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 bacterial 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 red colored 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: (1) shading or low light intensity; (2) detrimental weather like drought, frost, hail, or low temperatures; (3) herbicide applications; and (4) diseases. The amount of nitrate in plant tissue will also depend on: (1) plant species - certain plants like pigweeds, lamb's quarter, oats, millet, sorghum, Sudangrass, and corn are often high in nitrate, but other grasses and legumes can have excessive levels under extreme conditions; (2) stage 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. An example (Wisconsin study) of drought stressed corn nitrate levels in plant parts is: total plant = 978 ppm nitrate nitrogen, bottom 1/3 stalk = 5524 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 - there is a direct relationship between the level of nitrogen fertilization and the nitrate content of the plants. This effect may be less important than previously listed factors; (5) rain - in plants that survive drought, nitrates may be high for several days following a rain; (6) time of day - levels differ from a.m. to p.m.; and (7) location is the field--great variability of NO_3 levels within a field.

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 40-60%; (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; and (4) don't cut immediately following a rain - nitrate content of forages is high following a rain.

When ensiling high nitrate feeds, wait until the plant dries to the proper moisture level before chopping (bunker or bags = 30-35% DM, conventional silo = 35-45% DM, oxygen limiting structure = 45-55% DM). Wait 2-3 weeks for fermentation to reduce the nitrate level (40-60%) before feeding. Do not add non-protein 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 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 following 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 following a rain because of the increased nitrate level.

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

TESTING FOR NITRATE

The only method 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 .5 g of diphenylamine dissolved in 20 ml of water. Add sulfuric acid to a total 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 to 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 2 percent nitrate. Samples that react in this manner should be submitted for quantitative analysis at a laboratory. Proper sampling to ensure that a representative sample is tested is very important. Fresh samples are needed because nitrates can break down. Many commercial laboratories will run a nitrate test for a minimal fee. It is important to check how nitrate levels are reported and that they are reported on a DM basis. Methods of reporting nitrates in feed are shown in Table 1 and the nitrate content of some common feeds is shown in Table 2. Other general feeding recommendations include: (1) feeding limited amounts several times daily rather than large amounts once or twice daily; (2) feeding a balanced diet to ensure that no nutrients are deficient; and (3) avoid feeding damp forages in which the nitrate may be converted to nitrite which is more toxic.

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

	Chemical formula or designation	Atomic, molecular, or ionic weight	Multiplication factors
Nitrate nitrogen	NO^3-N	14	4.4
Nitrite nitrogen	NO_2-N	14	4.4
Nitrite	NO_2	46	1.3
Nitrate	NO_3	62	1
Sodium nitrate	$NaNO_3$	85	0.73
Potassium nitrate	KNO_3	101	0.61

[a]To convert parts per million (ppm) to percent you divide by 10,000 (i.e., 1500 ppm is .15%)

Table 2. Nitrate Content of Feedstuffs, Dry Basis

	No. of Analyses	Average Nitrate ppm	Range in Nitrate: Low ppm	Range in Nitrate: High ppm
Alfalfa				
Dehy	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. By weighing the corn and doing a dry matter analysis, an exact value can be determined. 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% DM corn silage per acre for every foot that is harvested. Short corn may produce 1, 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 10 tons per acre of 30% DM silage.

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

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

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

Step 2. Test the stressed silage to determine feed value or use an average value of 80% of normal silage. The value would be $21/ton for 80% corn.

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

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

UTILIZING HIGH-NITRATE FORAGE

The levels of nitrate that can be fed before you can expect problems are listed below (Table 3). Higher levels have been successfully fed in some cases, but there is risk associated with this practice.

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

Nitrate Content %	Comment
0.0- 0.44	This level is considered safe to feed under all conditions.
0.44-0.66	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% of the total dry matter in the ration.
0.66-0.88	Feeds safely fed if limited to 50% of the total dry matter in the ration.
0.88-1.54	Feeds should be limited to about 35-40% of the total dry matter in the ration. Feeds containing over 0.88% nitrate should not be used for pregnant animals.
1.54-1.76	Feeds should be limited to 25% of total dry matter in ration. Do not use for pregnant animals.
over 1.76	These feeds are potentially toxic. Do not feed.

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

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 to 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.

Table 4. Guidelines for Nitrites in Water

PPM of NO_3	Estimated Effect
0- 44	Not harmful
45-132	Slight possibility
122-220	Risky, especially over long period
221-440	Interference syndrome likely
441-660	More serious, possible acute losses
661-880	Increased, acute losses, secondary diseases
881 and over	Heavy acute losses

FEEDING DROUGHT STRESSED CORN SILAGE TO BEEF CATTLE

The nutrient content of the silage should also be analyzed. Drought silage will generally have 80% (65 to 95%) 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:

$$TDN = 87.84 - (0.7 \times \%\ ADF).$$

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 utilized by stocker cattle (including replacement heifers). Nebraska research indicates that feeding drought silage results in about 0.2 pound per day less performance with stocker cattle. The research also showed that soybean meal supplementation improved performance 0.3 pound per day on drought silage and 0.2 pound 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 utilize drought silage as a roughage source at 10-20% 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 prior to the finishing phase if a producer wants to utilize 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 which had no grain formation due to 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% 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 parts per million in the total ration dry matter caused open and early pregnant cows to have lower levels of serum progesterone (3 to 6 nanograms per milliliter) than mid-pregnant cows or cows on a low-nitrate diet (6 nanograms per milliliter). Low pregnancy rates are associated with levels below 1 nanograms per milliliter. Nutrient imbalances must be considered.

Young animals are more susceptible to nitrates then 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 quietly as possible to minimize their oxygen needs. Veterinarians use one or more of the following treatments: (1) Methylene blue (1 to 4% solution at the rate of 2 g per 500 lb 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; and (4) Antibiotics and 3 to 5 gallons (11.4 to 19.1) of cold water by stomach tube to control the rumen bacterial that convert nitrate to the very toxic nitrite. The response to these procedures is generally quite rapid.

ACUTE TOXICITY

In the non-acclimated cow, acute poisoning can occur as soon as ½ to 4 hours after abrupt feeding of high nitrate feed or water or combination. Symptoms may not develop until 3 to 4 days after daily feeding of moderate nitrate feedstuffs. Symptoms appear when 30-40% of the hemoglobin has been converted to methemoglobin, with death occurring at 70-80% 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 1950's as causing poor growth, abortion, repeat breeding, vitamin A deficiency, goiter and increased susceptibility to infection. Such problems may occur during the feeding of high nitrate forages or water to animals in poor condition, but controlled experiments of well-fed animals do not substantiate this. Nitrate results in high non-protein nitrogen value and elevated crude protein value, but reduced by-pass protein. Carotene is lower in drought-stressed corn silage than in 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 5 minutes before entering a silo which 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, 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 which can convert nitrates to nitrites.
13. Feeding grain or other forage prior to feeding high nitrate forage so the cattle are not hungry.
14. Feed Bova-Pro* to help safely feed high nitrate forages.

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