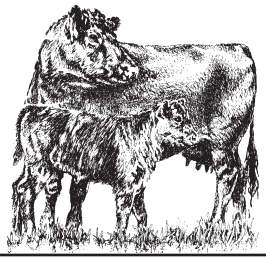

Western Beef Resource Committee *Fourth Edition*

Cattle Producer's Handbook

Nutrition Section 355

Nitrates in Cattle Feed and Water

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Nitrate toxicity in cattle is a noninfectious condition whereby animals consume nitrates in feed, forage, or water sources at detrimental and potentially lethal concentrations. The condition leads internal to anoxia, or suffocation. Animals suffering from the onset of nitrate toxicity may exhibit off-colored mucus membranes, respiratory distress, or staggering and/or weakness after extreme weather or successive cloudy days. Also, animals may show these symptoms after fields have been fertilized with nitrogen (O'Hara and Fraser 1975).

Nitrate toxicity is preventable. Therefore, it is important to identify potentially lethal nitrate sources, the symptoms associated with the condition, and how to implement strategies to prevent losses to an operation.

Cattle experience nitrate toxicity when nitrite accumulates in the blood. Rumen microbes convert nitrates (NO_3) in cattle feed and water into potentially toxic nitrites (NO_2). Once produced, it crosses the rumen wall and enters into the circulating blood. In the blood, nitrite disrupts the normal oxygen binding capacity of hemoglobin in red blood cells by oxidizing Fe^{2+} to Fe^{3+}. The change converts hemoglobin to methemoglobin, a molecule that does not bind oxygen and thereby leads to anoxia. Nitrate toxicity is diagnosed when circulating methemoglobin levels are 10 to 20 percent, and death occurs when methemoglobin levels approach 80 percent (Kemp et al. 1977).

Symptoms of Nitrate Toxicity

Cattle can consume lethal nitrate concentrations within hours. Therefore, it is important to recognize nitrate toxicity symptoms to minimize cattle losses. Cattle may exhibit acute or chronic symptoms in response to nitrate toxicity. Cattle health and production diminishes rapidly after consuming toxic levels of nitrates, so it is important to remove cattle from pasture, feed, or water sources if these symptoms become evident.

Acute nitrate toxicity can be identified by unique symptoms related to oxygen deprivation as early as 3 hours after cattle ingest toxic nitrate levels. Animals consuming these levels begin to increase their respiratory rate followed by respiratory distress, muscle tremors, and overall weakness. Increased movement produces more severe symptoms, and cattle may lie on their sides and retain open mouths. Their mucous membranes are either brown or discolored due to oxygen deprivation. Death typically occurs within 12 hours.

Chronic nitrate toxicity is subtle and potentially devastating. For example, it can decrease reproductive performance and cause dams to abort their calves (Singer 1972). Additionally, nitrites or gases derived from nitrates can destroy carotene and vitamin A and thereby lead to vitamin A deficiency. It can also decrease feed intake and result in weight loss or prevent weight gain. Finally, it can disrupt normal thyroid function by reducing iodine uptake. Additional symptoms associated with chronic nitrate toxicity include a coarse coat and watery eyes.

Nitrate Accumulation in Feed/Forage

Nitrate has an essential role in the life cycle of plants. Under normal conditions, nitrates are absorbed from the soil through plant roots. Once the nitrate is sequestered in the plant, enzymes are able to convert the nitrate to nitrite and then to ammonia. Ammonia is then used to make amino acids, which are used to form plant proteins. This process is referred to as the nitrate-to-protein cycle and primarily occurs in growing leaves. Adequate water, energy from the sun, and a temperature favorable to chemical reactions prevent nitrate accumulation. Plants can accumulate nitrates when these processes are altered.

Several factors can induce plants to accumulate nitrates. Recognition of these factors allow managers to prevent nitrate toxicity before it becomes costly.

- **Weather**—Extreme temperatures can cause nitrates to accumulate in plants. Nitrates tend to accumulate in hot, dry weather; however, it is does not always coincide with drought conditions. Soil moisture is needed for plants to absorb nitrate from the soil. During drought conditions, nitrate concentrations are increased in plants several days after the first rain that restores soil moisture.

  Temperatures below 55°F can reduce photosynthetic activity and increase nitrate concentrations in plants. Likewise, frost, hail, or extreme weather that damages leaves and reduces plant photosynthesis can cause nitrates to accumulate in plants. In general, nitrates accumulate in the plant stalks and stems until photosynthesis resumes.
- **Plant Species**—Certain plant species are known to accumulate more nitrate compared to others. Crops such as corn, oats, canola, and wheat can possess excessive nitrate concentrations when harvested prematurely. Likewise, several weed species are known to accumulate lethal nitrate levels. Examples of such weeds include bindweed, Canada thistle, kochia, lambsquarters, and nightshade. Sorghum and sudangrass are susceptible to nitrate accumulation, as well as brome and orchardgrass to a lesser extent. A more thorough list of plants commonly associated with nitrate toxicity is included in Table 1.
- **Stage of Growth**—The stage of growth is a factor to consider when assessing nitrate concentrations. Immature plants generally have higher nitrate concentrations compared to mature plants.
- **Plant Part**—Nitrate accumulation is not distributed evenly throughout the plant (Crawford et al. 1961). They mainly accumulate in the stalk or in the bottom third of the plant. The middle portion of the stalk has lower concentrations followed by the leaves, the seed/grain, and then the flower.
- **Fertilization**—Soil nitrate is the primary nitrate source that accumulates in plants. However, fertilizing a field with nitrogen (N) can promote the accumulation of nitrates in plants. Orchardgrass and sudangrass are known to accumulate vast N concentrations after fertilizing, which is known to induce nitrate toxicity in cattle (Murphy and Smith 1967).
- **Shading**—Several scenarios show that photosynthesis rates are reduced in plants because of shading. Plants will accumulate nitrates after successive cloudy days. Valleys with limited sunlight are also likely to have plants that accumulate nitrates. Other areas where shading could cause increases in nitrates are sites where plant populations are dense.
- **Herbicide**—Herbicides can potentially disturb the nitrate to protein cycle and cause nitrate accumulation. An example of one such herbicide is 2,4-D. It can temporarily induce high nitrate levels in plants after application. However, spraying plants with herbicides can also reduce the risk of nitrate toxicity by killing plants high in nitrates.
- **Disease**—Plant diseases can also disrupt photosynthesis, thus leading to potentially lethal nitrate concentrations in cattle. These diseases disrupt the chemical processes that are necessary to convert nitrate to plant protein.

Levels of Nitrate

The extent of nitrate toxicity depends on the amount of nitrate consumed, diet, nutritional status, pregnancy status, and acclimation to a nitrate-rich diet. In general, it is considered safe to feed cattle feedstuffs containing less than 4,399 ppm nitrate on a dry matter basis (Table 2). Forages with nitrate concentrations of 4,400 to 9,299 ppm are considered safe for non-pregnant animals yet can be toxic for pregnant animals. Diets with feeds containing nitrates ranging between 9,300 to 14,999 ppm are not safe for pregnant animals unless they are diluted to safe levels with feedstuffs without nitrates. On the other hand, it is possible for non-pregnant animals to consume these nitrate levels if they are slowly incorporated into the ration and remains less than 50 percent of the total ration on a dry matter basis.

Feed sources exceeding 15,000 ppm nitrate are not safe for pregnant females and should be avoided. While

Table 1. Nitrate accumulators classified as crops, weeds, and vegetables.

Crops		Weeds		Vegetables	
Alfalfa	Oats	Bindweed	Johnson grass	Beets	Radishes
Barley	Orchardgrass	Bull thistle	Kochia	Celery	Spinach
Canola	Rye	Canada thistle	Lambsquarters	Cucumbers	Squash
Corn	Sorghum	Fiddleneck	Mustard	Kale	Swiss chard
Fescue	Soybean	Dock	Nightshade	Lettuce	Turnips
Flax	Sweetclover	Fescue	Pigweed	Parsnips	
Millet	Wheat	Fireweed	Russian thistle		

Table 2. Nitrate recommendations based on varying nitrate types and concentrations.

Nitrate NO_3 (ppm)	Nitrate-nitrogen NO_3N (ppm)	Potassium nitrate KNO_3 (ppm)	Recommendations
0 to 4,399	0 to 999	0 to 7,039	Generally safe and not toxic.
4,400 to 9,299	1,000 to 2,099	7,040 to 14,879	Generally safe for non-pregnant animals. Incorporate slowly into the ration of pregnant animals or dilute safe feeds.
9,300 to 14,999	2,100 to 3,389	14,880 to 23,999	Incorporate these feeds into a ration slowly. Feed less than 50% of the total ration on a dry matter basis. Not safe for pregnant animals unless diluted with a ration without nitrates.
15,000 or more	3,390 or more	24,000 or more	Potentially dangerous so limit to less than 25% of ration on a dry matter basis. Incorporate with low nitrate feed and slowly adapt animals to the mixture. Do not feed to pregnant animals.

Calculate % by dividing ppm by 10,000.

it is recommended to refrain from nitrate concentrations exceeding 15,000 ppm, non-pregnant animals can consume forages with these toxic levels as long as they are incorporated into a ration with low nitrate feedstuffs at a maximum of 25 percent of a ration on a dry matter basis.

Nitrate in Water

Contaminated water can be another source of nitrate toxicity. Nitrate and nitrite are soluble in water, which allow cattle to ingest these compounds at higher rates compared to forages and feedstuffs. As a result, acceptable nitrate and nitrite concentrations in the water are lower compared to those in feedstuffs and forages.

It is important to identify the water sources that accumulate nitrates. Nitrate toxicity is likely to occur when cattle consume water from shallow or contaminated sites and less likely to occur from well water. For example, nitrates may accumulate in ponds, ditches, and shallow surface areas that collect the drainage from operations with confined animals on feed. Nitrate levels in water should not exceed 200 ppm because it could induce nitrate toxicity, especially if cattle are also consuming diets high in nitrates.

Interpreting Nitrate Reports

Nitrate evaluation can be difficult because different laboratories report different nitrate parameters. Some laboratories may report nitrate as a percentage whereas others report it as either potassium nitrate, nitrogen nitrate, or nitrate. To convert a nitrate percentage to ppm, divide the percentage by 10,000. For example, a feed containing 0.06 percent nitrates on a dry matter basis will have a nitrate equivalent of 600 ppm. Table 3 provides conversion factors that can be used to compare different nitrate reporting methods.

Sampling Plants or Feeds

Feedstuffs and forages should be analyzed before giving animals access to feedstuffs or pastures that may be high in nitrates. Testing is inexpensive and can prevent losses from nitrate toxicity. A representative sample of the feed source is key to get an accurate nitrate concentration.

When sampling feedstuffs such as green chop or silages, collect samples directly from the mound or pit. In both cases, dig deeper than 2 feet and grab a handful of green chop or silage. Mix the samples from at least six different locations. Afterwards, partition about half a pound of sample into a plastic bag and remove excess air before sealing the bag. Send the bag for laboratory analysis or store it in a freezer until analysis is desired.

Obtaining samples in a pasture is more challenging because the sample must be representative of what the cattle will consume. Collect forage samples by clipping plants in the pasture. Estimate the extent of grazing that will occur based on management decisions and clip that amount. Clip plants at six different locations within the pasture in question.

Nitrates are concentrated at the base of the plant with lower concentrations in the leaves. So, if the forage utilization is likely to be "light" estimate the upper third of the plant. Thoroughly mix the samples and partition at a half pound into a plastic bag, remove any excess air, and seal the bag. The bag can be stored in a freezer or sent for analysis. Proper grazing management is key to avoiding nitrate toxicity when grazing cattle on potentially affected pastures.

Table 3. Nitrate conversion factors to compare different reporting methods.

Potassium nitrate (KNO_3):	
	= Nitrate x 1.6
	= Nitrate nitrogen x 7.0
Nitrate:	
	= Potassium nitrate x 0.6
	= Nitrate nitrogen x 4.4
Nitrate nitrogen:	
	= Potassium nitrate x 0.14
	= Nitrate x 0.23

Treatment

Death due to acute nitrate toxicity is quick and is not commonly realized until deaths occur. However, if an affected animal is found alive with acute symptoms, an immediate intravenous dose of methylene blue IV by a veterinarian is a potential solution. Methylene blue IV converts methemoglobin back to hemoglobin and reestablishes oxygen transportation in the blood.

Prevention Measures

Prevention is the most effective way for cow-calf producers to manage nitrate toxicity. The key is to be cognizant of the circumstances that increase nitrate concentrations in feed and water sources. For example, do not let cattle graze sites that are suspected to accumulate nitrates and submit samples to an analytical lab if there is any doubt. Additionally, keep the total nitrate concentration in the diet less than 0.5 percent on a dry matter basis.

Submit forages and feedstuffs suspected of elevated nitrate for laboratory analysis. Likewise, do not allow cattle to graze sites that may contain elevated nitrates. If nitrates are known to be a problem in a feedstuff or in a pasture, slowly adapt cattle to feeds high in nitrates. The adaptation will allow the microbe population in the rumen to adjust where nitrates can be readily converted to ammonia.

Know the history of the pasture and do not let the animals out hungry on pasture with elevated nitrate levels. Furthermore, avoid strip grazing or heavy utilization rates on stalks of crops or grass stems. Refrain from grazing crops or grasses that are susceptible to nitrate accumulation for a week. This includes after rainfall, frosts, cloudy days, shaded areas, or elevated temperatures that wilt plants. Graze these areas when there is sunlight and do not allow grazing in the evening. Applying these strategies will prevent losses due to nitrate toxicity and promote a healthy herd.

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