NebGuide

Nebraska Extension

Research-Based Information That You Can Use

G1779 · Index: Animal Agriculture, Beef

Nitrates in Livestock Feeding

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Nitrate does not have to be toxic to ruminant livestock (cattle, sheep, goats, etc.). Learn about nitrate poisoning, include the cause, signs, prevention, and treatment.

Nitrate poisoning in cattle occurred long before the use of nitrogen fertilizers. In the late 1800s there were reports of cornstalk poisoning in Nebraska, and nitrate poisoning from oat hay in North and South Dakota and from weeds in the high-organic matter soils in Florida and Wisconsin. Nitrate concentrations in feeds for livestock depend more on plant species and environmental conditions prior to harvest than on the amount of available nitrogen in the soil.

What is Nitrate Toxicity?

Nitrate is not always toxic to animals. Almost all forages contain some nitrates. When feeds containing nitrates are consumed by ruminants, nitrates are changed in the rumen, first to nitrites and then to ammonia that then may be converted by bacteria in the rumen into microbial protein.

Nitrite is one of the intermediate products in the breakdown of nitrate and is the actual toxic compound in nitrate poisoning. Nitrite can be absorbed into the bloodstream where it changes hemoglobin to methemoglobin. Hemoglobin carries oxygen from the lungs to other tissues but methemoglobin is incapable of carrying oxygen. Thus, nitrites become a problem when enough methemoglobin is produced that the oxygen carrying capacity of blood is reduced to a critical level. If enough methemoglobin is produced (more than 80% of the total hemoglobin), the animal will die.

Signs of Nitrate Toxicity

Brownish discoloration of the blood, due to the presence of methemoglobin, is a sign of nitrate poisoning. Besides the chocolate-colored blood, other physical signs of nitrate poisoning include difficult and rapid breathing, muscle tremors, low tolerance to exercise, incoordination, diarrhea, frequent urination, collapse, and death.

Nitrates in blood may also cause blood vessels to dilate and are responsible for peripheral circulatory failure. Lack of oxygen to the fetus can cause abortions that sometimes occur following nitrate poisoning. Abortion due to nitrate is accompanied or preceded by some evidence of nitrate problems in the pregnant female, including chocolate-colored blood and bluish discoloration of unpigmented (around the eyes) areas of the skin or mucous membranes.

Nitrate Levels and Toxicity

When reading nitrate level reports, be sure to note what method of reporting is used. Methods of reporting nitrate values in feed and formulas to convert from one method to another are shown in *Table I*. Both nitrate nitrogen (NO_3-N) and nitrate ion (NO_3-) will be used to evaluate and discuss nitrate concentrations in feed and water in this NebGuide.

Table I. Methods of Reporting Feed Nitrates Concentrations (Dry Basis).

	Potentially toxic concentrations in unadapted animals	
	%	Ppm
Nitrate nitrogen (NO_3-N)	> 0.21	> 2,100
Nitrate (NO_3-)	> 0.93	> 9,300
Potassium nitrate (KNO_3)	> 1.5	> 15,000

The **risk of toxicity** depends upon the amount of nitrate in the feed, how fast the feed that contains nitrate is consumed, how fast the nitrate in the feed is released in the rumen, the energy content of the diet and whether the animals (i.e., rumen microbes) are adapted to nitrates.

Formulas for Converting Methods of Reporting.

Potassium Nitrate = Nitrate Nitrogen × 7.22

Potassium Nitrate = Nitrate × 1.63

Nitrate = Nitrate Nitrogen × 4.43

Nitrate = Potassium Nitrate × 0.613

Nitrate Nitrogen = Potassium Nitrate × 0.139

Nitrate Nitrogen = Nitrate × 0.226

Deaths in cattle have been reported when nitrate content in the overall diet contained as little as 2,100 ppm NO_3-N (9,300 ppm NO_3-). However, rations containing substantially more than 2,100 ppm NO_3-N have been fed without harm. One such instance was reported from Missouri where researchers fed rations containing 2,800 to 3,300 ppm NO_3-N from sudangrass hay. Steers were slowly adapted (four to seven days) to the high nitrate feed and performed satisfactorily. Additional research indicates that beef heifers may safely graze sudangrass containing high levels, up to 6,500 ppm NO_3-N (28,795 ppm NO_3-) of nitrates. Cattle grazing sudangrass pastures tend to selectively graze the leaf portion of the plant, which is usually low in nitrate, and slowly adapt themselves to feeds that may be high in nitrate. If a pasture suspected of high nitrate concentrations is heavily stocked, it may cause cattle to consume plant parts such as lower stem bases that can be high in nitrate, increasing the possibility of nitrate poisoning.

Causes of High Nitrates in Forage

Nitrates taken up from the soil by plant roots are normally incorporated into plant tissue as amino acids, proteins, and other nitrogenous compounds. The primary site for converting nitrates to these plant products is the actively growing green leaves. Nitrates accumulate in the stalk or stem of plants when factors interfere with normal plant processes.

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, including drought, frost, hail, low temperatures; (3) herbicide applications; or (4) diseases. The amount of nitrate in plant tissues also will depend on: (5) plant species; (6) stage of maturity; (7) part of the plant; and (8) soil nitrate level.

Shading. Conversion of nitrates to amino acids and proteins is linked closely with photosynthesis. Light is the energy source for these activities, so shaded plants or lower leaves may be higher in nitrates than plants grown in full light. Tall forages planted at high plant populations, coupled with good soil fertility and adequate water, will create shade and may contain high nitrate concentrations.

With normal growing conditions, nitrate content will be slightly higher in the morning than in mid-afternoon, and may be higher on cloudy days than on sunny days. For example, oat hay harvested after cloudy weather is likely to be much higher in nitrate content than oat hay harvested during sunny periods.

Weather. Not all drought conditions cause high nitrate concentrations in plants. Some moisture must be present in the soil for nitrate absorption and accumulation. If the major supply of nitrates for the plant is in the dry surface soil, very little nitrate will be absorbed by plant roots. In plants that survive through drought, nitrates often are high for several days following the first rain.

Frost, hail, and low temperatures all interfere with normal plant growth and can cause nitrate accumulation in the plant. Frost and hail may damage, reduce, or completely destroy the leaf area of the plant. A decrease of leaf area limits the photosynthetic activity of the plant so nitrates absorbed by the roots are not converted to plant proteins and instead are accumulated in the stem or stalk.

Most plants require temperatures above 55°F for active growth and photosynthesis. Nitrates can be absorbed quickly by plants when temperatures are low, but conversion to amino acids and protein occurs very slowly in plants during low temperatures.

Herbicides. Herbicides, such as 2, 4-D, tend to disrupt normal plant processes and can result in temporary high nitrate content in plants. However, spraying pastures and silage crops to control weeds actually may reduce the nitrate hazard of these feeds, especially when weeds high in nitrates are killed.

Disease. Plant diseases interfere with normal growth and development. This can cause nitrate to accumulate by interfering with nitrate reduction, protein synthesis, or manufacture and translocation of carbohydrates.

Plant Species. In general, annual species accumulate more nitrate than perennials. Many commonly used annual forages have the potential for nitrate accumulation, including brassicas (turnips/radishes/collards, etc.), corn, millet, oats, cereal rye, sorghums and sorghum x sudangrass hybrids, and sunflowers. Certain weeds, such as pigweed, kochia, puncture vine, and lambsquarter, are often high in nitrate. In a recent report, brassicas were five times more likely to contain concentrations above 2,100 ppm NO_3-N (9,300 ppm NO_3-) than small grain forages, sorghum/sudangrass, and millet, exceeding 2,100 ppm NO_3-N in 48% of samples.

Stage of Growth. Stage of growth markedly changes the nitrate content of forages. Nitrate concentrations usually are higher in young plants and decrease as the plant matures. However, plants grown in soils with excessive nitrates or grown under stress may be high in nitrate content at maturity.

Plant Parts. Plant parts closest to the ground usually contain the most nitrate. Leaves contain less nitrate than stalks, and the seed (grain) and flower usually contain little or no nitrate. Most of the plant nitrate is usually found in the bottom third of the stalk.

Nitrogen Fertilization. Nitrates in the soil are the source of nitrate in plants. While a positive relationship exists between soil nitrates and nitrate in the plant, the effect of nitrogen fertilization appears to be less important than the conditions listed previously in causing high nitrate content in forages.

Harvest Methods Affect Nitrate Levels

Harvest as Silage. Ensiling tends to reduce the nitrate content of forages. Forages high in nitrate can lose from 40% to 60% of their nitrate content during fermentation. Harvest forages suitable for silage at the stage of maturity where forage quality and quantity are optimal. Excessive nitrate in forages will not always be reduced to safe values during ensiling. If silage is suspected to be high in nitrate, analyze the feed for nitrates before feeding. The analysis will help in designing rations to prevent livestock losses from nitrate poisoning.

Harvest Near Maturity. Crops normally have lower nitrate levels at maturity, so crops such as drought-damaged corn or sorghum silage should be harvested as near maturity as possible. If the corn or sorghum field being harvested as silage is suspected of having high nitrate concentrations, consider raising the cutter head to selectively avoid stalk bases, which have the highest nitrate concentration.

In crops such as oats for hay, it may be wise to harvest the crop at a more mature stage than desirable for maximum yield of digestible nutrients.

Harvest as Green Chop. Some forages are harvested in an immature stage and fed to cattle in the form of green chop. Green chop feeds that contain high nitrate concentrations should be fed immediately after chopping and never be allowed to heat before feeding. Green chop that is allowed to heat is especially dangerous to feed to livestock. For example, do not green chop in the evening and then feed the remaining green chop the next morning. Heating causes the conversion of nitrate to nitrite, making the feed about 10 times as deadly.

Sampling and Testing Feeds for Nitrates

The cost of testing for nitrates is inexpensive so get samples of questionable feeds analyzed by a laboratory before feeding. The methods used to sample forages for nitrates often need to differ from those used when testing forage quality. Sampling for forage quality seeks to represent the average of the entire lot of forage. With nitrates, though, it often is important to know the worst-case scenario, or the highest concentration of nitrates that might be consumed by the animals.

In some situations, it may be possible to identify which bales or forages are most likely to contain the highest nitrate levels due to knowledge of the factors described earlier that affect nitrate concentrations. In these situations, collect samples specifically from the suspect forage to determine the highest concentration of nitrate to which livestock may be exposed. For example, some fields have sites that are droughtier than other areas. Hay harvested from these sites might be expected to contain more nitrates due to drought stress. Samples could be collected just from this hay and tested. Other samples might be collected from the remainder of the hay.

If the stressed hay contains potentially risky nitrate levels, it can be separated from the rest of the hay and fed in ways to reduce the risk, such as combining it with a much lower nitrate containing feed to reduce the overall concentration of nitrates in the diet. Some laboratories identify feed as high risk at lower thresholds than indicated in *Table I.* This is because they assume the sample is the average of the lot and thus it is likely that some of the forage is higher than the analyzed value and some is lower.

When sampling suspected silages or green chop for

nitrates, take representative grab-samples from at least six areas of 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 the air out of the bag and seal. For suspected forages being put into an upright silo, take grab-samples for three successive days, then sub-sample and transfer to a plastic bag as mentioned previously. Samples should be frozen between days or whenever kept in storage.

It is difficult to obtain a representative sample from pastures suspected of high nitrates that cattle are grazing. Cattle are selective in the plants and plant parts they consume, and a clipped sample will not represent what is actually being consumed. However, sampling can be used to identify fields that are high risk and allow you to manage the grazing of high-risk forages to reduce the problems due to nitrates. In fields that will be grazed, clipping the forages to the lowest level the animals will graze will give you an idea of the highest nitrate content in the plant. Samples of each individual species in a forage mix can again tell you the maximum amount of nitrates if animals select a single species.

Bacterial activity in wet forage samples can reduce the nitrate level. Thus, samples should be placed in plastic bags and immediately put in a cooler on ice. It is recommended to deliver samples directly to the lab or freeze the samples for 24 hours prior to shipping and ship in an insulated container. Also, avoid shipments late in the week to avoid delayed arrival to the lab.

Managing High Nitrate Feed

Extensive losses can occur when non-acclimated, hungry livestock are permitted unlimited access to high nitrate feeds. Cattle losses to nitrate toxicity usually occur in hungry cattle that have not had time for some adjustment to feeds with potentially toxic levels of nitrates. For example, cattle that go without feed for a day or longer during snowstorms often rapidly eat a large amount when gaining access to feed. If the feed they receive is high in nitrates, cattle losses may occur.

Recommendations for feeding forages containing various levels of nitrates to unadapted animals are shown in *Table II*. Forages that contain high nitrate levels can be diluted in the diet with grains or other forages low in nitrates and then can be fed safely. The capacity of the microbial population in the rumen to detoxify nitrite will increase over time with exposure to nitrate. Thus, nitrate content in the diet can be slowly increased. Frequent consumption of small amounts of a high nitrate feed increases the total amount of nitrate that can be consumed daily without adverse effects, and helps livestock adjust to high nitrate feeds. If cattle are allowed to adapt to feeds containing potentially toxic levels of nitrates, they will develop microbes in the rumen that convert nitrates to a nontoxic form more efficiently than unadapted animals.

If possible, feed long stem forages such as wheat, oat, and cane hay that contain high amounts of nitrate in limited amounts several times daily rather than feeding large amounts once or twice daily. In addition, long stem hays suspected of nitrates can be fed in combination with hay low in nitrate to dilute the nitrate intake with little risk of nitrate problems. Grinding and blending of low and high nitrates hay is best to reduce risk. If blending is not possible, unroll the low-nitrate hay first, and then after the cattle have consumed most of the low-nitrate hay, roll out high nitrate hay.

Be sure animals are not hungry when eating the high nitrate hay (slow intake is key to reducing risk). To adapt the cattle, start by feeding the lowest-nitrate hay and then work up to higher levels. Even with adaptation, feeding hay free-choice is risky when the hay has higher than 2,100 ppm NO_3-N (9,300 ppm NO_3-). Do not feed hay, straw, or fodder suspected of being high in nitrate when it is damp. Damp feed tends to be more toxic because some of the nitrate already has been converted to the more toxic nitrite before being consumed.

Feeding grain in combination with high nitrate feeds helps reduce the risk of nitrate toxicity. Energy from the grain helps complete the conversion of nitrate to bacterial protein in the rumen.

Corn forage grown in drought conditions can potentially contain nitrates. The majority of the nitrates will be in the lower 8 inches of the stalk. Raising the chopper height to 6–8 inches will reduce the amount of nitrates in the silage. Yield will be reduced, but so will the nitrate level. Ensiling drought-damaged corn can reduce nitrates in the silage 40%-60%. Allow a fermentation period of at least 21 days before feeding. Shorter fermentation times may cause some of the nitrates to still be in the dangerous nitrite form, just like heated green chop.

Using feeds that contain high nitrate concentrations is not without risk, but can be fed successfully. Use the management practices mentioned previously to reduce the chance of animal loss. Livestock should have access to clean water at all times.

Grazing High Nitrate Forages

When grazing, a few factors may reduce the risk of nitrate toxicity. Grazing animals eat at a slower rate than in a bunk or hay feeding scenario. This reduces the rate of

nitrate inflow and reduces the likelihood of nitrite accumulation. Cattle also graze selectively. Generally, they initially select leaves that usually contain less nitrate than do stems. This also enables them to adapt slowly to higher nitrate concentrations.

Cattle have grazed small grain and brassica forage mixes in the fall that contain 4,000 to 8,000 ppm NO_3-N (17,720 to 35,440 ppm NO_3-) on a whole plant basis without showing nitrate toxicity symptoms. These cattle were lightly stocked (given 60 days of grazing at once) allowing them to selectively graze. Additionally, the forage was high moisture. Nitrate contained in the plant cells of moist fresh forage is not as rapidly available to rumen microbes as the nitrate in dry plant cells, such as in dried hays. Research showed that in 20 minutes, 80% of the nitrates in dry hay were released into water but only 30% of the nitrates in fresh forage were released. The slower release rate allows rumen microbes to convert toxic nitrite to ammonia rapidly enough to avoid toxicity.

Immature annual forages are highly digestible and thus, also high energy. Higher dietary energy increases the rate of nitrite detoxification. This indicates cattle grazing immature forages may be lower risk than grazing mature forages with the same amount of nitrate. Allowing livestock to graze pastures suspected of having high nitrate levels is not without risk but proper management can reduce that risk.

Recommendations when grazing higher nitrate forages

- *Slow down intake rate*. Make sure cattle are full before putting them on fields. Regardless of the nitrate level, a good management practice is to fill cattle up with hay before turnout. Keep them full. If intake becomes restricted at any point (forage runs out or weather impedes grazing) fill them up on lower-nitrate hay before they go back to grazing the high nitrate forage.
- *Gradual adaptation* is a key management strategy to minimize risk when using high nitrate forages. Slowly increase the amount of nitrate in the diet so the number of bacteria in the rumen capable of degrading nitrate to ammonia will increase. Adapted animals can safely be fed higher levels. Adapt cattle by first grazing the lowest nitrate fields and then work up to the highest. Also, graze higher nitrate fields lightly to allow animals to selectively graze plant parts that are lower in nitrate concentration.
- *Consider grain supplementation* while feeding cattle high nitrate forages that are lower quality, such as corn plants, mature sorghum x sudangrass hybrids, or pearl millet. This will supply energy for rumen microbes to convert nitrate into bacterial protein and minimizes nitrite accumulation. Brassicas, such as turnips and radishes, are highly digestible and as such may provide enough energy to allow for increased microbial protein synthesis. Grain feeding may be of limited benefit when grazing high quality cover crops.

Table II. Feeding Guidelines of Feeds According to Nitrate Concentrations.

Nitrate Ion (NO3-)ppm	Nitrate-N (NO3-N)ppm	Recommendation for unadapted animals
<4400	<1000	Safe, nontoxic level
4400–9300	1000–2100	Safe for nonpregnant animals. Adapt pregnant animals slowly or mix with low nitrate feed.
9300–15,000	2100–3390	Limit to less than 50% of ration DM. Do not feed to pregnant animals without mixing with low nitrate feed. Adapt animals to mixture.
>15,000	>3390	Limit to less than 25% of ration DM. Do not feed without diluting with low nitrate feed. Adapt animals to feed mixture.

The risk when grazing high nitrate forages differs from feeding harvested forages (see the Grazing High Nitrate Forages section for recommendations).

Nitrate in Water

Mature livestock can tolerate higher concentrations of nitrate in their water supply than can young livestock.

Livestock drinking well water are not likely to experience nitrate toxicity. Nitrate toxicity from water is more likely to occur when livestock drink water from ponds, road ditches, or other surface impressions that collect drainage from feedlots, heavily fertilized fields, silos, septic tanks, or manure disposal lagoons. As with feed, frequent intake of water containing nitrates appears to increase the total amount of nitrate that can be consumed daily without harmful effects. However, when evaluating possible toxic situations, the nitrate in both the feed and water must be considered because they are additive.

Nitrate toxicity is not likely to occur from water containing less than 100 ppm NO_3-N, provided animals are fed a balanced ration that is not high in nitrate, and sound feeding, watering, and management practices are followed. When elusive nutrition or disease problems appear, a hasty implication of nitrate in water should not be made, even though water may contain more than 100 ppm NO_3-N. Refer to NebGuide G2060, *Water Requirements for Beef Cattle* for more details on water quality.

Treatment

When choosing to provide high nitrate feeds that could potentially cause nitrate poisoning, contact your veterinarian prior to feeding to ensure the necessary treatment is available. Nitrate poisoning can be rapidly fatal. If nitrate toxicity is suspected, remove the contaminated feed and provide a high-energy feed such as corn grain. Call a veterinarian immediately to confirm the tentative diagnosis.

Because oxygen shortage can result in death, handle cattle as little and as quietly as possible to minimize their oxygen needs. A veterinarian can administer methylene blue in a case of nitrate poisoning. An example dosage is a 4% methylene blue solution intravenously at a dosage rate of 4.55 mg per lb of body weight to treat cattle with nitrate poisoning. Treatment may have to be repeated every six to eight hours because the rumen may be full of forage or feed that contains nitrate, and nitrites will continue to move from the rumen into the blood stream. However, methylene blue is not approved for animal use and the administration of this to cattle is an off-label use. A veterinarian must determine dosage, administration, and the withdrawal date.

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