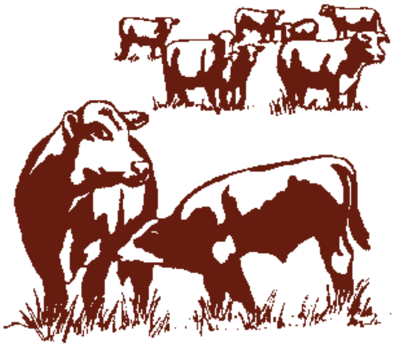

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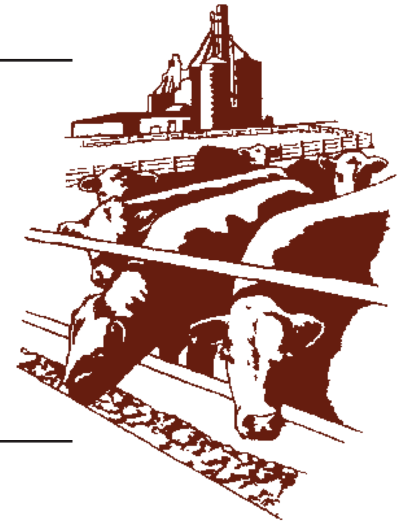

BCH-5610 Product of Extension Beef Cattle Resource Committee

Nitrates in Livestock Feed

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Drought conditions often result in poor pastures and reduced forage yields. Often producers wish to use barren or low-producing grain crops as replacement forage. These forages may be toxic due to high nitrate levels.

The problem of high nitrate feeds is not new. Reports of corn stalk poisoning, abortions caused by immature oat hay, and decreased milk production from feeding drought-damaged sorghum silage have all been attributed to the high nitrate content of the forage.

Nitrate itself is not particularly toxic to animals. Nitrates consumed by ruminants are normally reduced to ammonia and then absorbed and excreted as urea in the urine or converted by bacteria into bacterial protein. Nitrite, one of the intermediate products, is the cause of "nitrate poisoning." Some of the nitrate is absorbed into the blood, where it changes the hemoglobin to methemoglobin. Hemoglobin carries oxygen from the lungs to other tissues, but methemoglobin cannot carry oxygen. Nitrate becomes toxic when methemoglobin production is high enough that the oxygen-carrying capacity of the blood is reduced to a critical level. If enough methemoglobin is produced, that animal will die. The toxic level depends both upon how much and how fast nitrate was consumed.

Causes of High Nitrate in Forage

All plants contain some nitrate, but excessively high amounts are likely to occur in forages grown under stress conditions such as shading or low light intensity; detrimental weather like drought, frost, hail, or low temperatures, herbicide applications, and diseases. The amount of nitrate in plant tissue will also depend on:

1. Plant species — Plants like pigweeds, lambsquarters, oats, millet, sorghum, sudangrass, and corn are often high in nitrate, but other grasses and legumes can have excessive levels under extreme conditions.
2. State of growth — The nitrate level is usually higher in young plants and decreases as the plant matures.
3. Plant parts — Various parts of the plant contain different levels of nitrate. A Wisconsin study of drought-stressed corn found nitrate levels in plant parts as follows: total plant, 978 ppm nitrate nitrogen; bottom 1/3 stalk, 5,524 ppm nitrate nitrogen; middle 1/3 stalk, 803 ppm nitrate nitrogen; top 1/3 stalk, 153 ppm nitrate nitrogen; leaves, 64 ppm nitrate nitrogen, and ear, 17 ppm nitrate nitrogen.
4. Nitrogen fertilization — The level of nitrogen fertilization and the nitrate content of plants are directly related. This effect may be less important than previously listed factors.
5. Rain — In plants that survive drought, nitrates may be high for several days after a rain.

Harvesting Strategies for Drought-stressed Feed

Four general harvest recommendations can be made:

1. Harvest as silage. Proper fermentation can reduce the nitrate level of forages by 40 - 60 percent.
2. Harvest near maturity. As the plant matures, the nitrate level will go down.
3. Cut extra high. Nitrates tend to be concentrated in the lower part of the plant.
4. Don't cut immediately after a rain. Nitrate content of forages is high after a rain.

When ensiling high-nitrate feeds, wait until the plant dries to the proper moisture level before chopping (bunker or bags = 30 - 35 percent DM, conventional silo = 35 - 45 percent DM, oxygen limiting structure = 45 - 55 percent DM). Wait 2 - 3 weeks for fermentation to reduce the nitrate level (40 - 60 percent) before feeding. Do not add nonprotein nitrogen (NPN), since the feed will tend to be already high in soluble protein. A bacterial additive can be added to improve fermentation. Limestone (20 lb./ton) can extend the fermentation-converting nitrates under favorable conditions but it can also limit fermentation if feed is dry or low in fermentable carbohydrates.

When greenchopping high-nitrate feeds, introduce the feed gradually and in limited amounts initially to reduce the possibility of nitrate problems. Cut the feed high to avoid the nitrates concentrated in the stem. Avoid feeding greenchops for a few days after a rain because of the high nitrate levels.

When pasturing high-nitrate feeds, control initial intake by filling the cows with dry feed first. Cattle should be limited to a small area with an electric fence to minimize waste. Do not overgraze, because this will force cattle to eat the high nitrate lower part of the stalk. Feeding a poor-quality dry roughage may help performance. Cattle should be removed after a rain because of the increased nitrate level.

When haying high-nitrate feeds (in addition to the strategies discussed for greenchop), crush the forage stalks to get proper drying and storage. Many feeds will be better used if they are ground before feeding to avoid sorting.

Testing for Nitrate

The only way to determine if nitrates may be a problem is through testing. The diphenylamine test can be used as a field screen to determine if testing is necessary. The test solution consists of 0.5 g of diphenylamine dissolved in 20 ml of water. Add sulfuric acid to atotal volume of 100 ml. Cool the solution, store in a brown bottle, and keep refrigerated. Split the stem or stalk to expose the inside and add 1 - 2 drops of reagent to the cut surface of the plant. An immediate color change to intense blue or black is a positive reaction indicating more than two percent nitrate. Samples that react in this manner should be submitted for quantitative analysis at a laboratory.

Table 1. Methods of Expressing Nitrate and Nitrite Contents of Feeds and Water, Atomic Weights of the Various Substances, and a Conversion Factor.[1]

Nitrogenous substance	Chemical formula or designation	Atomic, molecular, or ionic weight	Multi-plication factors
Nitrate nitrogen	NO3-N	14	4.4
Nitrite nitrogen	NO2-N	14	4.4
Nitrite	NO2	46	1.3
Nitrate	NO3	62	1
Sodium nitrate	NaNO3	85	0.73
Potassium nitrate	KNO3	101	0.61

[1]To convert parts per million (ppm) to percent, divide by 10,000 (i.e., 1,500 ppm is 15%).

Proper sampling to ensure that a representative sample is tested is important. Fresh samples are needed because nitrates can break down. Many commercial laboratories will run a nitrate test for a minimal fee. Methods of reporting nitrates in feed are in Table 1, and Table 2 shows the nitrate content of some common feeds.

Other general feeding recommendations include:

1. Feed limited amounts several times daily rather than large amounts once or twice daily
2. Feed a balanced diet to ensure that no nutrients are deficient
3. Avoid feeding damp forages in which the nitrate may be converted to nitrite, which is more toxic

Table 2. Nitrate Content of Feedstuffs, Dry Basis.

	No. of analyses	Average nitrate (ppm)	Range in nitrate Low (ppm)	High (ppm)
Alfalfa				
Dehydrated	430	2,400	600	8,400
Hay	56	2,400	600	6,000
Silage	13	1,200	0	3,600
Beef pulp	2	36,00	3,000	3,600
Corn				
Green chop	11	7,800	1,200	17,400
Silage	66	4,800	0	26,400
Stalks	12	12,000	0	36,000
Kochia (fireweed)	4	2,400	0	3,600
Oats				
Hay	11	7,800	0	24,000
Silage	3	5,400	0	12,000
Pasture				
Bluestem	6	600	0	1,200
Bromegrass	19	4,800	600	13,200
Clover	3	3,000	1,800	4,800
Pigweed	7	26,400	2,400	48,000
Prairie hay	22	0	0	600
Sorghum				
Stalks (milo)	11	2,400	0	16,200
Silage	40	3,000	0	9,000
Sundangrass				
Green chop	16	15,600	1,200	28,800
Hay	12	3,000	0	19,800
Silage	2	1,800	1,200	2,400

Guyer and Flowerday (1969).

Pricing Drought-damaged Corn

Corn is a major forage source during a drought. The weight and dry matter (DM) content of the corn will determine its value. An exact value can be determined by weighing the corn and doing a dry matter analysis. When grazing corn or when it is not possible to weigh the corn, it may be necessary to estimate the amount of standing corn in a field. Drought corn with no ear will generally produce from 1 - 1.5 tons of 35 percent DM corn silage per acre for every foot that is harvested.

Short corn may produce one ton and tall corn may produce 1.5 tons per foot harvested per acre. For stressed corn with grain, you can expect to harvest one ton of silage per acre for each five bushels of corn grain per acre. For example, if you expect a grain yield of 50 bushels per acre, you can expect ten tons per acre of 30 percent DM silage.

A quick method of calculating the maximum value of drought corn silage is as follows:

Step 1. Calculate the value of normal corn silage using the equation (cost per bu of corn x 6) + harvesting costs = value per ton of 30 percent DM silage. The harvesting cost may vary from $6 - $10/ton depending on the yield and type of equipment used. Harvesting costs should not be included if the buyer harvests the corn. If corn is $3.50 per bu and the cost of harvesting is $6 per ton, the value of normal corn silage would be $27.

($3.50 per bu x 6) + $6 = $27 per ton silage

Step 2. Test the stressed silage to determine feed value or use an average value of 80 percent of normal silage. In this example, the 80 percent value would be $21/ton.

$27 per ton x 80% = $21 per ton stressed silage

Step 3. Adjust the value of the corn for the DM content (if it is known) by multiplying the price per ton of 30 percent DM corn by the actual percent DM and dividing by 30 percent. This will work for both silage and corn hay. If the DM content of corn hay is 90 percent, then the corn in our example is worth $63 per ton. If the DM content of silage is 40 percent, then it is worth $28 per ton.

($21/ton x 90% DM)/30% DM = $63/ton corn hay
($21/ton x 40% DM)/30% DM =
$28/ton 40% DM corn silage

Table 3. Guidelines for Nitrate in Feedstuffs (Express on 100 percent Dry Matter Basis in the Total Diet).

Nitrate content (%)	Comment
0.0 to 0.44	This level is considered safe to feed under all conditions.
0.44 to 0.66	This level should be safe to feed to nonpregnant animals under all conditions. It may be best to limit its use for pregnant animals to 50 percent of the total ration on a dry basis.
0.66 to 0.88	Feeds safely fed if limited to 50 percent of the total dry matter in the ration.
0.88 to 1.54	Feeds should be limited to about 35 - 40 percent of the total dry matter in the ration. Feeds containing over 0.88 percent nitrate should not be used for pregnant animals.
1.54 to 1.76	Feeds should be limited to 25 percent of total dry matter in ration. Do not use for pregnant animals.
over 1.76	These feeds are potentially toxic. Do not feed.

Using High-nitrate Forage

The levels of nitrate that can be fed before you can expect problems are listed in Table 3. Higher levels have been successfully fed in some cases, but the practice is risky.

Silage sample should be taken after fermentation is complete (3 weeks), because proper fermentation will decrease the nitrate content by 40 - 60 percent.

Nitrates in Water

Normally, water sources of nitrates will not cause problems (Table 4). However, high feed levels with elevated water levels contribute to the total nitrate load on an animal. Well water is usually safe. Nitrate toxicity from water is most likely to occur when livestock drink water from ponds, road ditches, or other surface impressions (drainage from feedlots, fertilized fields, silos, or manure disposal lagoons). Immature ruminants are more susceptible to nitrate toxicity. Water (aqueous solution) sources are more dangerous (almost twice) than food sources in causing toxicity. Nitrites can be found in water, but the level is usually below 1 - 2 ppm (maximum level is 50 ppm of nitrite nitrogen). Dirty water troughs with microbial growth can convert nitrates to nitrites, but this effect is small.

Feeding Drought-stressed Corn Silage to Beef Cattle

The nutrient content of the silage should also be analyzed. Drought silage will generally have 80 percent (65 to 95 percent) the energy value of normal corn silage. A laboratory test for acid detergent fiber (ADF) will reflect the altered energy content, which is the key nutrient variable. Total digestible nutrients (TDN) is a common measure of energy that can be calculated from ADF as follows:

Table 4. Guidelines for Nitrites in Water

ppm of NO3	Estimated effect
0 to 44	Not harmful
45 to 132	Slight possibility
122 to 220	Risky, especially over long period
221 to 440	Interference syndrome likely
441 to 660	More serious, possible acute losses
661 to 880	Increased, acute losses, secondary diseases
881 and over	Heavy acute losses

TDN = 87.84 - (.7 x % ADF)

The calcium and phosphorus levels of drought silage may be lower than normal silage. Analyze for these minerals and supplements accordingly. It is important that all types of cattle be supplemented with calcium, phosphorus, vitamin A, trace minerals, and salt. Drought silage is generally adequate in protein and energy for beef cows in all stages of production.

The protein level of drought silage is generally higher than normal silage. Unfortunately much of this protein is in the form of nonprotein nitrogen (NPN). It can be used by cows and feedlot cattle, but it is of limited use for young cattle (under 600 pounds) and dairy cattle.

Drought silage can be used by stocker cattle including replacement heifers. Nebraska research indicates that feeding drought silage results in about 0.2 lb per day less performance with stocker cattle. The research also showed that soybean meal supplementation improved performance 0.3 lb per day on drought silage and 0.2 lb per day on normal silage. This was observed despite the higher protein content of the drought silage. For this reason, natural protein should be supplemented to drought silage and urea or ammonia should not be added at harvest. Corn can be added to drought silage, but increases in performance may be less than expected due to negative associative effects.

Finishing cattle can use drought silage as a roughage source at 10 - 20 percent of the diet dry matter. Intermediate mixtures of grain and drought-damaged silage should be avoided once the cattle are adapted to the finishing diet. These mixtures will not give the expected performance due to negative associative effects. It may be beneficial to grow cattle longer on a drought silage diet before the finishing phase if a producer wants to use more drought silage.

Feeding Drought-stressed Corn Silage to Dairy Cattle

Three types of drought-stressed corn silage were harvested by Midwest dairy producers in 1988. Some corn was stressed in an early vegetative stage, resulting in short corn that was high in energy and low in fiber. A second type was normal corn (in height), but little or no grain formed because of heat-stress at pollination. This type of silage was high in fiber and low in energy. The third type was short corn with small to average-sized cobs. The energy content was above normal because the cob-to-stalk ratio was actually higher than normal corn. All three forms of silage performed satisfactorily if ration adjustments were made (see the section on beef cattle).

Milk yields were not reduced when cows received rations containing over 1.8 percent nitrate in Washington studies. Lower milk yields usually are attributed to changes in nutrient level, feed, dry matter intake, or water consumption.

Reproductive changes due to nitrate are difficult to repeat under controlled conditions. Abortions have been reported in the field. Recent Georgia work with lactating cows found rations containing 1,600 ppm in the total ration dry matter caused open and early pregnant cows to have lower levels of serum progesterone (3 - 6 ng per ml) than mid-pregnant cows or cows on a low nitrate diet (6 ng per ml). Low pregnancy rates are associated with levels below 1 ng per ml. Nutrient imbalances must be considered.

Young animals are more susceptible to nitrates than older animals with functioning rumens. Calves receiving milk replacer will be susceptible to high nitrates in water.

Nitrate Toxicity

Nitrate poisoning can be rapidly fatal. When nitrate poisoning is suspected, a veterinarian should be called immediately to confirm the tentative diagnosis and to start treatment. Since death comes from oxygen insufficiency, cattle should be handled as little and as quietly as possible to minimize their oxygen needs. Veterinarians use one or more of the following treatments:

1. Methylene blue (1 - 4 percent solution at the rate of two grams per 500 pounds of body weight) injected intravenously to convert methemoglobin to hemoglobin. This should be repeated as absorption of nitrate will continue from the full rumen.
2. Oral mineral oil to speed elimination.
3. Purging with saline cathartics such as Epsom salts.
4. Antibiotics and 3 - 5 gallons of cold water by stomach tube to control the rumen bacteria that convert nitrate to the very toxic nitrite.

Nitrate levels from 15 - 45 grams per 100 pounds of body weight are considered toxic levels of nitrate from feed and water sources. Nitrite is ten times more toxic than nitrate, while water sources are more rapidly available than feed sources.

Acute Toxicity

In the non-acclimated cow, acute poisoning can occur as soon as 1/2 - 4 hours after abrupt feeding of high-nitrate feed or water or combination. Symptoms may not develop until 3 - 4 days after daily feeding of moderate nitrate feedstuffs. Symptoms appear when 30 - 40 percent of the hemoglobin has been converted to methemoglobin, with death occurring at 70 - 80 percent methemoglobin levels. Respiratory distress, incoordination, weakness, muscle tremors, and collapse occur. Forced movement may trigger the onset of symptoms. Terminal convulsions due to suffocation occur in untreated animals in 12 - 25 hours. Mucous membranes appear gray (cyanotic) or dark brown. Recovered animals may abort. Common toxicants that may be confused with nitrates and nitrites are silo gases (slight brown-colored blood), cyanide (cherry red), carbon dioxide (dark blue), and carbon monoxide (bright red).

Chronic Toxicity

Subacute, or chronic nitrate poisoning was described in the 1950s as causing poor growth, abortion, repeat breeding, vitamin A deficiency, goiter, and increased susceptibility to infection. Such problems may occur when high-nitrate forages or water are fed to animals in poor condition, but controlled experiments with well-fed animals failed to substantiate nitrate as the specific causative agent. Drought-damaged high-nitrate feeds have a high nonprotein nitrogen value and elevated crude protein value, but reduced by-pass protein. Carotene is lower in drought-stressed corn silage than n normal corn silage, because the amount of grain is markedly lower. Problems attributed to chronic nitrate toxicity may in reality be due in part to nutritional deficiencies.

Human Toxicity

When silage is made from high-nitrate forage, toxic gases (oxides of nitrogen) are produced the first few days of fermentation. These pungent, yellowish-brown gases are heavier than air. They may travel down a chute or duct and collect in poorly ventilated buildings in sufficient concentration to kill humans and livestock. Always run the blower for five minutes before entering a silo that is being filled or was recently filled. A second person should remain outside to provide help in the event of an emergency. Throat irritation may be the first symptom observed. Death may occur after as little as 30 minutes exposure to the oxides.

Management Guidelines

for High-nitrate Feeds and Water

1. Leave drought-damaged feeds in the field as long as practical since nitrate will diminish as plants mature.
2. Cut suspected forages at higher than usual heights to avoid the higher nitrate-containing portions of the stalks.
3. Avoid use of drought-stricken forage for 3 - 5 days after a rain.
4. Control weeds closely to avoid nitrate from weed sources.
5. Regulate the intake of nitrate feeds so that small amounts are fed initially and increases are gradual.
6. Run an analysis on suspect feed to determine nitrate level.
7. Feed a balanced nutrient ration, high in energy and undegradable protein and supplemented with vitamin A and iodized trace mineral salt.
8. Avoid changes in forage ration and other situations that may impair rumen function.
9. Observe good herd health practices. Healthy animals are better able to handle nitrates.
10. Avoid unnecessary handling and excitement of animals during feeding of high-nitrate feeds.
11. Check water as a source of nitrates.
12. Avoid mold formation in high-nitrate forages that can convert nitrates to nitrites.

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This publication was prepared in cooperation with the Extension Beef Cattle Resource Committee and its member states and produced in an electronic format by the University of Wisconsin-Extension, Cooperative Extension. Issued in furtherance of Cooperative Extension work, ACTS of May 8 and June 30, 1914.

BCH-5610 Nitrates in Livestock Feed