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MontGuide

Nitrate Toxicity of Montana Forages

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High nitrate levels frequently occur in forage crops, particularly in small grains grown under drought stress. This publication outlines strategies for avoiding nitrate toxicity, including proper management, monitoring forage nitrate levels and appropriate feeding programs.

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FORAGE CROPS CAN ACCUMULATE TOXIC AMOUNTS of nitrate (NO_3). High nitrate has been reported in cereal grains (oats, rye, wheat, barley, triticale, etc.), bromegrass, orchardgrass, fescue, sorghum, sudangrass, millet, corn, sweetclover and alfalfa. Several weeds, such as kochia, lambs- quarter, pigweed, quackgrass and Russian thistle, can also have high nitrate levels, especially when growing under adverse conditions.

Nitrate poisoning of livestock was reported as early as 1895. Livestock losses occurred for many years before elevated nitrate levels in forage were determined to be the cause of death. The term "oat hay poisoning" was the common explanation for livestock losses in the 1930s, because large acreages of oats were harvested for forage during drought years.

Nitrate toxicity

Nitrate itself is not toxic to animals, but at elevated levels, it can cause a noninfectious disease called **nitrite** poisoning. Nitrate normally found in forage consumed by ruminant animals is broken down to nitrite (NO2) and then to ammonia (NH3). The ammonia is then converted to protein by microbes in the rumen (second compartment of the ruminant stomach). Ruminant animals with high nitrate levels in their diets accumulate nitrite. Nitrite is absorbed into the blood and combines with hemoglobin to form methemoglobin, which causes a reduction in the ability of the blood to carry oxygen from the lungs to body tissues. When the blood can no longer supply oxygen to the body, the animal can suffocate.

Symptoms of nitrate poisoning

Signs of early or chronic toxicity:

- Watery eyes
- Reduced appetite
- Reduced milk production
- Rough hair, unthrifty appearance
- Weight loss or no weight gain
- Signs of Vitamin A deficiency\
- Abortion

Signs of acute toxicity:

- Accelerated pulse rate
- Labored breathing, shortness of breath
- Muscle tremors
- Weakness
- Staggering gait
- Cyanosis (membranes such as the tongue, mouth, vulva and the whites of eyes, turn blue)
- Death

Treatment of nitrate poisoning

Acute nitrate toxicity can occur very rapidly, sometimes within minutes of observing the first symptoms. Oxygen transport in the blood is sharply reduced, and the venous blood becomes chocolate brown in color.

In these cases, the only way to save an affected animal is an immediate intravenous dose of methylene blue by a veterinarian. Due to the risk and speed of nitrate poisoning, treating livestock after they consume toxic levels of nitrate is not a good option. Therefore, producers should be aware of species, growing conditions and management strategies to reduce potential nitrate toxicity.

Nitrate levels in plants

Nitrogen from the soil is taken up by plant roots in the form of nitrate. Plants convert nitrate (NO_3) to nitrite (NO_2) which in turn is converted to ammonia and then to amino acids, the building blocks of protein. Nitrate levels cycle during a 24-hour period; during the night, nitrate accumulates when photosynthesis is inactive, then during the day, nitrate is quickly converted to protein. Under normal growth conditions, there is little nitrate buildup, even though plant roots are absorbing large amounts of nitrate, because protein conversion keeps pace with root absorption. However, in certain conditions, this balance can be disrupted so that the roots will accumulate nitrate faster than the plant can convert the nitrate to protein. Abnormal growing conditions such as drought, frost, unseasonable or prolonged cool temperatures, hail, shade, disease, high levels of soil nitrogen, soil mineral deficiencies or herbicide damage can cause high nitrate accumulation in forages.

When do toxic levels occur?

All plants contain nitrate, but nitrate levels toxic to livestock are mostly associated with forages (hay, fodder, silage, pasture or weeds). Crops grown under "stress" conditions or on soils that have received high applications of manure or nitrogen fertilizer are suspect (Table 1).

Avoid cutting when nitrate concentrations are at peak levels. For example, toxic levels of nitrate can accumulate in forages immediately after a drought-ending rain or irrigation. Since peak nitrate levels occur in the morning, delay haying or grazing until the afternoon of a sunny day.

Nitrate toxicity is most likely to occur when livestock are pastured or fed green-chop, followed by hay. Silage is the least hazardous feed. Ensiling forage usually lowers the nitrate level 10 to 60 percent. The nitrate level in hay will usually remain constant or decline slightly in storage.

Producers should never assume their forage levels are safe if they know a crop was exposed to any adverse growing conditions that increase nitrate accumulation. Higher nitrate levels are usually present in immature plants (vegetative to the boot stage in small grains) and decrease as plants mature (milk to dough stage in small grains). Nitrate concentration is highest in the stems, especially in the lower third of the stem, and at the nodes. An intermediate level usually exists in leaves, and very little is found in the grain.

The effects of sub-lethal nitrate levels on livestock health and performance are not well-defined. In Montana, chronic symptoms such as abortions and poor winter health are of concern because we rely on hay during pregnancy and lactation. Safe and unsafe levels of nitrate in livestock feed have been established. Despite these guidelines, the effects of nitrate vary among individual animals, condition and age of livestock, other feeds in the diet and weather.

Sampling plants or feeds for nitrate

Take precautionary measures if you suspect high nitrate concentrations prior to harvesting or feeding forage. Even under ideal conditions, nitrate accumulation is unpredictable. Nitrate concentration can vary in areas of a single field, haystack or silo. Therefore, nitrate testing is advised in many situations. Most MSU Extension Service agents can provide the "Nitrate QuikTest," which is a rapid, qualitative test for high nitrate levels.

Prior to harvest, sample standing crops such as oats or barley. Collect 20 stems randomly by traversing in a zigzag pattern across an entire field. Clip the plants at ground level and test them with an Extension agent trained in nitrate testing. If nitrate is detected using the qualitative test and growing conditions are normal, delay harvest for several days, which will usually reduce nitrate levels rapidly. Periodic testing may be necessary to assure that the nitrate level has declined. Use the qualitative test as a preliminary screening measure, and submit forages suspected of having elevated levels of nitrate for laboratory analysis. Nitrate levels can be quantitatively determined by numerous commercial laboratories (see your Extension agent for a list).

Sampling hay or haylage (low moisture silage) for nitrate requires collection and testing of appropriate samples. An accurate measurement of forage nitrate is not possible unless the sample analyzed in the laboratory is representative of the forage lot in question. Poor sampling techniques or an inadequate number of subsamples are the main sources of error in analysis.

For hay, sample and composite at least 20 random bales from a lot using a hollow core probe. (A hay lot is defined as the hay from a single field that is uniform in maturity and harvested within a 48-hour period.) At least one pound of forage is necessary for an adequate sample. Keep representative silage samples frozen until analysis to prevent nitrogen losses from volatilization or chemical changes. Seal hay and silage samples in plastic bags and ship to the laboratory for testing.

Nitrate laboratory reports

Results of nitrate analysis may be confusing because of the variation in methods of reporting. Further confusion and questions exist because of varying guidelines on what levels of nitrate can be fed safely. In the chemical analysis for nitrate, the actual element determined is the oxidized nitrogen. However, values may be reported as percent nitrate (NO_3), nitrate-nitrogen (NO_3-N), or potassium nitrate (KNO_3). Efforts have been made to have nitrate analysis and tolerances for safety uniformly reported as nitrate-nitrogen on 100 percent dry matter basis. However, at present, reports may be given as nitrate or nitrate-nitrogen and, likewise, may be reported as either percent or as parts per million (Table 2).

Nitrates in forages and feed

Nitrate risk is generally characterized as the concentration of NO_3 in a forage or feed. Based on numerous research trials, levels of nitrate toxicity have been developed (Table 3).

Table 1. Typical nitrate concentrations reported in common feeds and forages

	Reported on 100% dry basis as:			
Feed	**Nitrate-Nitrogen in parts per million NO_3-N (ppm)**	**Nitrate-Nitrogen as percent of plant NO_3-N (%)**	**Nitrate in parts per million NO_3(ppm)**	**Nitrate as percent of plant NO_3(%)**
Oat hay at heading, 60 lbs. N/acre	402	0.0402	1781	0.1781
Oat hay at heading, 120 lbs. N/acre	1920	0.1920	8506	0.8506
Oat hay at anthesis, 60 lbs. N/acre	262	0.0262	1161	0.1161
Oat hay at anthesis, 120 lbs. N/acre	1307	0.1307	5790	0.5790
Oat hay at soft dough, 60 lbs. N/acre	485	0.0485	2149	0.2419
Oat hay at soft dough, 120 lbs. N/acre	1267	0.1267	5613	0.5613
Barley hay at heading, 60 lbs. N/acre	265	0.0265	1174	0.1174
Barley hay at heading, 120 lbs. N/acre	1077	0.1077	4771	0.4771
Barley hay at anthesis, 60 lbs. N/acre	179	0.0179	793	0.0793
Barley hay at anthesis, 120 lbs. N/acre	899	0.0899	3983	0.3983
Barley hay at soft dough, 60 lbs. N/acre	196	0.0196	868	0.0868
Barley hay at soft dough, 120 lbs. N/acre	593	0.0593	2627	0.2627
Oat grain	10	0.0010	44	0.0044
First crop alfalfa, vegetative	414	0.0414	1800	0.1800
First crop alfalfa, bud	437	0.0437	1900	0.1900
First crop alfalfa, 10% bloom	345	0.0345	1500	0.1500
Second crop alfalfa, vegetative	736	0.0736	3200	0.3200
Second crop alfalfa, bud	483	0.0483	2100	0.2100
Second crop alfalfa, 10% bloom	276	0.0276	1200	0.1200
Alfalfa hay	400	0.0400	1760	0.1760
Alfalfa silage	200	0.0200	880	0.0880
Fresh chopped corn (before ensiling)	1000	0.1000	4400	0.4400
Corn silage (after ensiling)	500	0.0500	2200	0.2200
Corn grain	5	0.0005	22	0.0022
Soybean oil meal	1	0.0001	4	0.0004

Nitrate in water

In addition to forages and other feeds, drinking water can contribute to nitrate toxicity. Soluble nitrate can pose a greater risk, because the nitrate is immediately available. Therefore, threshold hazard levels are lower than those for feeds. Nitrate and nitrite are water soluble, and they move with the water.

Nitrate applied to the soil or produced in the soil may be leached or washed away by moving water. Nitrate is more concentrated below or near areas of waste accumulation or disposal, such as manure piles, feedlots, septic tank disposal fields and cesspools. Excess nitrate is more likely to be found in ground water under low areas and waterways that collect or convey. Water samples from shallow, dug, bored and driven wells more frequently contain excess nitrate than water from deeper, drilled wells. Nitrate levels generally are highest following wet periods and lowest during dry periods. Therefore, test wells immediately following a wet period.

Guidelines for feeding livestock

Due to the variations existing in plants, livestock and water sources, it is difficult to develop specific guidelines that fit all conditions. The nitrate concentrations and risks listed in Table 3 assume that high-nitrate forages comprise the entire diet, rather than a portion of a ration. For example, a 700-pound steer may have nitrate toxicity after consuming 17 pounds of barley hay that contains 10,000 ppm NO_3. However, if hay intake is limited to eight pounds per day, no problems may occur. For this reason, the best recommendation for potential nitrate risk is to express total NO_3 consumption on a bodyweight basis (Table 5). The following guidelines were developed conservatively to help assure safety. Reasonable feeding and care of the animal is assumed. Safe levels of nitrate are not specifically known for all various livestock feeding conditions.

Forages with sub-lethal nitrate levels can be fed to livestock with appropriate precautions. If there is a potential nitrate problem, growers should first have an accurate laboratory analysis of nitrate concentration.

Table 2. Converting one form of nitrate to another.

	To convert reported data to one of these multiply by:	
Reported as	**NO_3-N**	**NO_3**
Nitrate-nitrogen (NO_3-N)	(1)	4.4
Nitrate (NO_3)	0.23	(1)

Examples: 0.1% NO_3-N = 0.44% NO_3 (0.1 x 4.4);
0.44% NO_3 = 0.1% NO_3-N (0.44 x 0.23)
0.1% = 1000 ppm (move decimal point four places to the right)
750 ppm = 0.075% (move decimal point four places to the left)

Table 3. Effect of nitrate concentration on livestock.
(Note: These guidelines for Montana are more conservative than those published from other states.)

Reported on 100% dry matter basis* as:		
NO_3-N (ppm)	**NO_3 (ppm)**	**Comment**
<350	<1500	Generally safe for all conditions and livestock
350-1130	1500-5000	Generally safe for nonpregnant livestock. Potential early-term abortions or reduced breeding performance. Limit use to bred animals to 50% of the total ration.
1130-2260	5000-10,00	Limit feed to 25-50% of ration for nonpregnant livestock. **DO NOT FEED TO PREGNANT ANIMALS** — may cause abortions, weak calves and reduced milk production.
>2260	>10,000	**DO NOT FEED.** Acute symptoms and death.

*If nitrate content of a feed is reported on an "as is" basis, convert to 100% dry matter basis to compare it to levels in this table. For example, silage at 50% moisture that contains 600 ppm NO_3-N on an "as is" basis contains 1200 ppm on 100% dry basis; thus it fits the second group in this table.

No single level of nitrate is toxic under all conditions. In some instances, cattle can safely convert the nitrate present at up to two percent of the total dry matter of the ration, or about 20 grams of nitrate per 100 pounds of body weight.

In addition to the variations in plant and environmental factors that contribute to nitrate toxicity, there can be extreme variability among livestock for predisposal to nitrate toxicity. In feeding trials where toxic doses of nitrate were administered to a uniform group of beef cattle, there were three-fold differences among animals in rate of blood methemoglobin formation. Diet and the environment of the rumen can significantly impact the tolerance of individual livestock to nitrate. Livestock that are thin or suffer from respiratory infections are more prone to nitrate toxicity. High-energy grains stimulate the rumen microbes to convert nitrate to nontoxic amino acids and proteins at a faster rate.

Observe these precautions when feeding high-nitrate forages:

- feed hungry livestock prior to exposure,
- graze or cut forages in the afternoon
- adapt livestock gradually to increasing levels of the suspect forage,
- dilute with low-nitrate feeds, and
- feed grain with the hay.

Consult with your local Extension agent and veterinarian for specific questions regarding nitrate poisoning or sampling of forage suspected of containing dangerous levels of nitrate.

High-nitrate feeds can be diluted with low-nitrate feeds to reduce the nitrate hazard by using the following equation:

$W_L = (W_H)$ (%H - %B) / (%B - %L), where
W_L = weight of safe, low-nitrate hay required,
W_H = weight of high-nitrate hay,
%H = nitrate concentration of high-nitrate hay,
%B = nitrate concentration desired in final blend,
%L = nitrate concentration of low-nitrate hay required for blending.

For example, a producer with 10 tons of hay tested at 0.6 percent (6000 ppm) nitrate, could blend 15 tons of hay tested at 0.1 percent (1000 ppm) to produce 25 tons of feed with 0.3 percent (3000 ppm) nitrate. The two hay lots should be processed and mixed thoroughly in a tub grinder to provide the proper dilution. Levels of non-protein nitrogen (urea, etc.) and nitrates in drinking water should be considered in rations blended to reduce nitrate problem.

References

Fjell, D., D. Blasi, and G. Towne. 1991. Nitrate and prussic acid toxicity in forage: causes, prevention, and feeding management. Kansas St. Univ. Coop. Ext. MF-1018, 4 pp.

Hibbard, C.A., T.G. Rehberger, J. Swartzlander and T. Parrott. 1998. Management of high nitrate forages for beef and dairy cattle. Oklahoma Agr. Exp. Sta. Conference Proceedings.

Undersander, D., D. Combs, T. Howard, R. Shaver, M. Siemans and D. Thomas. 1999. Nitrate poisoning in cattl e, sheep and goats. Univ. Wisconsin Coop. Ext. http://www.uwex.edu/ces/

Table 4. Guidelines for use of drinking water with known nitrate content.

NO_3-N (ppm)	NO_3 (ppm)	Comment
< 10	< 44	Generally regarded as safe for all animals and humans.
10-20	44-88	Questionable or risky for humans, especially young children and pregnant women. Safe for livestock unless feed also has high levels. Animals drinking 10 pounds of water per 100 pounds of body weight would have intake of less than 0.1 gram NO_3-N per hundred pounds of weight if water contains 20 ppm NO_3-N.
20-40	88-176	Considered unsafe for humans; may cause problems for livestock. If ration contains more than 1000 ppm NO_3-N and the water contains over 20 ppm, the total NO_3-N is likely to exceed safe levels.
40-100	176-440	Unsafe for humans and risky for livestock. Be sure that feed is low in nitrate and a well-balanced ration is fed. Fortify ration with extra vitamin A.
100-200	440-880	Dangerous and should not be used. General or non-specific symptoms such as poor appetite are likely to develop. Water may also be contaminated with other foreign substances. When allowed free choice to cows on a good ration, acute toxicity not likely.
> 200	> 880	**DO NOT USE**. Acute toxicity and some death losses might occur in swine. Probably too much total intake for ruminants on usual feeds. In research trials, water containing up to 300 ppm NO_3-N has been fed to swine and water containing over 1000 ppm of NO_3-N has been fed to lambs without causing any measurable growth or reproductive problems. However, for farm recommendation the suggestions given above are purposely conservative.

Table 5. Determining total (feed and water) nitrate uptake.

Total daily intake in grams per 100 pounds body weigh		
NO_3-N	**NO_3**	**Comment**
< 0.5*	< 2.0	Generally safe for all conditions and livestock.
0.5–1.4	2.0–6.0	Generally safe for nonpregnant livestock. Potential early-term abortions or reduced breeding performance. Limit use to bred animals and to 50 percent of the total ration.
1.4–2.8	6.0–12.0	Limit feed to 25–50 percent of ration for nonpregnant livestock. **DO NOT FEED TO PREGNANT ANIMALS** — may cause abortions, weak calves and reduced milk production.
>2.8	>12.0	**DO NOT FEED**. Acute symptoms and death.

*Values in this table are calculated from the levels given in Table 3 for feeds when feed intake is 3.0 pounds per 100 pounds of body weight (3.0% DMI - dry matter intake). When livestock are exclusively consuming high-quality forages, % DMI can approach 3%; lower-quality roughages are typically less than 2%. Be cautious with intake levels of hay barley, which can exceed over 4.5% DMI.

Example: A 1000-pound cow consuming 12 grams of NO_3 in the water and feed each day would be a considered “safe” at this intake level. However, if consumption was 12 grams in water and another 50 grams in feed, total intake is 62 grams, or 6.2 grams per 100 pounds of weight—potential danger.

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