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Causes and Prevention

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Nitrate poisoning is generally caused when animals eat too much forage that is high in nitrates not changed to protein in the plant. Poisoning can also happen when animals eat too much urea or nitrogen fertilizer spilled in the field or left where the animals can find it. Nitrate fertilizer is palatable, especially to cattle.

Causes of High Nitrates in Forage

All plants contain some nitrate, but excessively high levels are likely to occur in forages grown under stress conditions, such as when corn fertilized for high grain yield is stunted by drought and is alternatively harvested for silage.

Other plants such as sudangrass, sorghum, pearlmillet, oats, orchardgrass, and tall fescue can also accumulate nitrates at high levels. Most weeds commonly found in corn also accumulate toxic levels of nitrate; they include red root pigweed, common lambsquarters, ragweed, velvetleaf, witchgrass, Canada thistle, and black nighshade.

Nitrates accumulate in plants only when 1) there is a large amount of nitrate in the soil, or 2) some factor interferes with normal plant growth.

High rates of nitrogen fertilization and drought conditions are the most important factors contributing to nitrate buildup in plants. Generally there is a direct response in plant nitrate concentration to increasing fertilizer nitrogen. Nitrate accumulation is greater from nitrate fertilizers than from ammonium sulfate or urea and also greater with delayed applications of fertilizer.

The highest levels of nitrate accumulate when drought occurs during heavy nitrate uptake by the plant. A drought during or immediately after pollination is often associated with the highest accumulation of nitrates. Extended drought prior to pollination is not necessarily a prelude to high accumulations of nitrate.

The resumption of normal plant growth after a heavy rainfall will reduce nitrate accumulation in corn plants, and harvest should be delayed for 3 to 4 days after the rain.

Nitrates absorbed by plant roots are normally incorporated into plant tissue as amino acids, proteins, and other nitrogenous compounds. Thus, the concentration of nitrate in the plant is usually low. The primary site for converting nitrates to these products is in growing green leaves. Under unfavorable growing conditions, especially drought, this conversion process is retarded, causing the nitrate to accumulate in the stalks, stems, and other conductive tissue.

Highest concentration of nitrate is in the lower part of the stalk or stem. For example, the bulk of the nitrate in drought-stricken corn plants can be found in the bottom third of the stalk (Table 1). If moisture conditions improve, the conversion process accelerates, and within a few days nitrate levels in the plant return to normal.

Not all drought conditions cause high nitrate levels in plants. If the supply of soil nitrates is in the dry soil surface, plant roots will not absorb nitrates. Some soil moisture is necessary for their absorption and accumulation.

Nitrate Toxicity in the Animal

Like plants, ruminant animals also use the nitrogen in nitrates to make protein. Conversion is made by bacteria in the rumen. Nitrite, one of the intermediate products in this conversion, is the cause of nitrate poisoning. Nitrate toxicity occurs when high nitrate levels in the feed overwhelm the animal's digestive system to the extent that the rate of conversion of nitrate to nitrite is faster than the conversion of nitrite to ammonia (which is incorporated into amino acids and protein). When this happens, nitrite accumulates and is absorbed into the bloodstream. There, it reacts with the oxygen-carrying hemoglobin, changing it into a form (methemoglobin) that cannot transport oxygen to the lungs and body tissues. The animal literally suffocates. Cattle are much more likely to be affected than sheep or horses.

The toxicity level depends both on how much and how fast nitrate is consumed. For example, it takes about twice as much nitrate to kill a ruminant when nitrate is eaten in forage as when it is consumed quickly as in a supplement or accidental consumption of nitrate fertilizer. In the case of forage, toxicity generally occurs when cattle consume large amounts of forage containing 1.76% or more nitrate ion on a dry matter basis.

Even forage with lower levels of nitrate may adversely affect reproduction or become toxic if animals are nutritionally stressed or ill and they suddenly consume large quantities of the forage.

Table 1. Nitrate nitrogen in 28 samples of drought-stressed corn.

Plant part	*ppm NO_3N*[1]
Leaves	64
Ears	17
Upper 1/3 of stalk	153
Middle 1/3 of stalk	803
Lower 1/3 of stalk	5,524
Whole plant	978

[1] ppm = parts per million
Source: University of Wisconsin

The recommended uses for forages containing various levels of nitrate are listed in Table 2. A high level of nitrate or nitrite in drinking water may make it necessary to further reduce intake of nitrate-containing forage. A total intake of 30 to 45 grams of nitrate ion per 100 pounds of body weight is considered acutely toxic in normal animals. However, intakes of 8 to 22 grams per 100 pounds of body weight may be toxic when animals are ill or undergoing an abrupt diet change.

Symptoms of nitrate poisoning appear suddenly. Dyspnea (difficult breathing) becomes progressively more severe until signs of marked respiratory distress—mouth breathing, violent respiratory movements, and extreme apprehension—are observed. A rapid and weak heart beat, below normal body temperature, muscular weakness, loss of muscular coordination (staggering gait and muscular tremors), blue coloration of mucous membranes, and marked dilation of pupils follow initial observed

Table 2. Guide for nitrate levels in forages for mature cattle.[1]

Percentage nitrate ion (NO_3^-) (dry matter basis)	*Content of nitrogen (dry matter basis)*		*Comments*[2]
	percentage	*ppm*[3]	
less than 0.44	0.0 - 0.10	0 - 1,000	Safe to feed if adequate feed and water are available.
0.44 - 0.66	0.1 - 0.15	1,000 - 1,500	Safe for nonpregnant animals. Limit to 50% of total ration dry matter for pregnant animals; animals may go off feed, have a slow drop in production, some abortions are possible.
0.66 - 0.88	0.15 - 0.20	1,500 - 2,000	Limit to 50% of total ration dry matter for all animals; may experience some symptoms, possibly death.
0.88 - 1.54	0.20 - 0.35	2.000 - 3,500	Limit to 35 to 40% total ration dry matter. **Do not feed to pregnant animals**.
1.54 - 1.76	0.35 - 0.40	3,500 - 4,000	Limit to 25% total ration dry matter. **Do not feed to pregnant animals**.
greater than 1.76	greater than 0.40	greater than 4,000	**Toxic. DO NOT FEED**.

[1] Table partially adopted from August 25, 1970, Hoard's Dairyman, Fort Atkinson, Wisc: W.D. Hoard & Sons Co.
[2] Total ration dry matter refers to total dry matter being consumed as forages and concentrates.
[3] ppm = parts per million

symptoms. Brownish discoloration of the blood is characteristic of nitrate poisoning. Death may occur within 1 hour or, in the usual case, within 3 to 4 hours of the onset of difficult breathing.

Subacute or chronic nitrate poisoning may result in reproductive problems, including abortions. Abortions due to nitrate are usually accompanied or preceded by some evidence of nitrate poisoning in the animals, including bluish discoloration of unpigmented areas of the skin or mucous membranes.

Poisoning symptoms that precede abortions may be missed if animals are not being closely observed, since the abortions will occur several days after the animal consumes the nitrate.

Milk production and appetite generally are not affected by subacute nitrate intake. Reproductive problems may be prevented if nitrate-containing feeds are gradually introduced into the diet and the nitrate level in the total ration dry matter is maintained below 1.76%.

Treatment: If you suspect nitrate poisoning, call your veterinarian immediately. Since death comes from oxygen deficiency, cattle should be handled as little and as quietly as possible to minimize oxygen usage. Administration of a 2% solution of methylene blue by your veterinarian aids in the reconversion of methemoglobin to hemoglobin, increasing the oxygen carrying capacity of the blood and reversing the poisoning process.

This treatment may need to be repeated since absorption of nitrate will continue from a full rumen. Mineral oil or mucilaginous substances may be given orally to protect irritated mucous membranes, help reduce the absorption of nitrates, and aid in their elimination.

Reducing the Threat of Nitrate Toxicity

If growing conditions favor the accumulation of nitrate in forage, the following management practices will greatly reduce the chances of problems occurring:

1. Consider ensiling the forage; this will reduce nitrate levels. Studies at Purdue University showed that ensiling corn forage reduced nitrate concentration by about one third (Table 3). Feeding should be delayed until the fermentation process is complete. This usually takes about 4 weeks. Purdue studies have also shown that adding 20 pounds of limestone per ton of silage going into the silo further reduced nitrate levels. Adding more than 20 pounds per ton adversely affected fermentation and quality of the silage. Limestone tends to raise the pH which, in turn, can reduce silage quality.

Nitrate levels in silage also can be reduced by chopping the top two thirds of the plant, since nitrate accumulation is highest in the bottom third of the stalk or stem. Leaving that much of the plant in the field is often a difficult decision but it may be less costly than the possible loss of animals. Stalks left in the field can be a source of nitrogen for next year's crop.

Ensile at the proper moisture content (60 to 68%), chop clean, and pack well. Proper ensiling procedures improve the fermentation process and help to reduce nitrate levels. Application of anhydrous ammonia to drought-stricken corn is not recommended. The additional nitrogen has potential to impede breakdown of nitrates in the rumen, particularly if ration energy is limited.

2. Before feeding the forage, have it chemically analyzed for nitrate content. A complete feed analysis is advisable because drought-stressed forages tend to have higher protein content and reduced levels of total digestible nutrients (TDN) or energy.

When sampling suspected silages or greenchop for nitrates, take representative grab samples from six areas at the feeding face of the pit or mound. Mix the grab samples and sub-sample an amount to fill a plastic bag that can be sealed at the top. Compress or squeeze the air out of the bag and seal.

For suspected forages being ensiled in an upright silo, take grab samples for three days in a row. Keep samples in an airtight container in a cool location. On the third day, mix the samples and follow procedures described above.

Table 3. Effect of ensiling on nitrate concentration in corn silage.

Corn fed as	*Nitrogen applied (lb/acre)* *0*	*200*	*800*
Green forage			
Nitrate (ppm[1])	602	2,319	4,438
Silage			
Nitrate (ppm)	380	1,468	2,861
Decrease with ensiling percentage	37	41	36
pH	3.9	3.8	3.8

[1] ppm = parts per million. Nitrate values on dry basis. To convert values from ppm to percentage, move the decimal point four paces left; for example, 602 ppm = .06%.
Source: Purdue University

Suspect long hay should be sampled with a hay probe. For baled hay, probe at least 20 different bales; and for hay stacks, sample each stack in six different areas to obtain a representative sample. Transfer samples to a plastic bag, squeeze the air out, and seal.

It is difficult, if not impossible, to obtain a representative sample from pastures/fields suspected of high nitrates. Cattle are selective in the plants and plant parts they choose to eat, and a clipped sample will not represent what is actually being consumed. It is recommended you not test grazed forages for nitrate but that, if you choose to graze, you manage the grazing of such forages to reduce potential nitrate problems. Recognize you are managing risk.

3. Dilute known high nitrate feeds with low nitrate feeds, such as grain or legume hay, to reduce the percentage of nitrate in the daily ration. Grain feeding seems to be helpful in diluting the nitrate content of the feed. Energy from the grain helps to complete the conversion of nitrate to ammonia, which is then used by rumen bacteria to make bacterial protein. Corn forage is normally a high-energy feed that favors the use of nitrate in the rumen. Sudangrass, on the other hand, is a low-energy feed which, by itself, does not promote the conversion of nitrate to ammonia.

4. Frequent intake of small amounts of high nitrate feed increases the total amount of nitrate that can be consumed daily without toxic effects. Feed limited amounts several times daily rather than large amounts once or twice daily. With frequent intake of limited amounts of high nitrate feed, concentration of nitrate in the rumen does not become extremely high at any one time.

Feeding frequency and grain feeding recommendations to reduce the risk of nitrate toxicity refer primarily to milking cows. Use extreme caution if bred heifers or dry cows must be fed feeds containing greater than 0.44% nitrate ions. Typically these animals are not fed more than once daily, nor are they fed large quantities of grain, the primary ways to prevent toxicity if high nitrate feeds are fed. Young heifers should not be given feeds that are not safe for all livestock to consume.

5. Introduce questionable feed slowly over a period of a week or two so that the rumen bacteria can adapt. All sound management practices that are conducive to a successful feeding program should be followed when high nitrate feeds are fed.

In Purdue University experiments, when green corn with 2.29% nitrate was fed to unadapted steers, nitrate in the rumen fluid increased measurably within 1 to 1 1/2 hours after feeding. However, each succeeding day the nitrate levels were lower and did not increase again when the experimental forages were fed to the now-adapted animals.

6. Be sure that the ration is balanced. A balanced ration that provides needed nutrients will tend to reduce problems from nitrates in the ration. Rations should be adequate in vitamin A, vitamin E, and all minerals. Excessive supplementation does not appear to be necessary.

Nitrates in Water

Most well water is lower in nitrates than the maximum 10 parts per million (ppm) nitrate nitrogen (NO_3N) that is suggested as being safe for adult humans and mature livestock. Infants and immature ruminants are susceptible to nitrate toxicity when water exceeds 10 ppm NO_3N.

When livestock are drinking well water, nitrate toxicity resulting from the water is not likely to occur. Nitrate toxicity from water is most likely to occur when livestock drink water from ponds, road ditches, or other surface impressions that collect drainage from poultry houses, feedlots, heavily fertilized fields, silos, septic tanks, or manure disposal lagoons.

As with feed, frequent intake of water appears to increase the total amount of nitrate that can be consumed daily without harmful effects. Conversely, water consumption limited to only once daily will reduce the level of tolerable nitrates in water before poisoning symptoms appear.

From the information currently available it is difficult to set a maximum nitrate content for water that should be considered safe for mature livestock. Most data tend to suggest toxicity is not likely to occur in water containing less than 100 ppm NO_3N, provided that animals are fed a balanced ration that is not high in nitrate and that sound feeding, watering, and management practices are followed.

However, a high level of nitrate in the water can become critical and will contribute to toxicity when nitrate levels in forages approach 1.76%.

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