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Nitrates in Livestock Feeding

Richard J. Rasby, Beef Specialist; Bruce E. Anderson, Forage Specialist; and Paul J. Kononoff, Dairy Specialist

Nitrate poisoning does not have to be toxic to animals. Learn the symptoms, causes, preventions, and treatment of nitrate poisoning in livestock.

Nitrate poisoning in cattle occurred long before the use of nitrogen fertilizers. In the late 1800s there were reports of nitrate poisoning in Nebraska, 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 depends more on plant species and environmental conditions prior to harvest than on the amount of available nitrogen in the soil.

What is Nitrate Toxicity?

Almost all forages contain some nitrates. When feeds containing nitrates are consumed by ruminants, nitrates are changed to nitrites and finally to ammonia by the microbes in the rumen. *Nitrite* is one of the intermediate products in the breakdown of nitrate to ammonia and is the cause of nitrate poisoning. Nitrite can be absorbed into the bloodstream. Nitrite in the bloodstream changes hemoglobin to methemoglobin. Hemoglobin carries oxygen from the lungs to other tissues but methemoglobin is incapable of carrying oxygen. Thus, nitrates 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 percent of the total hemoglobin) the animal will die. The level of toxicity depends on the amount of nitrate in the feed and how fast the feed that contains nitrate is consumed. For example, it takes about twice as much nitrate to kill a ruminant when the nitrate comes from forages that are eaten over a 24 to 48 hour period of time compared to a feed high in nitrates that is consumed in a 4 to 6 hour period.

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

Reporting Nitrate Levels

Methods of reporting nitrate values in feed are shown in *Table I*. The amount of nitrate in water usually is expressed as parts per million (ppm) of nitrate nitrogen (NO_3N) or nitrate ion (NO_3^-). Both nitrate nitrogen and nitrate ion 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 (ppm)*
Nitrate nitrogen (NO_3N)	Over 0.21	2,100
Nitrate (NO_3^-)	Over 0.93	9,300
Potassium nitrate (KNO_3)	Over 1.5	15,000

Formulas for Converting Methods of Reporting.
Potassium Nitrate = Nitrate Nitrogen X 7.22
Potassium Nitrate = Nitrate X 1.63
Nitrate = Nitrate Nitrogen X 4.43
Nitrate = Potassium Nitrate X 0.613
Nitrate Nitrogen = Potassium Nitrate X 0.139
Nitrate Nitrogen = Nitrate X 0.226

Deaths in cattle have been reported when nitrate content in the overall diet contained 2,100 ppm NO_3N (9,300 ppm NO_3^-). However, rations containing more than 2,100 ppm NO_3N have been fed without cattle experiencing signs of nitrate poisoning. In a report, Missouri researchers fed rations containing 2,800 to 3,300 ppm NO_3N from sudangrass hay, and steers were slowly adapted (over at least 7 to 10 days) to the high nitrate feed and performed satisfactorily. Additional research indicates that beef heifers may safely

graze sudangrass containing high levels (over 2,100 ppm NO_3N) of nitrates. Cattle grazing pastures tend to selectively graze the leaf portion of the plant that is usually not high in nitrate, and slowly adapt themselves to feeds that may be high in nitrate. High stocking rates in a pasture suspected of high nitrate concentrations may cause cattle to consume plant parts such as lower stem bases that can be high in nitrate, increasing the possibility of nitrate poisoning. Feeding feeds high in nitrates is risky. The data sighted above suggest that cattle can be adapted to feeds high in nitrates without causing a reduction in performance or death.

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 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 having been grown under stress conditions such as:

- shading or low light intensity;
- detrimental weather, including drought, frost, hail, low temperatures;
- herbicide applications; and
- diseases.

The amount of nitrate in plant tissues also will depend on:

- plant species,
- stage of maturity,
- part of the plant, and
- nitrogen fertilization.

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 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 with nitrate for 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 nitrates to accumulate 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 times of low temperature.

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

Plants vary in the amount of nitrate that accumulates in various tissues. Certain weeds, such as pigweed, kochia, puncture vine, and lambsquarter, often are high in nitrate. Oats and millet cut for hay at an immature stage often have high nitrate concentrations. Sorghum and sudangrasses often store high amounts of nitrates. Brome and orchard grass store very little nitrate under normal growing conditions. Legumes generally do not contain high nitrate concentrations.

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 Part

Plant parts closest to the ground 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.

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, unless excessive, appears to be less important than the conditions listed previously in causing high nitrate content in forages.

Mineral deficiencies or imbalances in the soil also can influence the ability of plants to convert nitrates into nontoxic compounds. Fertilize with phosphorus and potassium according to soil test recommendations. Fertilizing with sulfur also may be beneficial, especially on low organic matter soils or on soils low in sulfur. Recent research has indicated that fertilizing with 1 pound of sulfur for every 5 pounds of nitrogen may reduce plant nitrate concentration due to better conversion of nitrates to protein.

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 percent of their nitrate content during fermentation. Fermentation of silage usually takes a minimum of three weeks. Harvest for-

ages 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, sample the silage and send to a commercial laboratory to be analyzed 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 that have the highest nitrate concentration. For 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 at 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. Such feeds are especially dangerous to feed to livestock. For example, do not green chop in the evening and then feed the green chop the next morning. Heating in the pile of green chop causes the conversion of nitrate to nitrite, making the feed about 10 times as deadly. An analysis of nitrates will help in designing feeding programs to prevent livestock losses from nitrate poisoning.

Managing High Nitrate Feed

Forages that contain high nitrate levels can be diluted in the diet with grains or with other forages low in nitrates and then can be fed safely *(Table II)*. This can be accomplished easily in feedlot rations where grain is fed and forages are chopped and mixed as a complete ration. Feeding grain in combination with high nitrate feeds helps reduce the effect of the nitrate content. Energy from the grain apparently helps complete the conversion of nitrate to bacterial protein in the rumen.

Frequent intake of small amounts of a high nitrate feed increases the total amount of nitrate that can be consumed daily by livestock without adverse effects, and helps livestock adjust to high nitrate feeds. Cattle losses to nitrate toxicity usually occur in hungry cattle that have not had time for adjustment to feeds with potentially toxic levels of nitrates. For example, cattle that go without feed for a day or longer during snow storms often rapidly eat a large amount when finally gaining access to feed. If the feed they receive is high in nitrates, cattle losses may occur. If cattle are allowed to adjust to feeds that have potentially toxic levels of nitrates, they will develop a population of microbes in the rumen that convert nitrates to a non-toxic form. Care must be taken when feeding feeds that contain nitrates.

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.

Livestock should have access to clean water at all times. Follow sound management practices conducive to a successful feeding program when high nitrate feeds are fed.

Allowing livestock to graze pastures suspected of having high nitrate levels is not without risk. Observe livestock frequently when they begin grazing a new pasture that is suspected of nitrates to detect any signs of nitrate toxicity. Implementing one or more of the following management practices will reduce the risk of livestock losses to nitrate toxicity.

- Don't overstock suspected pastures.
- Don't strip-graze suspected pastures.
- Provide other feeds that contain little or no nitrate during grazing.
- Graze suspected pasture during the day and remove at night the first week to reduce the amount of pasture consumed and to acclimate cattle.
- If possible, don't graze suspected pasture until one week after a killing frost.

Do not feed hay, straw, or fodder suspected of being high in nitrate when it is damp. Damp feed seems to be more toxic because some of the nitrate already has been converted to the more toxic nitrite before being consumed.

Corn 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 to 8 inches will reduce the amount of nitrates in the silage. Yield will be reduced but so will nitrate level. Ensiling drought damaged corn can reduce nitrates in the silage 40 to 60 percent. Before feeding drought damaged corn silage, allow it to go through at least a 21-day fermentation period before feeding. Shorter fermentation times may cause some of the nitrates to still be in the dangerous nitrite form, just like heated green chop.

There is a direct-fed microbial product available that reduces rumen nitrate and nitrite concentrations. Bova-Pro® can be fed as a "top-dress" on feed or given as a bolus. Bova-Pro populates the rumen with microbes that produce enzymes that convert nitrates and nitrites that enter the rumen to a non-toxic form. If this product is used to manage against high nitrate feeds it is important that all animals get the proper amount to

Table II. Feeding guidelines of feeds according to nitrate concentrations.

Nitrate Ion (NO_3)ppm	*Nitrate-N (NO_3-N)ppm*	*Recommendation*
<4,400	<1,000	Safe, non-toxic level
4,400-9,300	1,000-2,100	Safe for non-pregnant animals. Adapt pregnant animals slowly or mix with low nitrate feed.
9,300-15,000	2,100-3,390	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	>3,390	Limit to less than 25% of ration DM. Do not feed without diluting with low nitrate feed. Adapt animals to feed mixture.

establish the needed microbial population. Also, it is still recommended to adapt cattle to the high nitrate feed over a period of time. Bova-Pro is approved for both beef and dairy cattle.

Using feeds that contain high nitrate concentrations is not without risk, but feeds that contain nitrates can be fed successfully. Use the management practices mentioned above to reduce the chance of animal loss. Extensive losses can occur when non-acclimated, hungry livestock are permitted unlimited access to high nitrate feeds.

Nitrate in Water

Mature livestock can tolerate higher concentrations of nitrate in their water supply than can young livestock. In the case of calves, however, much of their fluid intake is derived from nursing and very little nitrate is secreted in milk.

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_3N, 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_3N. Refer to NebGuide *G2060, Water Requirements for Beef Cattle* for more details on water quality.

Treatment

Nitrate poisoning can be rapidly fatal. When nitrate is suspected, remove the contaminated feed and provide a high energy feed such as corn. A veterinarian should be called immediately to confirm the tentative diagnosis. Because death is a result of oxygen shortage, handle cattle as little and as quietly as possible to minimize their oxygen needs.

Administer a 4 percent 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. Mineral oil may be given orally to protect the irritated mucous membranes. When many animals are affected, additional methylene blue may be obtained from your local veterinarian.

Sampling and Testing Feeds for Nitrates

The cost of testing for nitrates is inexpensive so get representative samples of questionable feeds analyzed by a laboratory before feeding. 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 in an amount to fill a plastic bag that can be sealed at the top. Compress the air out of the bag and seal. The sample is now ready to send to the laboratory for analysis. Send samples early in the week to avoid weekend delays in delivery of the samples to the laboratory. 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 described above. Samples should be frozen between days or whenever kept in storage.

Long stem hay should be sampled using a hay probe. Sample bales or stacks that represent the suspected hay. For baled hay, probe about 20 different bales, and for hay stacks, sample each stack in six different areas to obtain a representative sample. Transfer the sample to a plastic bag, and compress the air out and seal before sending the sample to the laboratory. Refer to NebGuide *G331, Sampling Feeds For Analyses* for more details on sampling.

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.

It is difficult to obtain a representative sample from pastures suspected of 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. It is recommended you not test grazed forages for nitrate, but manage the grazing of such forages to reduce the problems due to nitrates, as mentioned above.

Most commercial feed laboratories will analyze feeds for nitrates. Contact your local extension office to obtain information regarding laboratories in your area that test feeds for nitrates. When reading nitrate level reports, be sure to note what method of reporting is used.

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