heifers for BRD or other types of abnormalities was conducted by trained personnel at the same time every day. Because a metaphylactic antimicrobial was administered during arrival processing, a 2-d moratorium was imposed for therapeutic treatment of BRD. A standard animal health protocol was used, which included the following: 1) if an animal exhibited the specified criteria (respiratory anomalies, depression, etc.), it was pulled from the pen and moved to the processing facility for further evaluation; 2) at the processing facility, the animal was restrained in a squeeze chute and weighed, a rectal temperature measurement was obtained, and if warranted by clinical assessment, therapeutic treatments were administered; and 3) after treatment, as long as the ability to compete for food and water was evident, heifers were returned to their home pen. Therapeutic treatment for BRD consisted of a single dose (per label instructions) of tulathromycin (Draxxin, Pfizer Animal Health, Exton, PA) for the first treatment. If heifers required a second treatment, they were given florfenicol (Nuflor, Schering Plough, Union, NJ) per label directions.

Table 6. Serum neutralizing infectious bovine rhinotracheitis virus (IBRV) antibody titer values from Holstein steers given either no supplemental Se or Se from either an organic complex (Sel-Plex) or sodium selenite and challenged intranasally with IBRV on d 0 of the study

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Sel-Plex</th>
<th>Selenite</th>
<th>SE</th>
<th>Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titer, log2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d -35</td>
<td>4.6</td>
<td>3.4</td>
<td>7.1</td>
<td>0.90</td>
<td>0.31</td>
</tr>
<tr>
<td>d -14</td>
<td>5.8</td>
<td>7.0</td>
<td>7.1</td>
<td>0.62</td>
<td>0.15</td>
</tr>
<tr>
<td>d -7</td>
<td>5.4</td>
<td>6.7</td>
<td>6.5</td>
<td>0.62</td>
<td>0.15</td>
</tr>
<tr>
<td>d 0</td>
<td>5.1</td>
<td>5.3</td>
<td>6.0</td>
<td>0.62</td>
<td>0.79</td>
</tr>
<tr>
<td>d 7</td>
<td>6.4</td>
<td>6.9</td>
<td>6.6</td>
<td>0.62</td>
<td>0.57</td>
</tr>
<tr>
<td>d 21</td>
<td>7.9</td>
<td>5.9</td>
<td>5.9</td>
<td>0.62</td>
<td>0.02</td>
</tr>
</tbody>
</table>

1Control = no supplemental Se; Sel-Plex = 1 mg/steer daily of Se from Sel-Plex (Alltech Inc., Nicholasville, KY); selenite = 5 mg/steer daily of Se from sodium selenite.

2Titers were measured in serum collected on d -35, -14, -7, 0, 7, and 21 relative to the IBRV challenge. For the times indicated, a treatment x day interaction ($P = 0.06$) was detected.

3SE of treatment means, n = 8 steers/treatment. All values were adjusted for baseline covariates.

4P-value for contrasts. C1 = control versus Sel-Plex; C2 = control versus selenite.

Figure 2. Least squares means of serum neutralizing infectious bovine rhinotracheitis virus (IBRV) antibody titer values from Holstein steers given either no supplemental Se or Se from either an organic complex (Sel-Plex, Alltech Inc., Nicholasville, KY) or sodium selenite and challenged intranasally with IBRV on d 0 of the study. Pooled SE of the treatment means ranged from 0.60 to 0.62 over the sampling times. A treatment x day interaction ($P = 0.06$) was detected. All values were adjusted for baseline covariates.
RESULTS AND DISCUSSION

**Experiment 1**

**Diet and Treatments.** Ingredients and chemical composition of the basal diet and the top dress for the 3 treatments are shown in Tables 1 and 2. Chemical composition results for the experimental diet were within the ranges expected from formulation. The analyzed Se concentration of the basal diet (0.41 mg/kg of DM) exceeded the NRC (1996) recommendation for Se and thereby should have provided an adequate supply of Se for cattle in all treatment groups. The concentration of Se in the top dress samples for the 3 treatments averaged 0.16 ± 0.02, 15.3 ± 1.75, and 67.4 ± 2.85 mg/kg for the control, Sel-Plex, and selenite treatments, respectively. As a result of the unfortunate manufacturing error described previously, all comparisons made are based on treatments of either no supplemental Se, 1.0 mg of Se/d from Sel-Plex, or 5.0 mg of Se/d from sodium selenite. Thus, it is not possible to directly compare Sel-Plex with sodium selenite supplemented at an equal dose of Se.

**Performance Data.** Performance responses for the 3 treatments in Exp. 1 are shown in Table 4. Individual steer BW did not differ \((P > 0.50)\) among treatments at the beginning of the experimental period \((d -35)\). A treatment \(\times\) day interaction \((P < 0.01)\) was detected in BW for the period during which steers were penned \((d -35\) through \(-8)\). Steers that received Sel-Plex weighed more on \(d -21\) than steers that received no supplemental Se \((P = 0.01)\). During the period of individual feeding \((d -7\) through \(21)\) relative to IBRV challenge), BW did not differ \((P > 0.25)\) among the 3 treatment groups.

As noted previously, daily delivery of basal diet was the same (6.7 kg of DM/steer) for all pens during the period that the cattle were grouped in pens \((d -35\) to \(-8\) relative to the challenge). Once the cattle were moved from the group pens to individual housing, no treatment effects were detected for DMI either before \((d -7\) through \(0)\) or after \((d 1 \) through \(21)\) the IBRV challenge \((P > 0.25)\). Our results are consistent with previous research in steers (Droke and Loerch, 1989; Lawler, et al., 2004) and in cows and their calves (Gunter et al., 2003) that received supplemental Se, in which no effect of Se supplementation or source of Se was noted for animal performance.

**Rectal Temperature.** Treatment averages of RT peaked at 75, 82, and 155 h after the IBRV challenge, reaching 40.4, 40.1, and 40.1°C for control, Sel-Plex, and selenite steers, respectively (Figure 1). According to Aiello and Mays (1998), the incubation period of IBRV is typically 2 to 6 d.

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**Table 7.** Total red (RBC) and white (WBC) blood cell counts, percentage of WBC types, and hemoglobin (Hb) of Holstein steers given either no supplemental Se or Se from either an organic complex (Sel-Plex) or sodium selenite and challenged intranasally with infectious bovine rhinotracheitis virus (IBRV) on d 0 of the study

<table>
<thead>
<tr>
<th>Item (^{1})</th>
<th>Treatment (^{2})</th>
<th>Contrast (^{4})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Sel-Plex</td>
</tr>
<tr>
<td>RBC, million cells/μL</td>
<td>8.67</td>
<td>8.72</td>
</tr>
<tr>
<td>WBC, thousand cells/μL</td>
<td>10.85</td>
<td>11.46</td>
</tr>
<tr>
<td>NEU, %</td>
<td>39.60</td>
<td>42.42</td>
</tr>
<tr>
<td>LYM, %</td>
<td>51.02</td>
<td>48.14</td>
</tr>
<tr>
<td>MONO, %</td>
<td>10.05</td>
<td>7.51</td>
</tr>
<tr>
<td>EOS, %</td>
<td>1.08</td>
<td>1.36</td>
</tr>
<tr>
<td>BASO, %</td>
<td>0.35</td>
<td>0.37</td>
</tr>
<tr>
<td>Hb, g/dL</td>
<td>12.1</td>
<td>12.2</td>
</tr>
</tbody>
</table>

\(^{1}\) All blood cells were measured in fresh whole blood collected on d -35, -28, -14, -7, 0, 12, 1, 7, 14, and 21 relative to the IBRV challenge. No treatment \(\times\) day of collection interactions were detected \((P > 0.13)\). Neutrophils (NEU), lymphocytes (LYM), monocytes (MONO), eosinophils (EOS), and basophils (BASO) are reported as percentage of total WBC count.

\(^{2}\) Control = no supplemental Se; Sel-Plex = 1 mg/steer daily of Se from Sel-Plex (Alltech Inc., Nicholasville, KY); selenite = 5 mg/steer daily of Se from sodium selenite.

\(^{3}\) SE of treatment means, \(n = 8\) steers/treatment. All values were adjusted for baseline covariates.

\(^{4}\) P-value for contrasts. C1 = control versus Sel-Plex; C2 = control versus selenite.
and recovery usually occurs between 4 and 5 d after the onset of symptoms of the infection. Thus, the peak and duration of the RT in our experiment are typical of IBRV infection. The challenge model that was used in the present experiment is similar to models used to test the efficacy of a vaccine. The steers were previously vaccinated with an IBRV vaccine, which obviously allowed them to clear the virus without succumbing to the disease. Nonetheless, the RT data indicated that the challenge resulted in a significant febrile response. Based on visual observation of the changes over time, RT data were analyzed for the following periods: 0 to 165 h, -18 to -1 h, 0 to 48 h, 49 to 120 h, and 121 to 165 h relative to the IBRV challenge (Table 5). No treatment × day interactions were detected (P > 0.15), and although numerical differences in RT were evident (Figure 1), no statistical effects of treatment (P > 0.15) were detected for any of the time periods evaluated. Lack of treatment effects might reflect differences among the 3 treatment groups in baseline (18 h before challenge) RT, such that when baseline differences were accounted for in the statistical model, no treatment differences were detected. It is interesting to note that only in the Sel-Plex treatment did the average RT return to the baseline by 165 h after the IBRV challenge.

**Serum IBRV Titters.** Statistical analysis indicated a treatment × day interaction (P = 0.06) for serum IBRV antibody titers; therefore, titer values were evaluated by sampling day (Table 6). Providing supplemental Se either from Sel-Plex or selenite tended to increase (P > 0.13) IBRV titer values on d -14 but decreased (P = 0.02) titer values d 21. Figure 2 depicts the steep increase from a lower baseline in anti-IBRV antibody titers in the serum from steers that were receiving Sel-Plex from d -35 through -14, whereas the increases in titers in the control and selenite steers were more moderate. Titters in all groups increased from d 0 to 7 after the challenge, and although they decreased from d 7 to 21 in the Sel-Plex and selenite steers, titers in the control group continued to increase through 21 d after the challenge (Figure 2). Wright et al. (2000) reported no differences among a control, Se + vitamin E, Cu, or the combination of Se + vitamin E + Cu on antibody titers to IBRV. Conversely, Droke and Loerch (1989) reported an increase in anti-*Pasteurella hemolytica*-specific IgG serum titers in steers that were receiving 25 mg of Se + 340 IU of vitamin E through d 14 after a *P. hemolytica* challenge. In contrast to present results for d-21 titers in control versus Se-supplemented steers, no differences were noted between treatments for d-21 titers in the Droke and Loerch (1989) study.

**Complete Blood Cell Counts.** Statistical analysis of data from the differential cell count performed on whole blood on d -35, -28, -21, -14, -7, and 0 at 12 h after the challenge and on d 1, 7, 14, and 21 (Table 7) showed no treatment × sampling time interactions (P > 0.13) or any effect of treatment (P > 0.10) on red blood cell count (×10⁶ cells/μL), hemoglobin (g/dL), white blood cell count (×10⁶ cells/μL), or percentage of white blood cells that were neutrophils, lymphocytes, monocytes, eosinophils, or basophils. Present results for complete blood counts are similar to those reported by Wright et al. (2000), who also found no influence of Se (or vitamin E or Cu) on differential cell counts in immunologically stressed (as a result of weaning, transport, and handling) beef calves.

### Table 8. Heifer performance during a 35-d receiving period when given either no supplemental Se or Se in the form of either an organic complex (Sel-Plex) or sodium selenite

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment1</th>
<th>Control</th>
<th>Sel-Plex</th>
<th>Selenite</th>
<th>SE</th>
<th>P-value3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial BW, kg</td>
<td></td>
<td>214.1</td>
<td>210.3</td>
<td>215.0</td>
<td>1.89</td>
<td>0.08</td>
</tr>
<tr>
<td>d-35 BW, kg</td>
<td></td>
<td>258.7</td>
<td>254.7</td>
<td>261.0</td>
<td>1.72</td>
<td>0.36</td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td></td>
<td>1.47</td>
<td>0.91</td>
<td>1.28</td>
<td>0.16</td>
<td>0.54</td>
</tr>
<tr>
<td>d 0 to 7</td>
<td></td>
<td>1.47</td>
<td>-0.017</td>
<td>1.26</td>
<td>0.52</td>
<td>0.45</td>
</tr>
<tr>
<td>d 8 to 14</td>
<td></td>
<td>1.03</td>
<td>1.23</td>
<td>1.12</td>
<td>0.06</td>
<td>0.83</td>
</tr>
<tr>
<td>d 22 to 28</td>
<td></td>
<td>1.47</td>
<td>1.47</td>
<td>1.22</td>
<td>0.07</td>
<td>0.84</td>
</tr>
<tr>
<td>d 29 to 35</td>
<td></td>
<td>1.31</td>
<td>1.34</td>
<td>1.01</td>
<td>0.10</td>
<td>0.37</td>
</tr>
<tr>
<td>d 0 to 35</td>
<td></td>
<td>1.35</td>
<td>1.21</td>
<td>1.27</td>
<td>0.04</td>
<td>0.53</td>
</tr>
<tr>
<td>DMI, kg/heifer per day</td>
<td></td>
<td>1.87</td>
<td>1.68</td>
<td>1.57</td>
<td>0.09</td>
<td>0.40</td>
</tr>
<tr>
<td>d 0 to 7</td>
<td></td>
<td>3.85</td>
<td>3.38</td>
<td>3.54</td>
<td>0.14</td>
<td>0.47</td>
</tr>
<tr>
<td>d 15 to 21</td>
<td></td>
<td>4.87</td>
<td>4.66</td>
<td>4.49</td>
<td>0.11</td>
<td>0.32</td>
</tr>
<tr>
<td>d 22 to 28</td>
<td></td>
<td>5.49</td>
<td>5.17</td>
<td>5.17</td>
<td>0.10</td>
<td>0.26</td>
</tr>
<tr>
<td>d 29 to 35</td>
<td></td>
<td>6.14</td>
<td>5.74</td>
<td>5.90</td>
<td>0.11</td>
<td>0.46</td>
</tr>
<tr>
<td>d 0 to 35</td>
<td></td>
<td>5.81</td>
<td>5.45</td>
<td>5.55</td>
<td>0.11</td>
<td>0.31</td>
</tr>
<tr>
<td>G:F</td>
<td></td>
<td>0.338</td>
<td>0.239</td>
<td>0.360</td>
<td>0.037</td>
<td>0.51</td>
</tr>
<tr>
<td>d 0 to 7</td>
<td></td>
<td>0.174</td>
<td>-0.049</td>
<td>0.157</td>
<td>0.072</td>
<td>0.40</td>
</tr>
<tr>
<td>d 22 to 28</td>
<td></td>
<td>0.123</td>
<td>0.132</td>
<td>0.107</td>
<td>0.007</td>
<td>0.79</td>
</tr>
<tr>
<td>d 29 to 35</td>
<td></td>
<td>0.097</td>
<td>0.104</td>
<td>0.077</td>
<td>0.008</td>
<td>0.49</td>
</tr>
<tr>
<td>d 0 to 35</td>
<td></td>
<td>0.105</td>
<td>0.100</td>
<td>0.104</td>
<td>0.001</td>
<td>0.76</td>
</tr>
</tbody>
</table>

1Control = no supplemental Se; Sel-Plex = 1 mg/heifer daily of Se from Sel-Plex (Alltech Inc., Nicholasville, KY); selenite = 1 mg/heifer daily of Se from sodium selenite.

2SE of treatment means, n = 4 pens/treatment.

3P-value for the overall effect of treatment.
Table 9. Percentage of heifers requiring therapeutic treatment for bovine respiratory disease (BRD) during a 35-d receiving period while given either no supplemental Se or Se in the form of either an organic complex (Sel-Plex) or sodium selenite

<table>
<thead>
<tr>
<th>Times treated</th>
<th>Treatment</th>
<th>Contrast 1</th>
<th>Contrast 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Sel-Plex</td>
<td>Selenite</td>
</tr>
<tr>
<td>Once, before d 7</td>
<td>32.6</td>
<td>46.5</td>
<td>27.1</td>
</tr>
<tr>
<td>Once, after d 7</td>
<td>9.4</td>
<td>14.6</td>
<td>9.4</td>
</tr>
<tr>
<td>More than once</td>
<td>2.8</td>
<td>3.1</td>
<td>0</td>
</tr>
</tbody>
</table>

1Clinical monitoring of heifers for BRD or other types of abnormalities was conducted daily. Because a metaphylactic antimicrobial was used, a 2-d moratorium was imposed for therapeutic treatment of BRD. When an animal exhibited specified criteria (respiratory anomalies, anorexia, depression, etc.), it was removed from the pen, and its BW and rectal temperature were measured. If warranted by clinical assessment, therapeutic treatments were administered, after which heifers were returned to their assigned pen.

2Data were analyzed based on the number of therapeutic treatments required and the period (within or after the first 7 d after arrival) during which treatments for BRD occurred as follows: percentage of heifers requiring only a single therapeutic treatment for BRD and that treatment occurred within the first 7 d after arrival; percentage of heifers requiring only a single therapeutic treatment for BRD and that treatment occurred after the first 7 d; and percentage of heifers requiring more than a single therapeutic treatment for BRD and that treatment occurred at any time after.

3Control = no supplemental Se; Sel-Plex = 1 mg/heifer daily of Se from Sel-Plex (Altech Inc., Nicholasville, KY); selenite = 1 mg/heifer daily of Se from sodium selenite.

4P-value for contrasts. C1 = control versus the average of Sel-Plex and selenite; C2 = Sel-Plex versus selenite.

Experiment 2

Diet and Treatments. Ingredient and chemical compositions of the experimental diet are shown in Table 3, and as with Exp. 1, results were within the ranges expected from formulation. The concentration of Se in the top dress samples for the 3 treatments averaged 3.9, 34.8, and 39.4 mg/kg for the control, Sel-Plex, and selenite treatments, respectively.

Performance and Morbidity. Performance data for the heifers in Exp. 2 are shown in Table 8. At the beginning of the experiment, heifers in the Sel-Plex group tended (P = 0.08) to weigh less than heifers in the control and selenite groups. Nonetheless, as noted previously, initial BW was not a significant (P > 0.05) covariate, and no differences (P = 0.36) were observed among treatment for BW by d 35 of the study. Neither dietary Se supplementation nor source of Se influenced ADG, DMI, or G:F (P ≥ 0.26) for either the overall experiment (d 0 to 35) or any of the 7-d measurement periods therein. In addition, no treatment differences were detected (P ≥ 0.10) for heifer morbidity (Table 9). Generally, morbidity was low to moderate (average 35.4%), presumably reflecting the use of tilmicosin phosphate as a prophylactic treatment at the time of arrival processing.

As noted for Exp. 1, the finding of no major effects of supplemental Se or source of Se on performance responses in cattle is similar to most previous data regarding supplemental Se effects on performance. Gunter et al. (2003) reported no differences in cow BW, BCS, or DMI, or in calf BW, ADG, or mortality in a comparison of 26 mg/kg of Se (fed to cow before parturition) from either sodium selenite or Sel-Plex. Supplementation of Se (0.2 mg/kg; sodium selenite) to young calves (7 wk of age) did not influence DMI or BW gain (Reffett et al., 1988). Lawler et al. (2004) compared high-Se by, high-Se wheat, and sodium selenate with no supplemental Se in diets of finishing beef steers and found no differences in DMI, G:F, or ADG among treatments. More recently, Arthington (2008) reported no differences in BW gain by steers fed either no supplemental Se or 2.5 mg/d of Se from either Sel-Plex or sodium selenite for 90 d.

Implications

Supplementing basal diets that contained adequate Se with additional Se had minimal effects on BW changes, DMI, rectal temperature, and blood cell types in Holstein steers in an IBR challenge model and on performance and morbidity in newly received heifers in a feedlot setting. Although present data help to define responses to a virus challenge in cattle, further evaluation is required to determine whether dose or duration of Se supplementation influences immune status in stressed cattle to an extent sufficient to affect animal performance, overall health, and economic outcomes.

Acknowledgments

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LITERATURE CITED


