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Nitrate Toxicity

Nitrate poisoning (methaemoglobinaemia) is always a concern for producers growing summer annuals for forage and for pastures receiving applications of swine or poultry waste. It is not uncommon, as many annual plants, including wheat, may accumulate nitrates under moisture stress. Symptoms are seldom obvious in livestock. Often, the first signs noticed by producers are coma or death.

Some farmers test a field for nitrates by turning in a "sacrifice animal" to see if it shows any abnormal behavior or dies. A word of warning is in order here. When one animal is turned into a field, it will lightly graze the new leaves, which contain the lowest concentration of nitrates in the plant. Thus a sacrifice animal may not detect a high nitrate problem that will show up latter when the herd is turned in and heavier grazing occurs.

What Causes High Levels of Nitrates in Forages?

Most plants take up nitrogen from the soil primarily in the form of nitrate. Under normal conditions, this poses no animal health problem because nitrate is rapidly converted into nitrite (NO2), then to ammonia (NH3), then into plant proteins and other nitrogenous compounds. When plant growth is slowed or stopped because of moisture stress or other stress, nitrate continues to be taken up by the plant but it cannot be changed into other forms fast enough, and therefore, nitrate accumulates. This is when nitrate poisoning can occur. The stresses that slow plant growth and cause nitrate to accumulate to toxic levels are normally drought or frost. However, small grains actively growing in the fall or spring have been shown to accumulate nitrates at toxic levels during several cloudy or overcast days. Additionally, spraying 2,4-D or 2,4-DB may cause increased nitrate accumulations in some plants.

Certain plants are more likely to accumulate toxic levels of nitrate than others. Pearl millet, Johnsongrass, sorghum, sudangrass, pigweed, lambsquarter, and oats are known to be accumulators. These plants may contain toxic levels of nitrate when other plants growing beside them will not. For instance, a fertilized and drought-stressed bermudagrass pasture may not result in any animal heath problems, but the same pasture containing pigweed would cause animal deaths if the pigweed were eaten. In a Missouri study, sudangrass, orchardgrass, and tall fescue accumulated nitrate at high levels; smooth bromegrass and ladino clover were intermediate; and alfalfa and wheat had only low levels.

Nitrate levels will be highest in the stalks or stem bases and lowest in the new leaf growth. Nitrate content can change dramatically (either higher or lower) from day to day. Once cut for hay, nitrate levels do not change appreciably. However, ensiling high nitrate material will cause a portion of the nitrates to be converted to a brown gas (Nitrous Oxide) and given off. Thus silage becomes safer to feed, but it can remain toxic. The brown-colored gas (Nitrous Oxide) given off by fermenting high nitrate silage is poisonous, and care must be taken when near the silo while forage is fermenting. This is especially true when venting the top of and upright, airtight silo.

Why Test Forages for Nitrates?

Nitrates themselves are relatively nontoxic. Their importance as a cause of poisoning is due to their conversion, either in the feedstuff or in the animal's digestive tract, to nitrite. The nitrite ion (NO2) oxidizes ferrous iron in blood hemoglobin to the ferric state, for methemoglobin, which is unable to act as an oxygen carrier. If enough of the hemoglobin is changed to methemoglobin, the lack of oxygen causes the animal to suffocate (tissue anoxia).

Sub-lethal symptoms of nitrate poisoning are seldom very apparent. Signs of abdominal pain and diarrhea are seen due to the irritant action of nitrate ions. Muscular weakness and incoordination, convulsions, and accelerated heart rate accompany this. Abortion may occur in pregnant animals. In severe cases, progressive cyanosis occurs, which is first visible as a bluish discoloration of the mucous membranes and unpigmented areas of the body and leads to torpor, coma, and death. Dead animals will have discolored, dark, tar-like blood (chocolate color blood).

Nitrate in the diet (feed or water) at moderate levels will cause reduced milk production, lowered rates of gain, and reproductive difficulties. At higher levels, death will result. The exact level at which a given response occurs depends on the condition of the animal and the energy level of the ration. Cattle in good condition can tolerate 50 percent of the hemoglobin being changed to methemoglobin with ill effects, while this could be lethal to cattle in poor condition. High levels of energy in the ration speed up the reduction of nitrate in the rumen to ammonia and detoxifies it.

Fasting increases the susceptibility to nitrate poisoning. Cattle feeders do not "fast" their cattle on purpose of course, but drought frequently leaves the cattle with little to eat. This commonly results in cattle that are in poor condition, that have low-energy diets, and that will gorge themselves if given the opportunity. All these factors will increase the severity of a given level of nitrate ingestion.

There appears to be some degree of adaptation to high nitrate levels. Animals that have gradually increased levels of nitrate in their diet tend to be able to tolerate higher levels of nitrate than animals first exposed to the higher levels.

The variable effects of nitrate make it difficult to make an absolute statement as to the actual toxic dose of nitrate.

Nitrate Sampling Procedures

The potential for nitrate poisoning can be assessed by being aware of the growing conditions prior to harvest. Plant stress indicates the potential for nitrate toxicity, especially when it is coupled with high nitrogen application rates, either inorganic (fertilizer), or organic (animal waste).

Before feeding forages that may be high in nitrate, first take a sample and send it in for laboratory nitrate analysis. The most critical factor in obtaining accurate and reliable information regarding nitrate levels in the forage is proper and careful sampling of the forage. For hay or silages, take several representative samples, mix them together thoroughly, and send a sample of the mixture to the laboratory. Sample silage after fermentation is completed because nitrate levels may be slightly lowered from that of the freshly chopped sample. In pastures, it is important to sample the entire portion of the plant that the animal will be eating. Remember that young leaves on top of the plant will tend to have a lower nitrate level than other parts of the plant.

Interpretation of Results

The results should be used as a guideline, rather than a guarantee. The results will be reported as a percent of nitrate (NO3) on a dry matter basis.

% Nitrates (NO3)	Comments
0.00% to 0.44%	Considered safe for feed.
0.44% to 0.66%	Limit pregnant animals to no more than 50% of the total dry matter in the ration. Considered safe for non-pregnant animals.
0.66% to 0.88%	Limit all livestock 50% of the total dry matter in the ration.
0.88% to 1.54%	Do not feed to pregnant animals. Limit non-pregnant animals to no more than 35% to 40% of the total dry matter in the ration.
1.54% to 1.76%	Do not feed to pregnant animals. Limit non-pregnant animals to no more than 25% of the total dry matter in the ration.
Over 1.76%	Do not feed. Likely to be toxic.

Symptoms of nitrate poisoning include staggering, muscular tremors, convulsions, rapid pulse, and dark-colored visible membranes.*

**** Contact a veterinarian immediately if any of these symptoms appear.***

Feeding Precautions

When feeding forages with elevated levels of nitrates, appropriate precautions should be taken.

1. Consider the class and condition of the animals to receive the forage. Animals such as milking cows and stockers, from whom a high level of productivity is expected may show reduced performance at lower levels than indicated in the chart. Animals in poor condition will be affected by lower levels of nitrate than animals in good to excellent condition.

2. Do not allow animals to gorge themselves on high-nitrate forages. Be sure that animals have not been fasted so that they will not eat excessive amounts.

3. Dilute high-nitrate forages with low-nitrate forages. Do this by feeding less high nitrate forages or by limiting the time animals are allowed to graze. Be sure to feed the forages at different times so that all animals consume some of each. If a big bale of high-nitrate hay is simply put alongside a bale of low-nitrate hay, some animals will eat only one type and those eating the high-nitrate hay may show symptoms of nitrate poisoning. Remember that nitrates convert to nitrite in hay that has become wet making it much more toxic.

4. Feed an energy supplement. An energy source, such as corn grain, will increase the rate of nitrate metabolism to ammonia in the rumen, thereby detoxifying it.

The standard treatment for animals suffering from acute nitrate toxicity is an intravenous injection of a reducing agent, generally methylene blue solution. The reducing agent converts methemoglobin to oxyhemoglobin and reverses the effect of nitrite. Treatment should be repeated in severe cases.

Bibliography

"Nitrate Toxicity," Bruce Pinkerton, Clemson University CES; Don Ball, Auburn University CES; Jim Green, North Carolina State University CES, 1998.