Integrated Livestock Management

Sulfur Intake in Cattle

Watching for Excess Sulfur Intake in Dairy Cows

Sulfur is an essential nutrient in cattle diets. Like many nutrients, however, it can be consumed at excessive levels that become harmful to the animal. The possibility that dairy cattle may be consuming too much sulfur has not received much attention, and so it is very reasonable that this nutritional issue can be routinely overlooked. Sulfur intake can occur from a variety of sources, and it requires a close look to determine what level of sulfur a herd is consuming. The purpose of this article is to draw your attention to this issue and encourage you to evaluate your herd's sulfur feeding. There is a very real possibility that you are limiting your cows' productivity by effects of high sulfur.

An Integrated Livestock Management research team, headed by Dr. Dan Gould, professor in Pathology at CSU, has been conducting research on effects of cattle sulfur intake for several years. The initial focus of these research efforts was on a brain disease of cattle known as polioencephalomalacia (PEM, polio, brainer cattle). This is a problem of the cerebral cortex that occurs suddenly and leads to blindness, abnormal behavior, severe depression, convulsions, and death. It is seen occasionally in individual animals, and historically has been attributed to problems with thiamine (a B-vitamin) metabolism. The disease can also occur as outbreaks of disease that affect several animals in a short time period. Dr. Gould and colleagues have demonstrated that a common cause of PEM is sulfur toxicity.

Initially, our sulfur research in herds of animals focused on cattle in the feedlot environment. These projects demonstrate that PEM is only one of the outcomes of excess sulfur intake. More commonly, lower sulfur intakes that do not produce clinical disease can substantially decrease animal performance. We also recognize this problem in range cattle. Research findings have clarified many aspects of how toxicity occurs, how the cattle respond to excess sulfur intake, and suggest that many dairy operations may have excess sulfur intake as well.

Effects of High Sulfur Intake

When dietary sulfur is consumed by ruminants it is reduced to sulfide by ruminal microorganisms. It can then be either incorporated into microbial protein or absorbed, converted to sulfate and excreted. If excessive sulfur is consumed, imbalances in ruminal microbial metabolism can occur, and excessive ruminal sulfide accumulates. Sulfide exists in the rumen in 2 forms. The soluble hydrosulfide anion is in the rumen fluid phase and hydrogen sulfide (H2S) gas accumulates in the rumen gas cap. H2S has the odor of rotten eggs.

Non-reduced forms of sulfur such as sulfate and elemental sulfur are relatively non-toxic, whereas H2S and its various ionic forms are highly toxic substances that interfere with cellular energy metabolism and cause tissue damage.

The adverse effects of excessive sulfur intake can vary. If sulfur intake is large, excessive rumen-generated sulfide can be absorbed in sufficient quantities to result in polio. The disease is characterized by blindness, staggering, inability to rise and sometimes, seizures. In our region, this severe form of sulfide toxicity is usually seen in feedlot and grazing beef cattle. But if dairy cattle consume sufficient sulfur, PEM will occur in dairy breeds as well.

Lower levels of ruminal sulfide can also produce adverse effects. Excess ruminal sulfide can depress ruminal motility Excess dietary sulfur can also result in secondary metabolic effects due to interference with other nutrients. Copper bioavailability is decreased by high dietary sulfur concentrations. This is probably due to the formation of copper sulfide and/or the thiomolybdate-copper complex. High sulfur intake conditions can result in conditions that lead to destruction of thiamin. Although severe thiamin deficiency states have not been demonstrated under high sulfur intake conditions, moderate thiamin deficits are possible.

Although the stimulus for the ILM research projects initially was PEM problems, it appears the more insidious problems are likely far more common and more important. With moderately high levels of sufur intake PEM may not occur, but animal performance can be affected. Such performance problems may attributed to another cause (heat stress, copper deficiency) while the potential role high sulfur has played goes unnoticed. Analysis of sulfur intake is required to identify this cause.

Calculating Sulfur Intake of Dairy Cattle

Courtesy of Drs. Dan Gould and Frank Garry

There are four basic steps to the calculation:

1. Analyze all feeds and estimate total feed intake,
2. Add sulfur contributions from supplements that may not be analyzed as part of the TMR,
3. Add the sulfur contribution from estimated water intake,
4. Express the sum of sulfur intakes as a % of total DMI

This assessment is relatively easy, but requires careful attention to the measurements and conversions between various analyses. When the estimated total sulfur concentration (TSC) has been calculated, it can then be compared to the maximum tolerable sulfur concentration. For dairy cows maximum tolerable TSC is recommended to be 0.26% to 0.4% on a dry matter basis.

To estimate sulfur concentration relative to DMI, contributed by water:

1. Determine the concentration of sulfate (SO4) in the water by laboratory analysis.

   Sulfate(SO4) concentration is usually expressed as mg/L.

   Milligrams per liter (mg/L) = part per million (ppm). Sulfate (SO4) is 1/3 sulfur (S), therefore milligrams of SO4/L divided by 3 = mg S/L of water.
2. Daily water intake of dairy cattle is influenced by many factors. An estimate of water intake in liters for lactating cows is = 16 + (1.6 X DMI in kg) + (milk production in kg) + (1.2 X minimum daily temperature in degrees C).

   A simpler estimate is 3.5 to 5.5 L water per kg of dry diet for temperatures up to 80 degrees F.

   A crude estimate of average water intake is 25 to 35 gallons per day = 95 to 135 L per day.

3. Liters of water intake multiplied by mg S/L = intake of S in mg. Divide by 1000 for intake of sulfur (S) in grams.
4. Daily dry matter intake = (1.85% X BW in lbs) + (0.3 X daily milk in lbs).

   Divide by 2.2 to get DMI in kg.

   % Sulfur (S) on DMI basis from water = total intake of S from water in grams divided by kg, DMI divided by 10.

To estimate sulfur concentration relative to DMI provided by feed:

1. Determine the concentration of sulfur (S) in the total mixed ration or individual diet ingredients.These are usually reported as % S as DM.
    - If a total mixed ration is analyzed, this is the value to be used as %S for feed.
    - If individual feed ingredients or forage components are analyzed, multiply the % as DM for each ingredient by the proportion of the diet it represents. Then add the proportionally adjusted sulfur concentrations for all the components. This sum is the %S of feed or forage.
2. In situations where individual's animals may consume more of a particular dietary ingredient selectively, dietary total sulfur concentration (TSC) may be elevated. Assessment of sulfur (S) content of each dietary component individually will help identify those that could increase TSC, if consumed selectively.
3. Be sure to include sulfur (S) contributed by feed additives used to adjust DCAD. If these are reported as sulfate (SO_4), remember to divide by 3 to calculate the actual sulfur (S) content.
4. To calculate the estimated total sulfur concentration (TSC) as a percentage of dry matter consumed: TSC = %S from water + %S from feed.

Assessing Potential Sulfur Intake Excess

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Sulfur is an essential component of certain amino acids, vitamins, hormones and sulfated polysaccharides. Sulfur is therefore a component of virtually all forages and concentrates. Cruciferous forages, such as turnip, rape, and oilseed meals are also rich in sulfur. The sulfur-containing amino acid content of the protein is probably the reason that protein rich forage such as alfalfa can contribute significant amounts of sulfur to the diet. Grasses tend to be low in sulfur, although under some circumstances grasses can accumulate high concentrations of sulfate. Certain weeds seem to be able to accumulate large amounts of sulfate if large amounts of sulfur are available in the soil. These weeds include Canada thistle, kochia and lambsquarter. Various combinations of these forages commonly explain some of the range cattle problems we have seen. Corn, molasses and sugar beet processing byproducts can be high in sulfur because sulfur-containing acidifying agents may be used in the process. Dairy cattle rations often include some of these high sulfur feeds.

One of the most important sources of dietary sulfur in our region is water. The sulfur occurs as sulfate salts. High water sulfate content is common in this region, but cannot be predicted solely on a geographic basis, requiring water analysis for proper identification. A recent national survey of water sources for beef cattle found 21% of samples exceeded the levels considered safe for all livestock. The accepted maximal safe water sulfate concentration is estimated at 300ppm. Water consumption by cattle is temperature dependent and increases greatly at high temperatures. In hot weather sulfur intake from water can be elevated due to increases in water consumption. Additionally, hot weather conditions also can result in evaporation which increases sulfate concentration.

As dairy rations increasingly include salts to modify the dietary anion/cation balance (DCAD), it is important to account for the amount of sulfate that some of these salts contain. Sulfate salts have been used in feedlot rations as intake limiting agents to minimize the risk of overfeeding. Since one of the effects of high sulfate intake is limited feed intake, this may explain some of the reduced performance seen in animals on high sufur diets.

This assessment requires estimation of total sulfur concentration (TSC) of dry matter consumed from all sources, including the contribution made by water. Many nutrient elements are assessed for total quantity of intake, such as grams/day or lbs/day. The minimal and maximal limits for sulfur intake are rather expressed as percent of intake, because the utilization and availability of sulfur are closely related to rumen microbial metabolism, and thus are related to total feed intake.

Many dairy ration formulations emphasize the use of legume forages and commodity feeds that are typically high in sulfur, and the ability to substantially reduce sulfur intake by feed modifications can be limited. Since some ground water has high concentrations of sulfate, water purification may be very beneficial for affected dairies. Although this article has focused on sulfur intake, other water impurities such as nitrate and nitrite can also affect dairy production. Water purification can be beneficial by removing multiple mineral contaminants.

Some Colorado dairies have indeed found production benefits from water purification. As an example on one dairy, water tested high for sulfate and a reverse osmosis purification system was installed. Estimated increased milk production per cow over the following year exceeded 3 lbs per day, and was sufficient to rapidly pay off the purification system. Whether this benefit was due entirely to reduced sulfate intake or the removal of several impurities was not specifically evaluated.

For cattle in general the maximum tolerable sulfur concentration has been estimated at 0.4% on a dry matter basis, and this estimate seems fairly accurate for tolerances in beef cattle in our research. Some researchers have suggested a lower maximum tolerable sulfur concentration of 0.26% for lactating dairy cattle. This is a question that needs to be studied more thoroughly. By estimating the TSC for your herd, based on measured sulfur content of all consumed nutrients, it is possible to evaluate potential hazards. Compared with all other farm animals, lactating dairy cows require the greatest amount of water in proportion to their size. Therefore high sulfate water can represent a substantial amount of sulfur intake in these animals. TSC is estimated by adding the % sulfur contributed by the water to the % sulfur contributed by the feed and all additives, all on a DM basis.