PEER REVIEWED

Case Report–Sulfur-Induced Polioencephalomalacia in Beef Steers Consuming High Sulfate Water

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Abstract

Central nervous system disease occurred in a group of beef steers placed into confinement feeding pens during a period of prolonged drought and high environmental temperatures. The steers began exhibiting neurological signs during the third week after placement into the pens. Microscopic examination of brain tissue revealed lesions consistent with polioencephalomalacia. Tissue analysis for lead and evidence of water deprivation-sodium ion toxicity were negative.

The steers had been drinking well water containing 3000 ppm sulfate. In addition, the total mixed ration contained 2950 ppm total sulfur. Total sulfur intake was calculated to be 77 grams of sulfur per steer per day, which equated to 1% (10,000 ppm) of the ration on a dry matter basis. Based upon clinical signs, histopathology and high levels of sulfate and sulfur in the water and feed, respectively, a diagnosis of sulfur-induced polioencephalomalacia was made.

No further cases occurred after the steers were provided water with low sulfate content.

Résumé

Une maladie du système nerveux central est apparue dans un groupe de bouvillons de boucherie maintenus dans des parcs d'alimentation pendant une longue période de sécheresse et de températures élevées. Les bouvillons ont montré des signes neurologiques trois semaines suivant la mise en parcs. L'examen microscopique de tissu cérébral a révélé des lésions compatibles avec la polio-encéphalomalacie. L'examen des tissus pour la présence de plomb ou de signes d'intoxication aux ions sodium suite au manque d'eau se révélèrent négatifs.

Les bouvillons avaient bu de l'eau de puits contenant 3000 ppm de sulfate. De plus, la ration alimentaire contenait plus de 2950 ppm de soufre total. La prise totale de soufre a été estimé à 77 g par bouvillon par jour, soit l'équivalent de 1% (10 000 ppm) de la ration en matière sèche. Se basant sur les signes cliniques, l'histopathologie et la présence de soufre à des concentrations élevées dans l'eau et la nourriture, un diagnostic de polio-encéphalomalacie causée par le soufre a été fait.

Aucun autre cas n'a eu lieu lorsque les bouvillons ont été abreuvé avec de l'eau contenant une faible quantité de sulfate.

Introduction

Sulfur-induced polioencephalomalacia (PEM) results from excess sulfur consumption, including both organic and inorganic forms.[2-5,9,11,14-17,19] Consumption of water containing greater than 500 ppm sulfate, sulfur accumulating plants, and corn, barley, sugar and dairy by-products are common causes of sulfur-induced PEM.[14-16] Sulfur-induced PEM can also occur following exposure to fertilizer, elemental sulfur and manure gas.[1,6,7,10,12,20]

Water containing high levels of magnesium sulfate, often called gyp water, is common in the western plains and intermountain areas of the United States and Canada.[3,5] Ideally water for livestock consumption should contain less than 500 ppm sulfate, and 1000 ppm is considered the maximum safe level in water for cattle exposed to moderate dietary sulfur levels or high environmental temperatures.[18] Two-thousand (2000) ppm sulfate in drinking water is the taste discrimination threshold for cattle.[18] Performance of feedlot cattle is reduced when offered water with sulfate levels of 2000 ppm or higher.[12,20] The National Research Council (NRC) reports the requirement of sulfur in feed to be 1500 to 2000 ppm for both growing and adult beef cattle; 4000 ppm is considered the maximum tolerated dose.[13]

Signs of polioencephalomalacia caused by ingestion of lead, water deprivation or sulfur toxicosis are clinically and microscopically indistinguishable, but the cause can be differentiated by determining tissue lead and sodium levels.[3,16] Whole blood, liver and kidney are routinely analyzed for lead content. Brain sodium levels greater than 1800 ppm, elevated sodium levels in serum or cerebral spinal fluid, and an appropriate case history support a diagnosis of PEM caused by water deprivation-sodium ion toxicity.[3]

Gross brain lesions associated with PEM include fluorescence under ultraviolet light at 365nm, swelling and edema. The swelling can cause herniation of the medulla and cerebellum into the foramen magnum. The brain loses its turgidity, becomes soft to the touch, and flattening of the gyri of the cerebral hemispheres and yellowish brown discoloration is common. Bilateral laminar cortical malacia, with occasional hemorrhage, and varying degrees of cavitation are often visible.[8]

Microscopic examination of brain tissue reveals neurons in affected areas that are smaller than normal or missing. Astrocytes become acidophilic, swollen, and lose their processes, creating increased space between neurons. Spongiform degeneration is present and eosinophilic globules replace dead neurons. Blood vessels increase in size and the density of the macrophages increases. Astrogliosis is evident with healing.[8]

Clinical Report

During late September of 2000, a northwestern Oklahoma cattleman moved 100 steers (estimated weight 650 lb; 295 kg) from summer pasture to feeding pens because of prolonged drought and peak daily temperatures in the upper 90 to low 100°F range. The steers were vaccinated with a combination IBR, BRSV, PI_3, and BVD vaccine, a 7-way clostridial bacterin-toxoid and treated with an endectocide shortly after confinement.

Steers were offered a free-choice total mixed ration (TMR) comprised of 45% alfalfa silage, 10% alfalfa hay, 30% crimped wheat and 15% pelleted supplement (calculated to balance the protein requirement). Water was provided by two wells.

Three weeks after placement in confinement pens, three calves died and four others become ill within a 3-day period. Affected calves exhibited ataxia (Figure 1), anorexia, depression, mental dullness and blindness (Figures 2 and 3). Some steers stood statue-like, were reluctant to move and had fine muscle tremors involving the head and ears. They were examined by the owner and treated for clinical signs of polioencephalomalacia, without restraint, while loose in the pen. Others were found recumbent, unresponsive to external stimuli and died within 24 hours.

On the third day of the outbreak, two calves were presented to the Oklahoma Animal Disease Diagnostic Laboratory (OADDL) for examination and necropsy. Both calves had been treated with florfenicol[a] (9.1 mg/

Figure 1. A calf with polioencephalomalacia exhibiting ataxia. Note that the front legs are crossed.

Figure 2. A blind calf with polioencephalomalacia with no menace reflex.

Figure 3. A blind heifer with polioencephalomalacia that trapped itself in a feed trough.

lb; 20 mg/kg IM) and thiamine (4.5 mg/lb; 10 mg/kg IM) earlier that day. One calf died in transit, the other was recumbent at arrival. The surviving calf was afebrile, in sternal recumbancy with its head turned to its flank, and unresponsive to external stimuli. It exhibited bruxism, extreme mental dullness, appeared blind and lacked a menace reflex, but had sluggish palpebral and pupillary reflexes. No other clinical signs were present. Both calves were in excellent body condition and no signs of illness were evident until the morning of presentation.

Based on the clinical findings and history, the differential diagnoses included lead poisoning, water deprivation-sodium ion toxicity and sulfur-induced PEM. Sulfur-induced PEM was considered the most probable cause because of the environmental conditions and location of the premises.

A blood sample was collected from the live calf for blood lead analysis before it was humanely euthanized. Necropsy examination was performed on both calves. Lesions were limited to the brain in both calves, and consisted of softening and edema of the brain with flattened cerebral gyri (Figure 4). No other gross lesions were noted in either calf. No fluorescence was observed in either brain with ultra-violet illumination. The rumen pH values were normal at 6.55 and 5.89.

Fresh brain was collected for sodium analysis, liver and kidney were submitted to determine lead levels, and lung tissue was submitted for bacterial isolation. Brain, liver, kidney, lung and spleen samples were fixed in 10% formalin for histopathology. A feed sample and water samples from each well were analyzed for sulfur and sulfate levels, respectively.

Blood (<0.01ppm) and tissue (<0.01ppm) lead values were normal for both calves. Brain sodium levels of 1680 ppm and 1550 ppm were within normal limits. These tests ruled out lead and water deprivation-sodium ion toxicity as the cause of the illness. Even though the lungs appeared normal, cultures were taken as per lab protocol. Significant bacteria were not isolated from the lung.

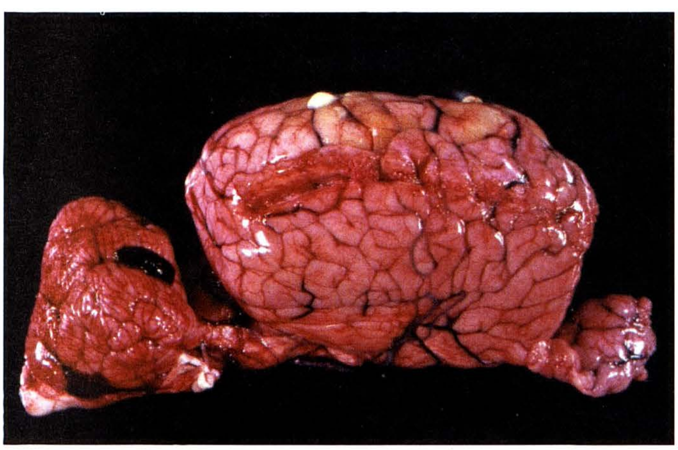

Figure 4. Swelling of the brain of a calf with polioencephalomalacia as grossly evidenced by flattened gyri and cerebellar coning.

Microscopic examination of the brain revealed deep cortical laminar spongiosis at the interface of the white and gray matter with perineural edema and extensive neuronal degeneration, which is diagnostic for PEM. No significant lesions were found in the liver, kidney, lung or spleen.

Well water samples contained 3000 ppm sulfate, the feed contained 2950 ppm sulfur.[b] These results supported a diagnosis of sulfur-induced PEM.

Discussion

The cattleman was advised to discontinue watering the cattle from wells and to provide low sulfate water. If not possible, he was advised to turn them back to pasture until significant rainfall occurred or to promptly ship them to a feedyard.

The owner stated that he had been providing purchased water to his livestock since a similar occurrence of PEM two years earlier. Environmental conditions at that time were very similar to those in late summer of 2000. In 1998, the same well water contained 2500 ppm sulfate. He had recently switched back to the well water because water purchased from the rural water district cost as much as $1000 per month. Neighboring cattlemen had convinced him that purchasing water was not necessary and too expensive.

Based on NRC guidelines, 30g of sulfur is the calculated maximum tolerated dose of sulfur for a 650 lb steer consuming 16.25 lb (7.39 kg; 2.5% of body weight) of feed daily. When the environmental temperature reaches 90°F (32°C), a 650 lb steer can drink 14.5 gallons (53.9 liters) of water daily.[13,18] Consumption of 14.5 gallons of water containing 3000 ppm sulfate results in a daily intake of 55g of sulfur. A 650 lb steer with daily feed intake of 2.5% of its body weight would also consume 22.2g of sulfur from feed containing 3000 ppm sulfur. The total daily intake of 77.2g of sulfur from both feed and water is 2.5 times the maximum tolerated dose, and equates to a total daily sulfur intake of 1% of the ration on dry matter basis. This illustrates that during very hot weather, the daily sulfur intake from high sulfate water alone exceeds the NRC's suggested maximum tolerance level. Ruminant diets normally contain between 1500 to 2000 ppm (0.15-0.20%) sulfur.[16]

A dramatic increase in PEM cases diagnosed at OADDL occurred because of prolonged drought conditions in the southern plains of the United States during the summer and fall of 2000. High sulfate levels in water from wells, natural springs and ponds have been associated with the higher incidence of PEM in stocker, feedlot and mature cattle.

Numerous samples of well water tested at OADDL have contained 2000 to 3000 ppm sulfate. One sample of well water in use for years contained 8000 ppm sulfate. Water from a natural spring in north-central Kansas that dried up because of drought contained 32,000 ppm sulfate, and water in a two-acre pond fed by this spring contained 8000 ppm sulfate. High sulfate water samples have been received by OADDL from Texas, Oklahoma, New Mexico, Colorado and Kansas.

The number of reported cases of sulfur-induced PEM has dramatically increased. One author theorized that cattle have become less tolerant to excess sulfur in their diets.[16]

Conclusions

High sulfate water poses a significant management problem to cattlemen, especially when drought and high temperatures persist. When these conditions exist, it is imperative that cattlemen know the sulfate content of the drinking water and the sulfur content of the feed. When cattle must consume water containing more than 500 ppm sulfate, supplemental feeds and mineral mixes should contain minimal amounts of sulfur.

Footnotes

[a]Nuflor, Schering-Plough Animal Health, Union, NJ
[b]Inductively Coupled Plasma Analysis

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