Iowa Beef Center

ETHANOL COPRODUCTS FOR BEEF CATTLE

Sixth in a series of six ethanol coproducts publications from the Iowa Beef Center

Avoiding the Negative Effects of High Dietary Sulfur

During ethanol production, starch from corn is fermented to ethanol while the protein, fiber, and fat in the corn are concentrated into coproducts called distillers grains (DGS). Excess liquid from the fermentation process that contains corn oil and soluble protein is sometimes available as condensed corn distillers solubles (CCDS). These coproducts are a logical substitute for corn in beef feeding systems, as they are rich in protein and energy. In fact, the energy value of DGS in finishing diets is greater than corn when included at up to approximately 50% of diet dry matter (DM).

However, during ethanol production sulfuric acid is used for both control of pH in the fermenter and for cleaning purposes. This can cause these coproducts to have a high sulfur (S) content, which can be quite variable among ethanol plants and even vary from load to load within an ethanol plant. The maximum tolerable limit for S in beef cattle diets has been suggested to be 0.30% in diets containing greater than 85% concentrate, such as typical feedlot diets, and 0.50% in diets containing greater than 40% forage. Therefore, S is a major factor limiting the inclusion of ethanol coproducts in feedlot diets.

Sulfur Toxicity Is Caused by Ruminal Production of Hydrogen Sulfide

Increased S intake by feedlot cattle has been shown to decrease intake, decrease gain, and can lead to a neurological disorder called polioencephalomalacia (PEM), commonly referred to as "polio" or "brainers." When fed to ruminants, S is reduced to the toxic gas hydrogen sulfide (H_2S) by ruminal bacteria called sulfate reducing bacteria (SRB). The ruminal accumulation, eructation, and inhalation of large amounts of H_2S is thought to be the cause of these negative effects on performance and health (Figure 1).

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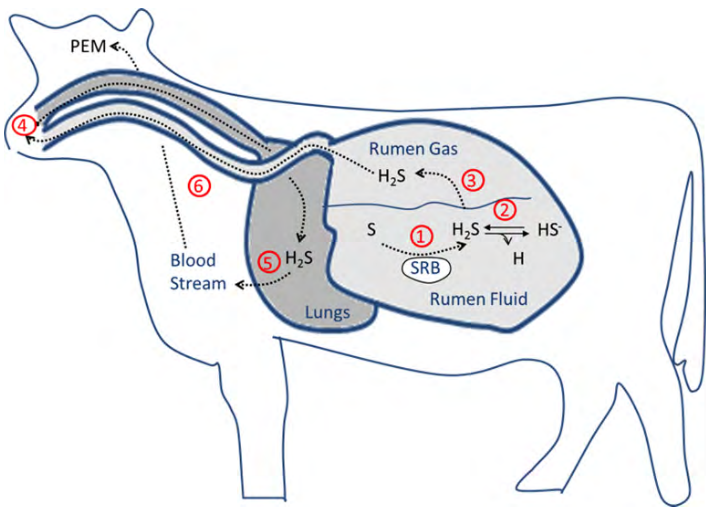
Figure 1. 1) Sulfur consumed by cattle is reduced to gaseous hydrogen sulfide (H_2S) by sulfate reducing bacteria (SRB). 2) Some of the H_2S will be converted to HS- (liquid). The amount that is converted to HS- and remains in the rumen fluid (to later be absorbed by the digestive tract and detoxified by the liver) is dependent on ruminal pH, with more remaining in the fluid at a greater pH. 3) H_2S that is not converted to HS- will mix with other gases in the rumen and 4) be expelled when the animal eructates (burps to relieve pressure in the rumen). Much (60%) of the gas that is eructated is inhaled by the animal, 5) entering the blood stream through the lungs and is circulated through the body, including to the brain, 6) H_2S that reaches the brain can cause cell death leading to PEM.



Low ruminal pH favors the formation of H_2S and increases the concentration of H_2S in the rumen. One reason why cattle that consume high forage diets have a greater tolerance for dietary S is because forage-based diets support greater ruminal pH.

Sulfur Content Affects Feeding Value of Coproducts

When considering cattle performance, DGS with lower S content are worth more than DGS with higher S content assuming fat and protein concentrations are similar between the two sources. When including DGS at 40% of diet DM, inclusion of DGS with 0.95% S instead of 0.70% S would result in a 0.10% increase in total dietary S. Data suggest this increase in S would decrease DM intake by 0.48 lb./day and average daily gain (ADG) by 0.08 lb./day, while an increase of 0.015 in feed-to-gain would be noted. However, due to the greater fat and protein content, cattle fed increased levels of DGS will have greater ADG relative to cattle consuming a corn-based diet without DGS, despite the increase in dietary S.

Consistent Coproduct Source Can Help Manage Risks Associated with Variability of Sulfur

Increasing inclusions of ethanol coproducts will increase risk of S toxicity due to the variability of S content in ethanol coproducts. Ideally, producers should test each load of coproducts before feeding it. Unfortunately, due to storage constraints this often is not feasible. Load-to-load variation of S within a plant typically ranges from 5% – 10% while the variation in S among ethanol plants is considerably greater. Some ethanol plants have DGS that typically contain 0.60% – 0.65% S while others may produce DGS with 0.90% – 1.00% S. Therefore, producers who want to include high levels of ethanol coproducts in their cattle diets should use a consistent source (ethanol plant) for these ingredients. Table 1 shows the calculated potential range of dietary S assuming within ethanol plant

Table 1. The range of dietary sulfur[1] in ethanol coproducts, assuming within plant variation of S

Sulfur (% of DM) expected in coproduct feed	Coproduct inclusion, % of diet DM				
	30	40	45	50	60
	Diet sulfur, % of DM[2]				
0.6 %	0.32-0.34	0.36-0.38	0.38-0.41	0.40-0.43	0.44-0.48
0.7 %	0.35-0.37	0.40-0.43	0.40-0.46	0.45-0.49	0.50-0.54
0.8 %	0.38-0.40	0.44-0.47	0.47-0.51	0.50-0.54	0.56-0.61
0.9 %	0.41-0.44	0.48-0.52	0.52-0.56	0.55-0.60	0.62-0.67
1.0 %	0.44-0.47	0.52-0.56	0.56-0.61	0.60-0.65	0.68-0.74

[1]Assumes no sulfur coming from drinking water
[2]Assumes a maximum of 10% variation of coproduct sulfur content

variation of 10%. Variation of some ethanol plants may be greater while others may be less. Thus producers using a consistent source may also want to track load-to-load variation. Using this information, producers can include a safety margin in their diet formulation to manage for this variability and reduce the risk of PEM.

Water Can Be a Significant Source of Dietary Sulfur

It is important to remember to include S from water sources in the calculation of total dietary S intake. Water in some parts of Iowa contains high levels (200 – 600 ppm) of sulfate (sulfate is 0.35% S). The S content of water can be highly variable and site-specific. Therefore, producers should have their water source tested before including increased levels of ethanol coproducts in their cattle diets. When calculating dietary S intake it also is important to account for the effect of environmental temperature on water intake, as increased water consumption during hot temperatures will lead to additional S intake (Table 2). Producers with high S water should be more conservative with their coproduct inclusion, especially during the summer months. The Iowa Beef Center has a calculator to determine total S intake at various environmental temperatures. This calculator can be found at http://vetmed.iastate.edu/sites/default/files/vdl/forms/SulfurCalculator.xls.

Table 2. Additional dietary sulfur intake from water at various sulfate concentrations and ambient temperatures.

Sulfate, ppm	Temperature, °F		
	40	70	90
	Sulfur from water[1], %		
200	0.02	0.03	0.05
300	0.03	0.04	0.07
400	0.04	0.05	0.10
500	0.05	0.07	0.12
600	0.06	0.08	0.14

[1]Add to % sulfur in diet to determine total dietary sulfur intake

Increasing Dietary Roughage Can Allow Increased Coproduct Inclusion

Independent research from University of Nebraska—Lincoln (UNL) and Iowa State University (ISU) has shown that the risk for S toxicity may be less when roughage levels in feedlot diets are increased. Researchers at UNL conducted a meta-analysis of their coproduct feeding studies and found that increasing roughage levels, described as amount of neutral detergent fiber (NDF) from roughage, in feedlot diets containing high levels of S will decrease risk of cattle developing S-induced PEM (Table 3).

Table 3. The predicted cases of polioencephalomalacia (PEM) over a 100-day finishing period at different concentrations of dietary sulfur and various amounts of roughage NDF included in the diet (DM basis)

Sulfur in diet, %	Roughage NDF			
	4%	6%	8%	10%
	PEM per 1000 head			
0.30	0.8	0.8	0.8	0.7
0.36	1.5	1.2	1.0	0.8
0.42	2.8	1.9	1.2	0.8
0.48	5.2	2.8	1.5	0.8
0.54	9.5	4.3	1.9	0.9
0.60	17.4	6.5	2.4	0.9

An ISU study showed that increasing inclusion of roughage NDF from 3.5% – 11.4% in a finishing diet (0.46% S) containing 39% ethanol coproducts decreased ruminal H_2S without affecting ADG. Because roughage substituted for corn in these diets it would be expected that gains would decrease or that cattle would increase intake to maintain energy intake. Feed intake by cattle in this study did not increase until roughage NDF inclusion reached 10.1% of the diet.

It is well known that ruminal conditions do not favor fiber digestion in corn-based finishing diets. However, there may be a synergy between DGS and roughage because DGS contains highly digestible fiber. Diets containing elevated levels of DGS and roughage may result in increased fiber digestion allowing cattle to obtain more energy from these feedstuffs.

While an increase in roughage NDF shows a decrease in ruminal H_2S and a corresponding decrease in the risk of developing PEM, these benefits may not be due strictly to an increase in ruminal pH. It seems likely that shifts in the microbial populations of the rumen and changes in eating behavior also contribute to this beneficial effect of increasing roughage NDF.

Roughage should be included to achieve a targeted level of roughage NDF. Lower quality roughages such as cornstalks (70% – 75% NDF) can be included at slightly lower levels than higher quality roughages such as grass hay (65% – 70% NDF) because they (lower quality roughages) contain more NDF. An inclusion of 5% cornstalks or 6% mature grass hay would equate to 4% roughage NDF, whereas an inclusion of 11% cornstalks or 12% mature grass hay would equate to 8% roughage NDF. These data indicate that producers should be able to increase dietary S levels up to 0.5% S when including 8% – 10% roughage NDF (12% – 15% roughage) in the diet. Increasing the level of S in the diet from 0.40% – 0.50% of the diet DM would equate to a 10% to 15% increase in the inclusion (DM basis) of DGS in the diet.

The Role of Management Practices in Preventing Sulfur Toxicity

In addition to increasing the roughage level in the diet, management strategies that help maintain a higher ruminal pH also may decrease the risk of S-induced PEM. Therefore, management strategies that limit the risk of acidosis may also be useful in reducing risk of S toxicity. Management that minimize the variation in intake across and within days, such as slick bunk management, consistent feed delivery, and/or increased feeding frequency, also may help decrease the risk of S toxicity.

Cattle Are Most Vulnerable to Sulfur Toxicity During the First 30 Days of Finishing

During the first 30 days on a full finishing diet, feedlot cattle consuming high S water or a high S diet appear to be the most susceptible to S toxicity. The increased incidence of PEM early in the feeding period coincides with a spike in ruminal concentration of H_2S. Research from ISU suggests that feedlot cattle consuming high dietary S appear to be most susceptible to S toxicity during this period. In one study, 2 of 48 steers (4%) receiving a high S diet (0.60% S), showed symptoms of PEM between days 23 and 28 on the finishing diet, corresponding to an observed spike in ruminal H_2S. No other incidences of PEM were noted in this study despite the fact that S intake increased later in the feeding period.

Researchers sampling rumen hydrogen sulfide gas

Steer experiencing symptoms (head pressing) of polio-encephalomalacia

The dramatic increase in ruminal H_2S concentrations that occurs when cattle are introduced to a high concentrate, high S diet may be due to a combination of factors such as decreased ruminal pH or increases in SRB numbers or their metabolism. Sulfate-reducing bacteria utilize lactate in their conversation of S to sulfide. Therefore, increased availability of lactate in the rumen during this period may allow SRB to increase their metabolic rate and produce more sulfide. Hydrogen sulfide concentrations appear to decrease later in the finishing period, which may be due to the establishment of the bacteria that utilize lactate and compete with SRB. Delaying the inclusion of high amounts of coproducts in the diet until after the rumen environment has adapted to a high concentrate diet (after the first 30 days) may decrease the risk of S toxicity.

Recommendations

1. Including greater levels of roughage and implementing management strategies that decrease the variability in feed intake and stabilize ruminal pH will help to decrease risk of S toxicity.
2. Good bunk management practices and the inclusion of 12% – 15% roughage in the finishing diet should enable producers to feed diets containing up to 0.50% S.
3. Cattle appear to be the most susceptible to toxicity during the first 30 days of consuming a high concentrate diet; therefore, delaying the inclusion of high levels of coproducts until after cattle are adapted to a high concentrate diet may decrease the risk of S toxicity.
4. Producers who want to include high levels of coproducts should use a consistent coproduct source (ethanol plant) to minimize the variation in S content, and should consider tracking the load-to-load variation to better refine the potential range of S content in their diets.
5. Increasing the level of S in the diet from 0.40% – 0.50% of the diet dry matter equates to a 10% – 15% increase in the inclusion (DM basis) of DGS in the diet.

Prepared by Mary Drewnoski, assistant professor of animal science, University of Nebraska—Lincoln, Dan Loy, professor of animal science, Iowa State University Extension and Outreach, and Stephanie Hansen, assistant professor of animal science, Iowa State University.

Illustration on page 2 by Mary Drewnoski, assistant professor of animal science, University of Nebraska—Lincoln.

Photos by Dan Loy, professor of animal science, Beth Doran, beef program specialist, Iowa State University Extension and Outreach, and Mary Drewnoski, assistant professor of animal science, University of Nebraska—Lincoln.

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For more information on ethanol coproducts for cattle, visit www.iowabeefcenter.org.

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