Effect of High-sulfate Water on Trace Mineral Status of Beef Steers

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Effect of High-sulfate Water on Trace Mineral Status of Beef Steers

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BEEF 2005 - 17

Summary

Two experiments were conducted to determine the effect of high-sulfate water on the performance, health, and mineral status of growing steers. The first experiment was conducted from June 20 to September 12, 2001, at the South Dakota State University (SDSU) Cottonwood Range and Livestock Research Station. Eighty-one crossbred steers (initial BW = 700 lb) were stratified by weight and randomly assigned to 12 dry-lot pens (6 or 7 steers/pen). Pens were then randomly assigned to one of three water quality treatments: 1) rural water (404 ppm sulfate), 2) well water (3087 ppm sulfate), and 3) stock dam water (3947 ppm sulfate). Steers were fed a diet consisting of grass hay and pelleted wheat middlings. The second experiment was conducted from May 23 to September 4, 2002, at the SDSU Cottonwood Range and Livestock Research Station. Eighty-four crossbred steers (initial BW = 640 lb) were stratified by weight and randomly assigned to 12 dry-lot pens (7 steers/pen). Pens were then randomly assigned to one of four water quality treatments: 1) 1000, 2) 3000, 3) 5000, and 4) 7000 ppm total dissolved solids. These treatment levels were created by mixing water of varying quality from three different natural sources. Steers were fed a diet consisting of grass hay and pelleted wheat middlings. In both experiments, initial and final liver biopsy samples were collected. Liver samples were analyzed for copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). In both experiments, initial liver Cu concentrations were not different between treatments. Provision of high-sulfate water reduced liver Cu concentrations in experiment 1 ($P < 0.01$) and 2 ($P < 0.01$). Liver Fe, Mn, Mo, and Zn were not affected by treatment. Results of these two experiments clearly demonstrate the dramatic impact that high-sulfate water can have on liver Cu stores in growing cattle.

Introduction

High-sulfate water is not a new concern for beef producers in the Upper Great Plains. Ranchers and cattle feeders alike have been dealing with water quality issues for quite some time. Previous research has clearly documented the detrimental effects of high-sulfate water on the health and performance of cattle (Weeth and Capps, 1972; Patterson et al., 2003; Patterson et al., 2004).

Previous research has also clearly documented the detrimental effects of dietary sulfur (S) and molybdenum (Mo) on the copper (Cu) status in sheep (Suttle, 1974) and cattle (Wittenberg and Boila, 1988). Minimal research has been conducted to examine the effect of high-sulfate water on the trace mineral status of beef cattle. Marked reductions in liver Cu have been observed in suckling calves, that, together with their dams, consumed water containing nearly 950 ppm sulfate (Cameron et al., 1989) and growing cattle consuming water formulated to contain 1500 ppm sulfate (Wright et al., 2000). In certain areas of South Dakota the sulfate levels of available water (surface or well) may be well in excess of 3000 ppm. These experiments were designed to determine the effect of high-sulfate water on the trace mineral status of growing steers.

Materials and Methods

Two experiments were conducted to determine the effect of high-sulfate water on the performance, health, and mineral status of growing steers. Performance and health data are reported elsewhere (Patterson et al., 2003; Patterson et al., 2004). The first experiment was conducted from June 20 to September 12, 2001, at the South Dakota State University (SDSU) Cottonwood Range and Livestock Research Station. Eighty-one crossbred steers (initial BW

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1 The authors acknowledge Dr. Connie Larson and Zinpro Corporation, Eden Prairie, MN, for financial support of this project.
2 Assistant Professor
Mineral concentrations in feed samples were analyzed using inductively coupled plasma-optical emission spectroscopy by Servi-Tech Laboratories, Hastings, NE.

Liver biopsies were collected from each steer on d 0 and 84 in experiment 1 and d 0 and 104 in experiment 2 using the true-cut technique described by Pearson and Craig (1980), as modified by Engle and Spears (2000). Following collection, samples were stored on ice during transport, then frozen and stored at -20°C prior to analyses. Ten liver samples per treatment (n = 30 in experiment 1; n = 40 in experiment 2) were randomly selected for trace mineral analysis. Frozen samples were then sent to Michigan State University Diagnostic Center for Population and Animal Health, Lansing, MI, for analysis of trace mineral concentration using inductively coupled plasma-atomic emission spectroscopy as described by Braselton et al. (1997).

Initial and final liver trace mineral concentrations and the associated change were analyzed as a completely randomized design using the Proc GLM procedure of SAS (SAS Institute, Cary, NC). Animal was used as the experimental unit. Significance was declared at \( P < 0.05 \).

**Results**

Liver trace mineral concentrations from experiment 1 can be found in Table 4. Initial liver copper concentrations were not different between treatments. However, steers that consumed well or dam water (3087 and 3947 ppm sulfate, respectively) had lower \( P < 0.01 \) final liver copper concentrations than steers that consumed rural water (404 ppm sulfate). Final liver iron concentrations were greater \( P < 0.01 \) in steers that consumed dam water compared to those that consumed rural water. Treatment had no effect on liver manganese, molybdenum, or zinc concentrations.

Liver trace mineral concentrations from experiment 2 can be found in Table 5. Initial liver copper concentrations were not different between treatments. However, steers that consumed water formulated to contain 3000, 5000, or 7000 ppm TDS had lower \( P < 0.01 \) final liver copper stores than steers that consumed water formulated to contain 1000 ppm TDS. Treatment had no effect on liver iron,
manganese, molybdenum, or zinc concentrations.

**Discussion**

In these experiments, consumption of high-sulfate water resulted in precipitous declines in liver 
Cu stores in growing cattle. In the first experiment, the steers had an average initial liver 
copper concentration of 78.9 ppm. This concentration would be considered adequate to 
marginally deficient (Puls, 1994). Cattle that consumed the high-sulfate water had liver 
copper concentrations of 26.3 and 35.2 ppm, concentrations that would be considered 
deficient (Puls, 1994).

In the second experiment, the steers had an 
average initial liver copper concentration of only 
35.8 ppm. This concentration would be 
considered borderline deficient (Puls, 1994). Cattle that consumed high-sulfate water had 
final liver Cu concentrations of 24.8, 7.7, and 6.5 
ppm. The dramatic effect of high-sulfate water, 
in the presence of dietary Mo, is clearly 
illustrated by these findings and agrees with 
previous research in growing cattle (Wright et 
al., 2000) and suckling calves (Cameron et al., 
1989). Provision of S and Mo as dry ingredients 
has also reduced liver Cu concentrations in 
growing cattle (Arthington et al., 1996).

The reason for the increase in liver Fe in the first 
year is unclear. It may be possible that the dam 
water contained higher levels of Fe; however, 
the Fe concentration in the water was not 
analyzed.

The lack of effect of high-sulfate water on the 
liver concentrations of other minerals is not 
unexpected. While the interactions of S, Mo, and 
Cu have been investigated extensively and 
clearly documented, interactions of S and other 
trace minerals analyzed in this experiment 
(manganese and zinc), have not been reported.

**Implications**

The dramatic effects of high-sulfate water on the 
health and performance of beef cattle has been 
clearly documented. However, while nutritionists 
have known for some time that high-sulfate 
water can interfere with Cu absorption and 
metabolism, only recently has the extent of that 
interference been documented. Producers in 
areas where high-sulfate water is prevalent 
should test their water sources routinely as part 
of their management strategy. Challenges 
associated with high-sulfate water can often be 
overcome with alterations to grazing 
management, water development, and 
appropriate supplementation strategies.

**Literature Cited**

Arthington, J. D., A. R. Spell, L. R. Corah, and F. Blecha. 1996. Effect of molybdenum-induced copper 
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sulfates in drinking water for growing steers. South Dakota State University Beef Report. Beef 
2004-05.

Pract. 61:233–237.


### Tables

**Table 1. Sulfate concentrations of water from different sources over time in 2001**

<table>
<thead>
<tr>
<th>Date</th>
<th>Rural</th>
<th>Well</th>
<th>Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 20</td>
<td>421</td>
<td>3165</td>
<td>3167</td>
</tr>
<tr>
<td>July 17</td>
<td>374</td>
<td>3096</td>
<td>3766</td>
</tr>
<tr>
<td>July 30</td>
<td>410</td>
<td>3174</td>
<td>3667</td>
</tr>
<tr>
<td>August 13</td>
<td>404</td>
<td>3120</td>
<td>4107</td>
</tr>
<tr>
<td>August 28</td>
<td>421</td>
<td>3044</td>
<td>4359</td>
</tr>
<tr>
<td>September 10</td>
<td>394</td>
<td>2920</td>
<td>4603</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>404</strong></td>
<td><strong>3087</strong></td>
<td><strong>3947</strong></td>
</tr>
</tbody>
</table>

*Adapted from Patterson et al. (2003).*

*ppm = parts per million.*
Table 2. Mineral composition of feed ingredients used in 2001 and 2002

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th></th>
<th>2002</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grass hay</td>
<td>Wheat middlings</td>
<td>Grass hay</td>
<td>Wheat middlings</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.82%</td>
<td>0.11%</td>
<td>0.89%</td>
<td>0.10%</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.24%</td>
<td>0.52%</td>
<td>0.17%</td>
<td>0.50%</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.17%</td>
<td>1.23%</td>
<td>0.12%</td>
<td>1.21%</td>
</tr>
<tr>
<td>Potassium</td>
<td>2.20%</td>
<td>1.45%</td>
<td>1.76%</td>
<td>1.25%</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.17%</td>
<td>0.22%</td>
<td>0.15%</td>
<td>0.20%</td>
</tr>
<tr>
<td>Copper</td>
<td>7.0 ppm</td>
<td>13.0 ppm</td>
<td>6.5 ppm</td>
<td>12.0 ppm</td>
</tr>
<tr>
<td>Iron</td>
<td>276 ppm</td>
<td>183 ppm</td>
<td>95 ppm</td>
<td>153 ppm</td>
</tr>
<tr>
<td>Manganese</td>
<td>59 ppm</td>
<td>166 ppm</td>
<td>54 ppm</td>
<td>153 ppm</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>4.9 ppm</td>
<td>1.4 ppm</td>
<td>3.4 ppm</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>23 ppm</td>
<td>108 ppm</td>
<td>22 ppm</td>
<td>101 ppm</td>
</tr>
</tbody>
</table>

*a ppm = parts per million.

Table 3. Actual sulfate concentrations of targeted water treatments in 2002a

<table>
<thead>
<tr>
<th>Target total dissolved solids, ppmb</th>
<th>1000</th>
<th>3000</th>
<th>5000</th>
<th>7000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfate</td>
<td>441</td>
<td>1725</td>
<td>2919</td>
<td>4654</td>
</tr>
</tbody>
</table>

*a Adapted from Patterson et al. (2004).
*b ppm = parts per million.
Table 4. Effect of poor quality water on liver mineral status in beef steers (2001)

<table>
<thead>
<tr>
<th>Source/sulfate</th>
<th>Initial</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural/404</td>
<td>Well/3087</td>
<td>Dam/3947</td>
</tr>
<tr>
<td></td>
<td>Rural/404</td>
<td>Well/3087</td>
</tr>
<tr>
<td></td>
<td>ppm</td>
<td>(DM basis)</td>
</tr>
<tr>
<td>Cu</td>
<td>81.0</td>
<td>70.2</td>
</tr>
<tr>
<td>Fe</td>
<td>268.0</td>
<td>281.0</td>
</tr>
<tr>
<td>Mn</td>
<td>9.1</td>
<td>8.5</td>
</tr>
<tr>
<td>Mo</td>
<td>3.1</td>
<td>2.9</td>
</tr>
<tr>
<td>Zn</td>
<td>96.1</td>
<td>107.9</td>
</tr>
</tbody>
</table>

<sup>a</sup>ppm = parts per million.<br>
<sup>b</sup>c Means within a row under one heading (e.g. Initial or Final) without common superscripts differ (<i>P < 0.01</i>).

Table 5. Effect of poor quality water on liver mineral status in beef steers (2002)

<table>
<thead>
<tr>
<th>TDS&lt;sup&gt;a&lt;/sup&gt;/sulfate</th>
<th>Initial</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000/441</td>
<td>3000/1725</td>
<td>5000/2919</td>
</tr>
<tr>
<td>1000/441</td>
<td>3000/1725</td>
<td>5000/2919</td>
</tr>
<tr>
<td>ppm&lt;sup&gt;b&lt;/sup&gt; (DM basis)</td>
<td>ppm&lt;sup&gt;b&lt;/sup&gt; (DM basis)</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>30.9</td>
<td>56.8</td>
</tr>
<tr>
<td>Fe</td>
<td>448.0</td>
<td>466.0</td>
</tr>
<tr>
<td>Mn</td>
<td>8.8</td>
<td>9.8</td>
</tr>
<tr>
<td>Mo</td>
<td>3.4</td>
<td>3.6</td>
</tr>
<tr>
<td>Zn</td>
<td>123.3</td>
<td>135.8</td>
</tr>
</tbody>
</table>

<sup>a</sup>TDS = target total dissolved solids.<br>
<sup>b</sup>ppm = parts per million.<br>
<sup>c,d</sup>Means within a row under one heading (e.g. Initial or Final) without common superscripts differ (<i>P < 0.01</i>).