TECH NOTES

Dietary Sulfur in Ruminant Diets

Much of the recent interest in sulfur in beef cattle diets has focused on the potential negatives of excess S intakes. This attention has been driven largely by the increased use of sulfur-containing corn byproduct feeds, and by recognition of the additive effects of high sulfate water. However, as with most nutrients, while too much may be a problem, a certain level of consumption is absolutely necessary.

The role of sulfur

Technically, cattle don't have a requirement for sulfur, but many rumen microbes do. These bacteria utilize the sulfur that enters the rumen from feed and water in creating a range of compounds essential to their host. High on the list are the S-containing amino acids methionine, cysteine and cysteine, which are needed for forming microbial proteins, and are eventually utilized by the cow in multiple processes. Many familiar hormones contain sulfur (e.g., insulin, oxytocin, glucagon and ACTH). Sulfur is needed for both formation and function of multiple enzymes, and is a key component of structural materials such as collagen and chondroitin. Additional roles include bone formation, hemoglobin, energy metabolism, and function of the nervous system. Ruminal bacteria also incorporate sulfur into the vitamins thiamine and biotin, which become available to the host animal.

Sulfur supply

Most basic foodstuffs, including forages, contain sulfur as a component of the S-containing amino acids. Sulfur fertilization will increase the S level of plants; forages are 'luxury accumulators' of sulfur, meaning that, when available, they will continue to take up additional S beyond the level that can be used to support additional growth. Byproducts from processes that utilize sulfuric acid, including those from wet (gluten feed and corn steeps) and dry (distillers grains and solubles) milling of grain, can contain significant levels of sulfur. Liquid feeds provide moderate levels of dietary sulfur, from both molasses and direct inclusion of small amounts of sulfuric acid. In some environments, water can be a major, and even problematic, contributor to total sulfur intake. Excess sulfur is not stored, and salivary recycling is minimal (especially in low-protein diets), so a steady intake is required.

Unlike humans and other monogastrics, many species of rumen bacteria can utilize both organic and inorganic sulfur sources. Most incoming sulfur goes through appropriate conversions to hydrogen sulfide, which is utilized in formation of amino acids, proteins, vitamins, etc. Incorporation into these products can be limited by a shortage of other nutrients required by the microbes, such as nitrogen or energy (just as nitrogen incorporation into microbial protein can be limited by insufficient sulfur or energy).

Supplemental sources of sulfur include methionine, elemental sulfur, sulfates, and hydroxy methionine analogs. L-Methionine appears to be the most bioavailable, followed by D-L methionine and sulfates, then molasses, elemental S, and finally the analogs. It is estimated that sulfate-S is about 70% available in the rumen, compared to 60% of the S in molasses.

Sulfur requirements

The NRC minimum requirement for dietary sulfur is given as 0.15% of the diet, although some research has shown improved fiber, and in particular cellulose, digestion with higher S concentrations. In practice, microbial requirements may increase with:

- Mature and other low-quality (i.e., low protein) forages, especially if grown on S-deficient soils;
- Supplementation with a non-protein nitrogen source such as urea;
- High by-pass protein sources;
- High levels of the trace minerals copper, manganese and/or zinc;
- Sorghum forages (due to use of sulfur in metabolism of glucosides).

At the other end of the scale, the NRC gives the maximum tolerable concentration of dietary S at 0.3% for diets containing at least 85% concentrate, and significantly higher, 0.5%, for diets containing more than 40% forage. At higher levels, reductions in performance may be expected (see below).

Sulfur deficiency

Acute S deficiency is unlikely in typical production scenarios, but less than desirable sulfur intakes have been shown to reduce appetite, digestibility, microbial protein formation, gains, milk production, and efficiency. As early as the 1950's, researchers were demonstrating that limiting sulfur supply can alter rumen microbial populations, as well as reduce the total number of bacteria. Over the years, multiple research trials have demonstrated positive responses to sulfur supplementation (with low-S diets), including increased gains, improved efficiency, and reductions in lactate accumulation. It has been suggested (*VanSoest, 1994*) that NPN supplements have a S:N ratio near 1:12.

Excess sulfur

Most problems with excessive sulfur intakes can be linked to situations with high-sulfate water, high inclusion rates of ethanol by-products, and/or repeated use of sulfur-containing fertilizers. When the amount of S consumed from both feed and water exceeds the maximum tolerable concentrations given above, dry matter intake may be depressed and gains reduced. Some work suggests there may also be negative impacts on the immune system.

One topic that has received considerable attention is the potential for sulfur to inhibit availability or absorption of key trace minerals. Those impacted include copper, selenium, manganese and zinc; issues with Se and Cu are greatly magnified with high molybdenum levels. Research suggests antagonisms with Cu and Se may occur at S concentrations as low as 0.30 to 0.35% of the diet. Production responses at this level are unlikely, but because absorption of the trace minerals is impeded by the sulfur, animal stores of copper and selenium will begin to be utilized to make up any shortfalls. From a practical standpoint, this would not be of immediate concern as long as the animals are able to replenish these reserves once they return to a lower sulfur diet. A typical scenario might be supplementation with a high-sulfur feedstuff during a winter feeding period (resulting in utilization of some of the Cu and Se previously stored), followed by spring grazing with minimal supplement being fed (and natural return of stored Cu and Se to higher levels). Historically, a common response was to feed higher levels and possibly more available forms of these trace minerals when total sulfur intake was high, but Florida work has shown that this is not necessarily effective.

Excess sulfur has also been implicated in some cases of polioencephalomalacia (PEM), a potentially fatal condition. It has been hypothesized that a build-up of hydrogen sulfide in the rumen of feedlot animals has led to dangerous concentrations of this toxic gas escaping during eructation (belching), and subsequently being inhaled by the cattle.