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NebGuide

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Nitrates in Livestock Feeding

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This NebGuide describes signs, causes, prevention and treatment of nitrate poisoning in livestock.

What is Nitrate Toxicity?

Most forages contain some nitrates. When feeds containing nitrates are consumed by ruminants, nitrates are changed in the rumen to ammonia that is then converted by bacteria in the rumen into microbial protein. Nitrates are not always toxic to animals.

Nitrite is one of the intermediate products in the conversion of nitrate to ammonia and is the cause of nitrate poisoning. Some nitrite is absorbed into the bloodstream and 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 risk of toxic levels depends both 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 eaten over a long period of time compared to a supplement or a drench consumed quickly.

Signs of Nitrate Toxicity

Brownish discoloration of the blood, due to the presence of methemoglobin, is evidence 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, lack of coordination, diarrhea, frequent urination, collapse, and death.

Nitrite in blood also causes blood vessels to dilate and is responsible for peripheral circulatory failure. Abortion due to nitrate toxicity may be accompanied or preceded by some evidence of nitrate problems in the adult animal, including chocolate-colored blood and bluish discoloration of unpigmented areas of the skin or mucous membranes. There appears to be two different mechanisms that cause abortion due to nitrate toxicity. The mechanism of action that causes abortion immediately following nitrate toxicity is likely due to death of the fetus. It is speculated that the decreased oxygen carrying capacity of the maternal blood and decrease in maternal blood pressure lowers the perfusion pressure and transfer of oxygen to the fetus causing hypoxia and death. Abortions that occur from one week to two weeks following toxicity appear to be due to dead or impaired placental function.

Reporting Nitrate Concentrations

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^-)

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

	Potentially Toxic Amounts	
	(%)	*(ppm)*
Nitrate nitrogen (NO_3N)	Over 0.22	2,260
Nitrate (NO_3^-)	Over 1.0	10,000
Potassium nitrate (KNO_3)	Over 1.6	16,300

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

Both nitrate nitrogen (NO_3N) and nitrate ion (NO_3^-) will be used to evaluate and discuss nitrate concentrations in feed and water in this NebGuide.

Deaths have been reported when nitrate content in the overall diet contained as little as 0.21 percent NO_3N (0.93 percent (NO_3^-). However, rations containing substantially more than 0.21 percent NO_3N have been fed without harm. One such instance was reported from Missouri where re-

searchers fed rations containing 0.28 to 0.33 percent NO_3N from sudangrass hay. Steers were slowly adapted to the high nitrate feed and performed satisfactorily.

Recent research indicates that beef heifers can safely graze sudangrass that contains high concentrations (0.21 percent NO_3N) of nitrates. Sudangrass can contain up to 0.65 percent NO_3N (28,690 ppm (NO_3^-), but cattle grazing these pastures tend to selectively graze the leaf portion of the plant that is not high in nitrate, and slowly adapt themselves to feeds that may be high in nitrate. If stocking rates are heavy for a pasture suspected of high nitrate concentrations, it may cause cattle to consume plant parts such as stem bases that are high in nitrate, increasing the possibility of nitrate poisoning.

Causes of High Nitrates in Forage

Nitrates taken up from the soil by plant roots normally are incorporated into plant tissue as amino acids, proteins, and other nitrogenous compounds. The primary site for converting nitrates to these 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; and (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) 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. 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 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 (13°C) for active growth and photosynthesis. Nitrates can be absorbed quickly by plants when temperatures are low, but conversion to amino acids and protein occurs 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 temporarily high nitrate content. 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 nitrates 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. Oats cut for hay at an immature stage often have high nitrate content. Cane, millets, sorghums, and sudangrass often contain high concentrations of nitrates, even when weather and other conditions suggest nitrate concentrations should be low. Test hay, silage, and green chop for nitrates before feeding for maximum safety. Brome and orchardgrass store very little nitrate under normal growing conditions. Legumes generally do not contain high nitrate concentrations. Certain weeds, such as pigweed, kochia, puncture vine, and lambsquarter, often are high in nitrate. The nitrate content of some representative forages sent to the University of Nebraska for nitrate analyses is shown in *Table II.*

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.

Table II. NO_3N Content of Feedstuffs, Dry Basis

	Number of Analyses	*Average NO_3N %*	*Range of NO_3N Low %*	*Range of NO_3N High %*
Alfalfa				
Dehy	430	.055	.014	.191
Hay	56	.055	.014	.136
Silage	13	.027	0	.082
Beet pulp	2	.082	.068	.083
Corn				
Green chop	11	.177	.027	.395
Silage	66	.109	0	.600
Stalks	12	.273	0	.818
Kochia (fireweed)	4	.055	0	.082
Oats				
Hay	11	.177	0	.545
Silage	3	.123	0	.272
Pasture				
Bluestem	6	.014	0	.027
Bromegrass	19	.109	.014	.300
Clover	3	.068	.041	.109
Pigweed	7	.600	.055	1.091
Prairie hay	22	0	0	.014
Sorghum				
Stalks (milo)	11	.055	0	.368
Silage	40	.068	0	.020
Sudangrass				
Green chop	16	.355	.027	.655
Hay	12	.068	0	.450
Silage	2	.041	.027	.055
Potentially toxic amount		.21		

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

Nitrogen Fertilization. Nitrates in the soil are the source of nitrates in plants. While a positive relationship exists between soil nitrates and nitrates 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 Concentrations

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.

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 corn or sorghum silage should be harvested as near maturity as possible. If the corn or sorghum field being harvested as silage has been identified as or is suspected of having high nitrate concentrations, *raise the cutter head to selectively avoid the base of the stalk that has 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 in an immature stage and fed to cattle in the form of green chop. High nitrate feeds that are green chopped and piled in mounds or are allowed to heat before feeding are especially dangerous to feed to livestock. Heating causes faster conversion of nitrate to nitrite, making the feed about ten times as deadly. An analysis of nitrates will help in designing feeding programs to prevent livestock losses from nitrate poisoning.

Harvested by Grazing. Nitrates are most highly concentrated in the lower stem base of pasture plants and nitrate concentration of leaves usually is well below potentially toxic levels. Because selective grazing by livestock causes them to avoid the higher nitrate content in lower stems, livestock grazing green, growing pastures rarely experience nitrate toxicity. In addition, if stocking levels are low enough to permit cattle to selectively graze lower nitrate leaves when they initially graze a pasture containing potentially toxic levels of nitrate, cattle can slowly adapt themselves to high nitrate diets before consuming plant parts containing these higher nitrate concentrations.

However, nitrate toxicity can occur during grazing. It is most common when unadapted, hungry animals are stocked heavily on potentially toxic pasture and forced to eat the higher nitrate stem bases or when the pasture contains an abundance of nitrate-accumulating weeds. Nitrate toxicity also can occur shortly after fertilizing pasture with nitrogen, especially when liquid forms are used and before rain or irrigation wash the nitrogen off the foliage.

Managing High Nitrate Feed

Forages that contain high nitrate content can be diluted in the diet with grains or with other forages low in nitrates and then can be fed safely. This can be accomplished easily in dairy and 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.

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 nitrate can be fed in combination with hay low in nitrate with less 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.

A balanced ration tends to reduce problems from nitrates in the ration. The adverse effects of feeding livestock feeds that have high nitrate concentrations appear to be greater if the ration is not balanced properly. When feeding feeds that are high or suspected to be high in nitrate, make sure the ration is balanced nutritionally for vitamins (A and E), macro- minerals and trace minerals.

Allowing livestock to graze pastures suspected of having high nitrate contents is not without risk. Implement one or more of the following management practices to 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.

Observe livestock frequently when they begin grazing a new pasture that is suspected of nitrates to detect any signs of nitrate toxicity.

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.

Using feeds that contain high nitrate concentrations is not without risk, but feeds high in nitrate 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.

Nitrates in Water

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

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. Some acute nitrate toxicity of beef cattle in Nebraska has resulted from hauling drinking water in improperly rinsed nitrate fertilizer tanks. Livestock drinking well water (ground water) are less likely to be exposed to hazardous nitrate concentrations unless contaminated shallow wells are used as sources of water supply.

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. Remember that the total nitrate intake is what contributes to toxic condition. For example, the analyzed nitrate content in a feed and in the drinking water may indicate that by themselves they would not cause a toxic situation, but if consumed together in the total diet they may cause nitrate toxicity. The nitrate content in the feed and water supply 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 G85-763 Nitrate Nitrogen in Drinking Water* for more information.

Treatment of Nitrate Poisoning

Nitrate poisoning can be rapidly fatal. When nitrate poisoning 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 four percent (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. Mineral oil may be given orally to protect the irritated mucous membranes.

When many animals are affected, additional methylene blue is available and can be obtained from the three University of Nebraska veterinary diagnostic laboratories in Lincoln, North Platte, and Scottsbluff.

Sampling and Testing Feeds for Nitrates

Feeds can be tested for nitrate levels. The most important step in getting an accurate nitrate test is gathering a sample that accurately represents the diet of the animal.

When sampling suspected silage 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. The sample is now ready to send to the laboratory for analysis. Samples may be either chilled or frozen if a delay in shipping is anticipated.

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 above. Sampling as feed is put into the silo can give a preliminary estimate of eventual nitrate content, but the amount of nitrate reduction during fermentation is inconsistent so sample and test prior to feeding for a more accurate estimate of nitrate level.

Sample long hay using a hay probe. Because it is useful to determine the highest nitrate level that the animals will be exposed to, identify bales or stacks to sample that came from fields or portions of fields that were most likely to cause high nitrate levels (droughty, immature, heavily fertilized with nitrogen, etc.). For baled hay, probe 15 to 20 different bales and for hay stacks, sample each stack in several different areas to obtain a representative sample. Transfer the sample to a plastic bag, compress the air out, and seal before sending the sample to the laboratory.

Refer to *NebGuide G77-331 Sampling Feeds For Analysis* for more details on sampling.

It is difficult to obtain a representative sample from pastures suspected of nitrates. 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.

Most commercial feed laboratories will analyze feeds for nitrates. Contact your local Extension office to obtain information on laboratories in your area that test feeds for nitrates.

Table III. Guidelines for Nitrates in Feedstuffs (expressed on dry basis)

NO_3^-, ppm	*Recommendations*
0 - 5,000	Considered safe to feed.
5,000 - 10,000	Safe to feed to nonpregnant animals. May be best to limit to 50% of the ration on a dry matter basis to pregnant animals. Adapt cattle slowly. Total dietary nitrate concentrations should not exceed 5,000 ppm NO_3^- for pregnant animals.
10,000-15,000	Limit to 25% of the total blended dry matter in the ration to pregnant and 50% of the ration of non-pregnant animals. Adapt all cattle slowly.
15,000 - 20,000	Limit to 20% of the total blended dry matter intake to non-pregnant animals. Do not feed to pregnant animals. Adapt slowly. High risk of nitrate toxicity.

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