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Effect of High-sulfate Water on Trace Mineral Status of Beef Steers[1]

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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 (3947ppm 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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= 700 lb), purchased from local auction markets, 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 four water quality treatments: 1) rural water, 2) well water, 3) stock dam water, and 4) stock dam water, then switched to extremely high-sulfate water late in the summer. Sulfate levels associated with each treatment can be found in Table 1. Since actual total dissolved solids and sulfate measurements were less than anticipated, treatments 3 and 4 were combined for analysis (total of 6 pens). From June 20 to July 19, steers were fed a diet consisting of grass hay and pelleted wheat middlings (14.3% CP, 0.38 Mcal/lb NEg DM basis). Mineral composition of the feed ingredients can be found in Table 2. On July 20 the proportions of grass hay and wheat middlings were altered to improve animal performance. From July 20 to the end of the experiment the diet contained 14.9% CP, 0.42 Mcal/lb, and 0.19% S. Cattle had *ad libitum* access to white salt. Supplemental minerals, including Cu, were not provided.

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), purchased from local auction markets, 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. Actual average sulfate concentrations of each targeted water treatment can be found in Table 3. Throughout the experiment, steers were fed a diet consisting of grass hay and pelleted wheat middlings (15.7% CP, 0.44 Mcal/lb NEg DM basis). Mineral composition of the feed ingredients can be found in Table 2. Cattle had *ad libitum* access to white salt and limestone (36% Ca) was top-dressed at a rate of 0.15 lb/hd/d; however, other supplemental minerals, including Cu, were not provided.

Water sulfate concentrations were determined using ion chromatography by the SDSU Water Resource Institute, Brookings, SD. Water sulfate concentrations from 2001 and 2002 are reported in Tables 1 and 3, respectively. Complete results from the water analyses are reported elsewhere (Patterson et al., 2003; Patterson et al., 2004). 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.

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Tables

Table 1. Sulfate concentrations of water from different sources over time in 2001[a]

	Water Source		
Date	Rural	Well	Dam
	---------- ppm[b] ----------		
June 20	421	3165	3167
July 17	374	3096	3766
July 30	410	3174	3667
August 13	404	3120	4107
August 28	421	3044	4359
September 10	394	2920	4603
Mean	404	3087	3947

[a]Adapted from Patterson et al. (2003).
[b]ppm = parts per million.

Table 2. Mineral composition of feed ingredients used in 2001 and 2002

	2001		2002	
	Grass hay	Wheat middlings	Grass hay	Wheat middlings
	---------- % of DM ----------			
Calcium	0.82	0.11	0.89	0.10
Magnesium	0.24	0.52	0.17	0.50
Phosphorus	0.17	1.23	0.12	1.21
Potassium	2.20	1.45	1.76	1.25
Sulfur	0.17	0.22	0.15	0.20
	---------- ppm[a] (DM basis) ----------			
Copper	7.0	13.0	6.5	12.0
Iron	276	183	95	153
Manganese	59	166	54	153
Molybdenum	4.9	1.4	3.4	
Zinc	23	108	22	101

[a]ppm = parts per million.

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

	Target total dissolved solids, ppm[b]			
	1000	3000	5000	7000
Sulfate	441	1725	2919	4654

[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)

Source/ sulfate	Initial Rural/ 404	Initial Well/ 3087	Initial Dam/ 3947	Final Rural/ 404	Final Well/ 3087	Final Dam/ 3947
	ppm[a] (DM basis)					
Cu	81.0	70.2	85.5	84.8[b]	26.3[c]	35.2[c]
Fe	268.0	281.0	304.0	257.7[b]	286.4[bc]	331.6[c]
Mn	9.1	8.5	8.8	10.0	10.7	11.3
Mo	3.1	2.9	2.9	3.2	3.1	2.9
Zn	96.1	107.9	113.5	84.6	89.8	94.0

[a]ppm = parts per million.
[b,c]Means within a row under one heading (e.g. Initial or Final) without common superscripts differ ($P < 0.01$).

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

TDS[a]/ sulfate	Initial 1000/ 441	Initial 3000/ 1725	Initial 5000/ 2919	Initial 7000/ 4654	Final 1000/ 441	Final 3000/ 1725	Final 5000/ 2919	Final 7000/ 4654
	ppm[b] (DM basis)							
Cu	30.9	56.8	27.4	28.7	56.8[c]	24.8[d]	7.7[d]	6.5[d]
Fe	448.0	466.0	437.0	470.0	364.0	280.0	317.0	418.0
Mn	8.8	9.8	9.9	9.8	8.9	9.9	9.9	9.6
Mo	3.4	3.6	3.7	3.8	2.9	3.3	3.2	2.9
Zn	123.3	135.8	128.3	146.8	83.7	88.9	85.0	131.3

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