Nitrate Poisoning in Ruminants

WASHINGTON STATE UNIVERSITY EXTENSION FACT SHEET • FS139E

Introduction

Nitrate poisoning can kill large numbers of livestock when new feed is improperly introduced to a herd. Problems with nitrate poisoning can occur in grazing, hay, and silage situations when plant stress occurs in any form, but especially from inadequate irrigation or rainfall when nitrogen fertility is high, or when certain weeds known to be nitrate accumulators are present. Nitrate levels in summer forages should be monitored carefully as increased levels are more likely to occur in second and third cuttings of both grasses and legumes. Simple preventative steps can be taken to reduce the likelihood of significant loss of livestock to nitrate poisoning. This fact sheet discusses nitrate poisoning, its symptoms, its treatment, and what can be done to lower the risk of poisoning.

Nitrate Poisoning

Nitrate poisoning is characterized by elevated nitrate levels in the body. During normal digestion in ruminants, nitrate (NO_3) is converted to nitrite (NO_2) in the rumen. Rumen microbes convert nitrite to ammonia (NH_3), which is used by microbes to make amino acids and new microbial protein. If an animal consumes large amounts of nitrate, the rumen microbes cannot keep pace with the conversion of nitrites to ammonia, so excessive rumen nitrite levels can accumulate. If nitrites reach high levels, they can enter the bloodstream and be absorbed by red blood cells. When nitrites combine with oxygen-carrying hemoglobin, methemoglobin is formed and red blood cells can no longer transport oxygen. The result is functional suffocation of the animal.

Symptoms and Treatment of Nitrate Poisoning

The symptoms that indicate an animal is suffering from nitrate poisoning include increased heart and respiratory rates. Also, the animal's tissues (whites of eyes, around the nose) and blood may take on a bluish or chocolate-brown tinge. Tremors and staggering occur and the animal eventually suffocates. If nitrate poisoning is diagnosed quickly enough, a 4% solution of methylene blue injected intravenously at a rate of 100 cc per 1,000 lb of body weight may prevent death. This procedure should be performed under the supervision of a veterinarian.

Plants Most Susceptible to Nitrate Accumulation

Virtually all crops and weeds have the capability of accumulating nitrates. However, grass species have a greater tendency to accumulate nitrates compared to broadleaf plants (Table 1).

Table 1. Crops, weeds, and vegetables known to be nitrate accumulators.

Field Crops					
alfalfa	canola	flax	oats	sorghum	sudangrass
barley	corn	millet	rape	soybean	wheat
beet tops	fescue	mustards	rye	sweetclover	
Weeds					
bindweed	Canada thistle	goldenrod	lambsquarter	ragweed	sunflower
blue-green algae	carelessweed	jimsonweed	mustards	Russian thistle	velvetweed
bull thistle	elderberry	johnson grass	nightshade	smartweed	white cockle
burdock	fiddleneck	kochia	pigweed	stinging nettle	
Vegetables					
beets	cucumbers	lettuce	parsnips	spinach	Swiss chard
celery	kale	mangel wurzel	radishes	squash	turnips

Combined from Allison 2010, Stoltenow, and Lardy 2008

Alfalfa, timothy, bromegrass, orchardgrass, and ladino clover are species less likely to accumulate nitrogen but will do so if plants come under stress from heat, moisture, or an imbalance in soil fertility (Crawford et al. 1961).

Nitrates Accumulating in Hay

Several other factors may promote nitrate accumulation in forages. Nitrogen fertilizer rate, stage of maturity, amount of sunlight, and the part of the plant harvested for forage have all been identified as factors having a significant impact on nitrate accumulation. In general, any condition that puts crops under significant stress, such as temperature, drought, and frost, can cause nitrate accumulation. Therefore, nitrate testing of forage is recommended before feeding stressed forages. A lab test is much cheaper than the death of even one ruminant or one aborted calf. An example of what can happen when forage is not tested is a dairy farm that used one round bale of high nitrate feed grown under water stress, which killed 50% of the herd and half of the cows left alive quit producing milk (Bohle personal communication).

If irrigation water will be lacking after the first cutting of timothy hay, delay harvest for the first cutting to maximize tonnage. Fertilize only enough for the first cutting, typically half of the total normal nitrogen rate (Fransen and Hudson 2005). Do not irrigate the second cutting and allow the timothy crop to remain dormant until adequate water is available. Be sure to test forages grown during a drought for high nitrates.

Stems accumulate nitrogen more than leaves and seed heads do. In a corn plant, the highest nitrate level is at the base of the plant. Consequently, one method to reduce nitrate accumulation in corn silage is to cut silage higher than normal. Forage harvested in the vegetative stage is more likely to have nitrate accumulation than when it is in the boot or dough stage.

Nitrates accumulate and are stored in the vacuoles of plant cells (Granstedt and Huffaker 1982) and move from the vacuole to the cytoplasm, where nitrogen is used in metabolism, such as protein and DNA/RNA synthesis. Since nitrates are stored in vacuoles, plants maintain high nitrate levels longer after stress periods or after being harvested.

Prevention of Nitrate Poisoning

When growing forages, be aware of conditions that may cause increased nitrate levels, such as high nitrogen fertilization, crop species, and the part of the plant being fed or grazed. Certain weeds accumulate high levels of nitrate and can create dangerous situations if animals eat them. The average nitrate content for pigweeds tested in Nebraska was 26,400 ppm, which is highly toxic (Rasby et al. 2007). Proper grazing of grass may be safer than feeding hay because animals will most likely eat the top part of the plant, where nitrate concentrations are lower. Thus, overgrazed pastures under temperature or drought stress may lead to greater nitrate toxicity problems. If animals are forced to eat the whole plant, such as in strip grazing or in overgrazed conditions, there will be no difference in risk between grazing and haying. To reduce the level of nitrates in corn silage or other grasses known to be high in nitrate, harvest the plant higher than normal because nitrate levels are highest in the lower stalk. Testing for nitrates and following feeding recommendations based on nitrate content is a good way to prevent nitrate poisoning. Introduce questionable feed slowly over several weeks, allowing rumen microbes time to adapt to it; this will help reduce the likelihood of nitrate poisoning. Also, dilution of high nitrate feed with low nitrate feed is a very practical way of dealing with high nitrate forages, but special care must be taken to monitor the daily amounts to mitigate nitrate risk. It is also important to watch nitrate levels in water sources because immature animals are particularly sensitive to this source.

Methods for Sampling Forage

How forage is sampled is critical to protecting your ruminant animals from nitrate poisoning. If forage will be grazed, select a representative sample of the part of the plants that will be consumed. Always remember the upper portion of plants will be lower in nitrate than the bottom portion of the plant. If grazing is limited, sample the upper one-third of the plant. With rotational grazing or strip grazing, use a more conservative approach and sample the lower one-third to one-half of the plant. Sample at least 20 locations in the field to get an average of the nitrate concentration present. Place the samples in a paper bag to send to the lab or to conduct a quick test. When sampling baled hay, use a forage sampler and take 20 to 30 cores to get a good testing average. When testing large stems, such as corn or sorghum sudan, you must test the lower stem portions separately, in case some animals get to the hay late and only eat this portion.

The best way to find a good laboratory for forage testing is to use the National Forage Testing Certification website at http://www.foragetesting.org/. Click on certified labs for the most current year.

Forage Test Kits

Forage test kits for quick testing are available from different suppliers and can be vastly different in user safety and methods used. It is important to use a test kit that provides a control in order to ensure the kit is working properly, and use the kit according to the instructions provided. If the quick test is positive, it is generally best to have a professional lab test the samples in order to get a good quantitative assessment. Montana State University, using their own test kit, found that 34% to 43% of the forages tested in their state were potentially toxic to ruminants (Cash et al. 2005).

Laboratory Reports for Nitrate Levels

Nitrate levels are reported differently depending on which laboratory and references are used. First, make sure the nitrate is reported on a 100% dry matter basis. If it is not, convert it to a 100% dry matter basis. Check to see if the units are in percent (%) or parts per million (ppm).

Table 2. Nitrate–nitrogen and nitrate level categories toxicity ratings and comments.

NO_3–N ppm	NO_3 ppm	Rating	Comments
0 to 564	0 to 2,500	Safe	Considered safe in most circumstances.
568 to 1,136	2,500 to 5,000	Generally safe	Safe when fed in balanced rations. Limit to 50% of ration dry matter for pregnant animals. Check water for nitrates.
1,136 to 3,409	5,000 to 15,000	Danger	Limit to 25% of ration dry matter. Feed with a balanced ration. May encounter production losses and reproductive problems.
3,409 to 7,500	15,000 and 33,000	Toxic	Do not feed free choice. Feed only less than 15% of dry matter in a total mixed ration.

Adapted from Ball et al. 2002

To convert percent to ppm, move the decimal point four places to the right (Example: 0.2% = 2,000 ppm). Check to see if the laboratory reports NO_3 (nitrate) or NO_3-N (nitrate nitrogen). To convert NO_3-N to NO_3, multiply by 4.4 (Example: 0.1% NO_3-N = 0.44% NO_3).

Strategies for Feeding Higher Nitrate Forage

In general, it is recommended that nitrate levels (NO_3) not exceed 10,000 ppm (1%) of the ration on a dry matter basis for non-pregnant cows (Schneider 2012; Brownson and Zollinger 1996). Pregnant cows could have abortions if the NO_3 level is above 5,000 ppm. Do not turn hungry cows out onto high nitrate feed. Some animals have died from feed with NO_3 levels as low as 1,000 ppm when they have gorged themselves in a short amount of time. Livestock have some ability to adjust to nitrate levels if given enough time (Anonymous n.d.). To promote the safe use of forage, Table 2 provides suggested forage-feeding guidelines based on ppm of nitrate-N and nitrate (NO_3).

Nitrates in Water

In most situations, water with high nitrate levels will not be an issue because these levels have to be above 100 ppm NO_3- N, which is not likely, especially if the water comes from a well or is river water (Rasby et al. 2007). Nitrate problems are much more likely if livestock are drinking from ponds, road ditches in drainage areas from feedlots, silos, septic tanks, lagoons, or drainage from heavily fertilized fields. Nitrate problems are additive, so feed and water should be considered together when animals are consuming high levels of either of these.

Conclusions

Prevention of nitrate accumulation by not over-fertilizing, testing suspect forages, introducing new feed slowly, and limiting feeding of high nitrate feeds will help reduce the risk of nitrate poisoning. Applying these steps in the day-to-day operations of a livestock operation will assist in protecting livestock health.

References

Allison, C. 2010. Nitrate Poisoning of Livestock. *New Mexico State University Guide* B-807. New Mexico State University. http://aces.nmsu.edu/pubs/_b/b-807.pdf.

Ball, D.M., C.S. Hoveland, and G.D. Lacefield. 2002. *Southern Forages*. 3rd ed. Norcross, GA: Potash and Phosphate Institute.

Brownson, R., and B. Zollinger. 1996. Nitrates in Cattle and Water. *Cooperative Extension System Cattle Producers Library* CL355. http://www.uwyo.edu/ces/psas/documents/cl355.pdf.

Cash, D., J. Hagler, L. Keddington, R. Carlstro. 2005. Nitrate QuikTest for Rapid Detection of High Nitrate Levels in Forages. *Journal of Extension* 43, Article 1. http://www.joe.org/joe/2005february/iw6.php.

Crawford, R.F., W.K. Kennedy, and W.C. Johnson. 1961. Some Factors That Affect Nitrate Accumulation in Forages. *Agronomy Journal* 53: 159–162.

Fransen, S., and T. Hudson. 2005. Drought Advisory – Timothy Hay. *Washington State University Publication* EM4919E. Washington State University. http://cru.cahe.wsu.edu/CEPublications/em4919e/em4919e.pdf.

Granstedt, R.C., and R.C. Huffaker. 1982. Identification of the Leaf Vacuole as a Major Nitrate Storage Pool. *Plant Physiology* 70: 410–413.

Provin, T.L., and J.L. Pitt. 2003. Nitrates and Prussic Acid in Forages—Sampling, Testing and Management Strategies. *Texas A&M Agrilife Extension Publication* E-543. Texas A&M University. http://varietytesting.tamu.edu/forages/otherpublications/Nitrate.pdf.

Rasby, R.J., B.E. Anderson, and P.J. Kononoff. 2007. Nitrates in Livestock Feeding. *University of Nebraska-Lincoln NebGuide* G1779. University of Nebraska-Lincoln. http://ianrpubs.unl.edu/live/g1779/build/g1779.pdf.

Schneider, N.R. 2012. Overview of Nitrate and Nitrite Poisoning, in *The Merck Veterinary Manual*. http://www.merckmanuals.com/vet/toxicology/nitrate_and_nitrite_poisoning/overview_of_nitrate_and_nitrite_poisoning.html.

Stoltenow, C., and G. Lardy. 2008. Nitrate Poisoning of Livestock. *North Dakota State University Extension Service Publication* V-839. Revised May 2008. North Dakota State University. http://library.ndsu.edu/tools/dspace/load/?file=/repository/bitstream/handle/10365/5324/v839.pdf?sequence=1.

Vough, L.R., E.K Cassel, S.M. Barao. 2012. Nitrate Poisoning of Livestock—Causes and Prevention. *South Dakota State University Cooperative Extension* ExEx 4015. South Dakota University. http://pubstorage.sdstate.edu/AgBio_Publications/articles/ExExx4015.pdf.

Yaremcio, B. ed. 1991. Nitrate Poisoning and Feeding Nitrate Feeds To Livestock. Agri-Facts Publication Agdex 400/60-1. http://www1.foragebeef.ca/$foragebeef/frgebeef.nsf/all/ccf57/$FILE/nitrate-poisoning.pdf.

WASHINGTON STATE UNIVERSITY EXTENSION

By **Steve Norberg**, Agriculture Extension Regional Specialist, WSU Franklin County, Pasco, WA; and **Don Llewellyn**, Extension Area Educator, WSU Benton County, Kennewick, WA.

When medicating animals, you must use over-the-counter medications and products exactly as instructed on the label and follow all instructions on how long to withhold meat and milk produced from treated animals for human consumption after treatment. If your veterinarian determines it is necessary for your animal's health that you give a non-approved product or a different dose of an approved product, it is legal as long as you follow specific requirements from the FDA, including having a valid veterinarian-client-patient relationship, following the veterinarian's recommendations exactly and keeping detailed and accurate records of the animal's identity, medication used as well as its lot number, dose administered, administration route, person who administered the dose, date and meat and milk withholding times; keep such records for at least three years. Your veterinarian will tell you how long to withhold meat and milk produced from the treated animal after medication is administered.

Issued by Washington State University Extension and the U.S. Department of Agriculture in furtherance of the Acts of May 8 and June 30, 1914. Extension programs and policies are consistent with federal and state laws and regulations on nondiscrimination regarding race, sex, religion, age, color, creed, and national or ethnic origin; physical, mental, or sensory disability; marital status or sexual orientation; and status as a Vietnam-era or disabled veteran. Evidence of noncompliance may be reported through your local WSU Extension office. Trade names have been used to simplify information; no endorsement is intended. Published July 2014.

FS139E