



Sulfur in Distillers Grains for Dairy Cattle

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Sulfur is an essential element needed by animals for many functions. About 0.15% of body weight is sulfur. It is found in the amino acids methionine, cysteine, cystine, homocysteine, and taurine; in chondroitin sulfate of cartilage; and in the B-vitamins thiamin and biotin. Methionine, thiamin, and biotin cannot be synthesized in cattle tissues, so they must be supplied in the diet or synthesized by ruminal microbes. The sulfur content of most feed sources reflects the sulfur amino acid content of the proteins in the feed. See table 1 for example sulfur concentrations for various feed ingredients.

Table 1. Sulfur concentration of common feeds¹

Ingredient	% of DM	Ingredient	% of DM
Alfalfa	0.26	Fish mea	1.16
Barley	0.12	Linseed meal	0.37
Beet pulp	0.30	Grass hay	0.21
Blood meal	0.77	Meat & bone meal	0.39
Brewers grains	0.38	Oats	0.19
Canola meal	0.42	Safflower meal	0.32
Corn	0.10	Sorghum	0.11
Corn DGS	0.44	Soybean hulls	0.12
Corn distillers solubles ²	1.43	Soybeans	0.31
Corn germ ²	0.21	Soybean meal, solvent	0.42
Corn bran ²	0.75	Soybean meal, expeller	0.34
Corn gluten feed	0.44	Sunflower seeds	0.21
Corn gluten meal	0.83	Sunflower meal	0.39
Corn silage	0.14	Wheat	0.15
Cotton seed	0.23	Wheat middlings	0.18
Feather meal	1.39	Whey	1.15

¹ Nutrient Requirements of Dairy Cattle, 7th Ed., NRC (2001) unless otherwise indicated.

² Poet Nutrition, Sioux Falls, SD, May 2008.

The cow requires dietary sulfur primarily to provide adequate substrate for maximal ruminal microbial growth. Recommended dietary sulfur concentrations are 0.20% of diet dry matter for most dairy cattle (NRC 2001). Higher amounts (0.29%) are recommended for calves consuming milk or milk replacers. For efficient utilization of dietary nonprotein nitrogen, the dietary ratio of nitrogen:sulfur should be between 10 and 12:1. When supplementing with significant amounts of ruminally undegradable protein sources, this nitrogen:sulfur ratio may need to be checked on the ruminally degradable fraction to be sure that the rumen microbes' sulfur requirements are met.

The recommended maximal safe level of sulfur in diets is considered to be 0.4% of diet dry matter (NRC 1980), but that level is actually just an estimation that is not well substantiated in the literature; one may often feed in excess of that with no apparent problems. For instance, the sulfate ions added to diets of dry cows to decrease the ration cation-anion difference to help prevent milk fever often pushes dietary sulfur concentrations above 0.5%.

Excessive sulfur intake can interfere with the absorption of other elements, especially copper and selenium. Toxicity is more likely to occur with the sulfide than with the sulfate form of dietary sulfur. The odor of hydrogen sulfide, a rotten egg smell, may be an indication of excess sulfur in the diet. Some diarrhea may also occur with very high sulfur diets. In beef cattle, a few cases of polioencephalomalacia-like symptoms have been induced by feeding high sulfur diets; but no cases of sulfur toxicity have been reported in dairy cows. Consuming high-sulfur water (e.g., $\geq 1,000$ mg sulfur/L, i.e., $>1,000$ ppm as sulfur), which is approximately equivalent to adding 0.1% sulfur to the diet dry matter, may decrease water intake and milk production (NRC 2001). Feed intake of calves may be decreased by feeding three or more times the amount of methionine required, but decreased feed intake of older cattle with high sulfur diets is not documented.

Sulfur in distillers products has become a recent concern. When starch in corn is fermented to ethanol, other nutrients in the kernels are concentrated approximately three-

fold in the distillers grains with solubles (DGS). Therefore, the 0.1% sulfur in corn should translate to approximately 0.3% sulfur in DGS, which is close to the 0.44% sulfur listed in the dairy NRC (2001) for DGS. Such a level moves DGS into the low- to medium-end of sulfur levels found in some other common feeds (table 1). However, a recent survey of DGS from 40 ethanol plants in the Midwest (Univ. Minn. 2008) indicated an average of 0.7% sulfur with a range of 0.31% to 1.93% sulfur. Only a few values were above 0.8%; excluding those samples with very high sulfur only lowers the sulfur average from 0.7% to 0.6%. Also, a recent survey of five South Dakota ethanol plants (with two surveys per plant) indicated an average sulfur content of 0.53% of dry matter with a range of 0.31 to 0.82% sulfur. Thus, the industry norm for sulfur in today's DGS is greater than the 0.44% listed in the dairy NRC.

The extra sulfur in DGS is not from the corn. Most of it is likely from chemicals added during the processing to control pH and for cleanup. Such chemical sources of sulfur will usually be higher in the distillers solubles (often referred to as condensed distillers solubles or CDS) than in the distillers grains because the solubles fraction is where such compounds are originally collected. A recent survey indicated a range of 0.22 to 1.80% of dry matter as sulfur in the solubles, with average being typically higher than the average for DGS. Modified DGS also often contains more sulfur (e.g., 0.89 to 1.38%) than DGS because modified DGS often contains more than the proportionate amounts of solubles accounted for by the starting corn.

There are several reasons why DGS contains more sulfur than expected.

- Acids (especially sulfuric acid) used to control pH during the processing often contain sulfur.
- Acids used in the cleanup operation often contain sulfur. These chemicals usually become a portion of the "solubles" fraction of DGS. Such chemicals are likely cheaper than alternatives, which is the primary reason for their use, and are effective cleaning agents. Thus, the problem may persist unless ethanol plants take steps to decrease the amount of sulfur-containing agents used, or process those "cleanup solutions" in some manner such that they don't become a part of the DGS. At the least, ethanol plants should be encouraged to minimize the use of sulfur-containing cleanup agents.
- Water used in the ethanol plant may contain relatively high amounts of sulfur. For instance, there are several areas of the upper Midwest with high sulfur contents of the water. This is illustrated by a recent survey of well water used by some ethanol plants

(Pritchard 2008); the survey indicates 71 ppm of sulfate in Nebraska water, 122 ppm in Kansas water, 168 ppm in Iowa water, and 1007 ppm in South Dakota water.

- Inconsistency in the amounts of solubles added back to distillers grains to make DGS. Unfortunately for the users of DGS, varying the amount of solubles added back to the DGS is a major contributor to variation in the composition of the DGS, not just variation in sulfur but variation in other nutrients such as fat, protein, and phosphorus.

What to do if dealing with high sulfur diets. In most cases, one can formulate diets as usual without worrying about sulfur content of the distillers products. In our dairy cattle research at SDSU, we have fed diets containing as much as 40% of the diet dry matter as DGS or 20% as CDS with no problems. The diets were always below 0.4% of dry matter as sulfur and usually within the 0.2 to 0.3% sulfur range. This included times when the DGS fed contained as much as 0.9% sulfur (Anderson et al. 2006) or condensed distillers solubles that contained a very high 1.96% sulfur (Bharathan et al. 2008). One must remember that DGS is only one of many ingredients in the diet, and it is usually fed at 20% or less of the diet dry matter. Forages such as corn silage are usually low in sulfur. In fact, analyses of corn silage fed in our experiments usually contained less than the 0.14% sulfur listed in the dairy NRC (see table 1). Other ingredients often fed, such as alfalfa, corn, barley, oats, and wheat, are also low in sulfur. Water source is not usually a consideration unless one is in an area with high-sulfate water. Then, the water contribution may have to be considered.

A recent SDSU Beef Report (Ward and Patterson 2004) was conducted to test the response of growing steers to diets purposely containing near toxic levels of sulfur. The results indicated that feeding 1 g/head daily of thiamin virtually eliminated the incidence of polioencephalomalacia.

CONCLUSIONS

Sulfur is an essential mineral that must be included in the diets of cattle; however, feeding a great excess can be harmful to the animals. Distillers grains and associated coproducts such as CDS contain relatively high concentrations of sulfur, often more than is typically listed in reference tables, but still within the range of concentrations present in many other common feeds. One can usually formulate diets within the recommended range of 0.2 to 0.4% sulfur, even when dealing with high sulfur-containing distillers products. It is recommended that producers obtain sulfur content information when using DGS in diets of livestock.

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