Nitrate Toxicity in Livestock

Gary Strickland
Extension Educator
Agriculture/4-H/CED

Chris Richards
Associate Professor, Beef Cattle Extension Specialist

Hailin Zhang
Director of Soil, Water,
Forage Analytical Laboratory

D.L. Step, DVM
Assistant Professor
Veterinary Clinical Sciences

Oklahoma Cooperative Extension Fact Sheets are also available on our website at: **http://osufacts.okstate.edu**

Nitrate Poisoning

Farmers and ranchers depend on the successful combination of livestock and crops. Forage crops, in particular, are important to the producer, but they should be monitored due to plant toxicants that can be a problem. One toxicosis of concern is Nitrate ($N0_3$) toxicity.

Nitrate toxicity of cattle was noted as early as 1895 with corn-stalk poisoning. However, at that time nitrate was not recognized as the principle toxicant. In the late 1930s, after an outbreak of oat-hay poisoning in the high plains region, an indictment of nitrate was finally made. The term “Nitrate Toxicity” should actually be “Nitrite Toxicity.” When nitrate is ingested by a ruminant animal, it undergoes a chemical reduction action to nitrite. This reduction is accomplished by rumen microorganisms. Nitrite is readily absorbed into the bloodstream where it oxidizes the ferrous iron of the red blood pigment hemoglobin to ferric iron producing a modified red blood pigment called methemoglobin. Methemoglobin is incapable of transporting oxygen to various body tissues so the animal exhibits a characteristic chocolate brown blood color prior to and during death which is caused by asphyxiation. Ruminant animals affected in this manner by high nitrate feeds are said to be suffering from methemoglobinemia. Simple stomached animals such as swine and poultry do not have the microorganisms which can make this rapid conversion and are not as susceptible to nitrate toxicity.

The environmental scenarios that enhance accumulation of nitrates are similar to those of prussic acid, see OSU Fact Sheet PSS-2904, “Prussic Acid Poisoning in Livestock.” However, the location of the toxicant within a plant is different. Therefore, it is necessary to be familiar with plant factors, livestock factors, and management practices to safely utilize forages that have the potential of this toxicosis.

Plant Factors in Nitrate Accumulation

Practically all plants contain detectable amounts of nitrates. Excessive nitrate accumulation occurs when the uptake of nitrate exceeds its utilization in plants for protein synthesis. The sorghum plant has been noted as having a high potential for accumulating nitrates. However, with proper management this crop offers a great potential as a feed source. The following factors are related to nitrate accumulation in plants:

1. Plant species vary in their ability to accumulate nitrate (Table 1). Even common barnyard weeds can cause problems.

   Management: If nitrate accumulation is of concern in your area, select sources of feed that have lower accumulation potential. Consider the environmental conditions for that year and manage inputs to accommodate lower accumulation potential.

2. Stalks are highest in nitrate content, followed in order by leaves and grain in decreasing amounts.

   Management: Research with piper sudangrass, sorghum sudangrass, and pearl millet has shown that the lower six inches of the stem contains 3 times more nitrate than does the top part of the plant. Elevating the cutter bar above this six inch point can potentially lower nitrate levels.

3. Immature or young plants have a greater potential for nitrate accumulation than older plants (such as those with seed in the hard dough stage).

   Management: Be cautious when turning livestock in on a field that is still immature in growth. Hungry livestock are not as likely to selectively graze leaves over stems so allow them to feed before releasing them on a field. Always test fields of concern prior to releasing livestock on them.

4. Any weather condition which reduces plant growth may increase nitrate accumulation. This includes drought and sometimes cool, cloudy weather.

Table 1. Generalized rating of some forage grasses and forbs in their nitrate accumulation potential.

High Potential		Low Potential
Grasses	Forbs	
Barley	Horsenettle	Bermudagrass
Bromegrass	Kochia	Bluestem
Corn	Lambsquarter	Buffalograss
Fescue	Morningglory	Gramagrass
Johnsongrass	Pigweeds	Weeping lovegrass
Oats	Puncturevine	
Rescuegrass	Russianthistle	
Rye	Sunflower	
Sorghum		
Sudangrass		
Wheat		
Pearl millet		

Management: This condition is obviously out of your control. However, it is important to be aware of the weather conditions for that year and how they have affected your crop. The quantity of nitrate in a plant which is dangerous to ruminants is sufficient for only 2 to 4 days of active plant growth. Thus, problems created by weather usually disappear after a few days of sunshine, adequate moisture, and proper temperatures (70°F for small grains and 85°-90°F for sorghums). The exception to this would be late-planted material or regrowth that has been hit by a frost and immediately after a drought-ending rain. Research with millets has shown that 7 to 14 days are required for nitrate to return to safe levels after a drought-ending rain.

5. Forages high in nitrate will exhibit lower nitrate levels after being ensiled due to the microbial activity in the fermentation process.

   Management: Ensiling is one option when dealing with higher nitrate forage sources. However, caution should still be taken as ensiling corn has been reported to reduce nitrates by a range of only 20-50%. Therefore, if silage was put up with nitrate concentrations of 10,000 - 20,000 ppm, then the potential for high nitrate levels would still exist. If the silage has less than 10,000 ppm nitrate concentration levels, the range of use may be improved. If high nitrates are a concern prior to the ensiling process, silage should be tested before feeding.

6. Excessive use of nitrogen fertilizer may contribute to the problem.

   Management: Apply 50 pounds of actual nitrogen per acre as a preplant application and then the same amount after each cutting (refer to OSU Fact Sheets PSS-2225 and PSS-2568) for sudangrass being cut for hay. If grazing, a second application should only be made if adequate moisture and growing conditions exist and subsequent secondary growth is allowed. Research has sho-wn no significant differences between this application and a one time 100-pound application in terms of nitrate accumulation. However, research has shown the trend for greater nitrate accumulation with higher application rates (Table 3). Therefore, this is a conservative approach in managing for low nitrates.

7. Acid soils and phosphorus deficient soils will increase plant nitrate accumulation.

   Management: Soil testing is a necessity for any successful farming operation. Apply phosphorus fertilizer and ag-lime as determined by a soil test. The OSU soil testing laboratory recommends maintaining a soil pH greater than 5.5. Phosphorus fertilizer requirements vary depending on the soil test value of the field.

Pearl Millet and Nitrates

Pearl millet's ability to accumulate nitrates has often been confused with its reported freedom from prussic acid. It is accepted that pearl millet does not offer a prussic acid problem. However, when it comes to nitrate accumulation the opposite is true. Pearl millet has been noted to accumulate significantly higher quantities of nitrates than does sudangrass. This usually occurs in times of environmental stress. Pearl millets will cease growth earlier in stress conditions than will sudangrass, thus, allowing a buildup of nitrates in a greatly reduced plant volume. Recent Oklahoma research confirms this observation.

Oklahoma Research

A study conducted at three Oklahoma agronomy research field stations (near Haskell, Chickasha, and Tipton) found that when hot weather stress occurred, pearl millet contained greater concentrations of nitrate than did sudan x sudan, sorgo x sudan, or sorghum x sudan hybrids

Table 2. Average nitrate concentrations in ppm for four forage types at three locations grown in two years.

		Location	
Forage Type	Haskell	Chickasha	Tipton
SMXSU*	7795	3302	7049
SOXSU	7291	3255	6673
SUXSU	8079	3461	7190
PM	14122	6572	10534

*SMXSU=sorghum-sudangrass; SOXSU=sorgo-sudangrass; SUXSU=sudan-sudan; PM=pearl millet

Table 3. Average nitrate concentrations (ppm) of hybrid sudangrass hay grown under different nitrogen fertilizer schemes.

		Treatment		
0 lb. N	* 50 lb.	100 lb. N	150 lb. N	200 lb. N
3631	6282	6098	7083	8432

*Applied at planting and after each harvest.

(Table 2). A smaller but similar study ten years previously in central Oklahoma gave very similar results. When plants were stressed, pearl millets accumulated nitrates to a greater degree than sorghum forage plant types. When no stress was apparent, all the plant types were low in nitrate concentration and smaller differences were found.

Nitrogen fertilizer rates can also impact nitrate accumulation in livestock forage feeds. A study summarizing 220 sorghum forage samples illustrates the effects of nitrogen fertilizer at planting and after successive cuttings (Table 3). With the exception of the 50 and 100 pound treatments, nitrate concentration increases were noted in hybrid sudangrass hay with each increase in nitrogen application rate. Treatment 1 had no nitrogen fertilizer applied. Treatment 2 had 50 lbs. of actual nitrogen per acre applied at planting and after each harvest. Treatments 3, 4, and 5 had 100 lbs., 150 lbs., and 200 lbs. of actual nitrogen applied at planting time. The average concentration of nitrates from the hay produced from these plots is presented in Table 3. These data are from the Eastern Oklahoma Research station near Haskell and the South Central Oklahoma station near Chickasha. Eleven different harvests were produced in two growing seasons between 1990 and 1991.

Livestock Factors Related to Nitrate Poisoning

Despite a producer's best efforts to avoid growing forages that contain dangerous concentrations of nitrate, occasionally, drought-stricken pastures of hay crops produce feeds that test high in nitrates. There may be methods of handling the high nitrate hays or pastures that reduce the risk of death or production losses. However, if the forage has extremely high concentrations of nitrate, such as 25,000 ppm, then the risk to livestock health is very great even when all known management techniques are employed. Burning, or burying that forage may be the only safe alternative. Knowledge of the following livestock factors will aid in a producers decision on how to either prevent or manage the effect of high nitrate feed sources.

1. Thin cattle in poor health or those suffering from respiratory disease are more susceptible to nitrate poisoning.

2. Allow hungry cattle to fill prior to release. If cattle are hungry, take time (1 to 3 days) to make sure they are consuming a significant quantity of a bulky forage such as good quality grass hay. Then, release the cattle in the afternoon when they are not as hungry.

3. Adapt cattle to nitrate. The objective is to give the ruminal microorganisms the opportunity to adapt to high nitrate intake. With high nitrate hay, this can be accomplished by blending with low nitrate feeds such as grass hay or concentrates. Grain feeding has the additional benefit of providing ruminal energy to stimulate the conversion of nitrate to nontoxic nitrogen compounds. With grazed high nitrate forages, palatable, low nitrate hay or concentrates can be used. Another alternative with grazed forage is to limit grazing for the first 6 to 8 days by increasing the grazing time each day. For example, cattle might be allowed to graze high nitrate forage for 2 hours on the first day and increase by 2 hours each day for 6 days after which cattle could be released full time onto the high nitrate forage. Another strategy with grazed forage would be to feed the animals several times a day (3 to 5 times) to disrupt grazing periods and provide ruminal fill to decrease the rate and extent of consumption of the high nitrate feed.

4. Dilute high nitrate feeds with low nitrate feeds. Dilution is one method that can be used to help ruminal microorganisms adapt to high nitrate feeds. But, it may also be the only practical method that can be used to feed high nitrate forage (>10,000 ppm). Dilution is most effective when the low nitrate feed can be blended or mixed directly with the high nitrate feed.

5. Utilize propionibacteria. Some strains of propionibacteria are capable of rapidly reducing nitrate to nontoxic nitrogen compounds. Once established in the rumen, they have the capability of reducing ruminal nitrite and blood methemoglobin concentrations by 40 to 50%. A patent-pending product (developed by researchers at Oklahoma State University) containing propionibacteria (Bova-Pro™; FarMor Biochem, Milwaukee, Wisconsin) is available as either a feed additive or gel paste. The feed additive must be fed for a minimum of 8 days. The gel paste is administered similarly to gel paste type dewormers. With either method, hold animals off high-nitrate forages for 10 days from the time treatment ends to allow an adequate population of propionibacteria to become established in the rumen. Although the propionibacteria can effectively reduce the probability of nitrate toxicity, other methods of nitrate management should also be employed to minimize nitrate exposure.

6. Release cattle in the afternoon after they have been fed a low-nitrate safe feed. In addition, avoid grazing shortly after a drought-ending rain.

7. Stock lightly so animals can choose lower nitrate leaves over higher nitrate stems.

8. Provide large quantities of fresh drinking water. Water dilutes nitrate concentrations in the rumen and reduces the potential of toxicity.

9. Do not allow livestock to have direct access to fertilizer materials containing nitrate. Losses have occurred because cattle had access to storage areas, fertilizer spreaders, broken bags of fertilizer, or fertilizer spills in pastures.

10. Cattle in cold or inclement weather are more susceptible to nitrates and are more likely to consume stalks which contain more nitrate.

Nitrate Management Scenarios for Livestock

The objective of this section is to present four scenarios selected to illustrate the major concerns relative to a specific situation and the types of management that could be applied to minimize the effects of nitrate consumption.

Scenario 1: High nitrate hay as an emergency feed for beef cows.

Concerns:
- What is the stage of production (month relative to calving date)?
- What is the nitrate content of the hay?
- How much hay will the cows eat?

Management:
- Determine susceptibility of cows based on stage or production. Calculate potential nitrate from hay nitrate analysis and projected hay intake.
- Sort bales by nitrate content:
  Feed low to moderate nitrate bales (<10,000 ppm) as emergency feeds. Feed higher bales (>10,000 ppm) as a supplemental feed (4-8 lb/cow/day).
  Consider discarding extremely high nitrate bales (25,000 ppm).
- Consider some combination of the following:
  Watch weather and start feeding low to moderate nitrate hay prior to inclement weather to adapt ruminal microorganisms to nitrate. Slowly increase feeding level so that cows are adapted by the time the storm arrives. During snow or ice cover, cows can consume an extremely large quantity of hay (25-35 lb/cow). If hay is fed during cold, open weather, intake will likely be less (8-15 lb/cow) and dependent on feeding rate.
- Feed high energy grain cubes to dilute nitrate intake and provide energy to stimulate microbial detoxification of nitrate.
- Establish propionibacteria (feed for 8 days or give gel paste) prior to nitrate exposure to minimize the effects of nitrate intake.

Scenario 2: High nitrate hay as a supplemental feed for wintering beef cows

Concerns:
- What is the nitrate content of hay?
- How much hay do the cows need to eat?

Management:
- Determine the potential nitrate exposure based on hay intake and forage nitrate concentrations.
- Sort bales by nitrate content: Feed low to moderate nitrate bales (<10,000 ppm) as emergency feeds.
  Feed high nitrate bales (>10,000 ppm) as a supplemental feed (4-8 lb/cow/day).
  Discard extremely high nitrate (25,000 ppm) hay.
- Consider some combination of the following:
  Adapt cattle with low to moderate nitrate hay by slowly increasing the feeding level.
  Feed high energy grain cubes to dilute nitrate intake and provide energy to stimulate microbial detoxification of nitrate.
- Establish propionibacteria (feed for 8 days or give gel paste) to minimize the effects of nitrate intake.

Scenario 3: Summer grazing of sorghum/sudan by beef stockers

Concerns:
- What is the nitrate potential?
- Have cattle recovered from shipping stress?

Management:

Evaluate the potential nitrate exposure based on environmental conditions and previous management decisions. Stressed, hungry cattle should not be released directly on to potentially toxic forage. If necessary, delay release. Use the opportunity to put the cattle through a recovery program so that ruminal function and health status are normal. Consider some combination of the following:
- Adapt cattle to nitrate by increasing levels of high nitrate feeds harvested in previous years.
- Adapt cattle to sorghum/sudan forage by progressive limit grazing for 5 to 7 days.
- Feed a high energy receiving ration to stimulate ruminal recovery and increase ruminal energy prior to release.
- Feed frequently to disrupt grazing patterns and provide a fill.
- Establish propionibacteria (feed for 8 days or give gel paste) to minimize the effects of nitrate intake.
- Consider releasing in the afternoon when cattle are full and appetite is low.

Scenario 4: Dairy cows are fed a diet that contains 50% corn silage (DM basis) harvested during a dry summer and consume water that is known to be high in nitrate.

Concerns:
- What is the nitrate content of the corn silage?
- What is the nitrate content of the water?

Management:

Calculate total nitrate intake to evaluate risk.
- Silage nitrate concentration: 10,000 ppm
- Water nitrate concentration: 200 ppm

A 1,500 lb. holstein producing 100 lbs. milk/day will consume about 58 lbs. dry feed and 40 gallons of water.

58 lbs. Dm x 50% silage = 29 lbs. DM from silage

29 lbs. Dm x 10,000 ppm or 1.0% (.01) nitrate= .29 lbs. nitrate
.29 lb. nitrate x 454 grams per lb. = 131.66 grams nitrate
Total nitrate from silage = 131.66 grams per day

40 gallons of water x 8 lbs. per gallon = 320 lbs. of water
320 lbs. water x 200 ppm or .02% (.0002) nitrate = .064 lb. nitrate
.064 lb. nitrate x 454 grams per lb = 29.06 grams nitrate
Total nitrate from water = 29.06 grams nitrate per day

Total nitrate intake per day (silage + water) = 160.66 grams

58 lbs. DM feed x 454 grams/lb. = 26332 grams of feed per day
160.66 grams nitrate/26332 grams feed per day = 6101 ppm nitrate in total diet

This quantity of nitrate is within the range where milk production may be reduced and although unlikely, mid-to-late term abortions may occur. Acute toxicity, however, is even less likely to occur.

Evaluate alternative roughage sources. To completely compensate for water nitrate, silage intake must be reduced by 75 percent and replaced by another high quality forage. This level of corn silage may not be worth the trouble. Perhaps other, low nitrate forages should be purchased for use with the high producing cows. The higher nitrate corn silage could be mixed with other low nitrate forage for dry cows or other less productive animals.

Evaluate alternative water sources. If wells are the water source, consider drilling a deeper well to potentially draw lower nitrate water. Also, evaluate other water sources such as rural or city water. If surface water is used, determine the source of the nitrates (manure runoff, excess fertilizer, etc) and attempt to control the nitrate source.

Establish propionibacteria (feed for 8 days or give gel paste) to reduce nitrate effects in the rumen. **Caution:** Propionibacteria do not have a demonstrated effect on subacute nitrate toxicity. Observe milk production closely when starting to feed high nitrate forages to lactating dairy cows. If a dramatic drop in milk production is noted, consider purchasing alternative forages immediately.

Factors Associated with Nitrates in Hay

Nitrate in plant tissue persists after harvest and can cause problems even in well-cured hay. Sudangrass and its hybrids have often caused problems. Conditions that lead to high nitrate accumulation in sorghum and sudangrass types of hay are similar to those mentioned in the sections covering plant and livestock factors. However, one additional factor that should be mentioned when considering hay, is the large round baling system.

This system increases the danger of nitrate accumulation because the distribution of nitrate accumulation in sorghum plants is not uniform throughout a field. Nitrate accumulation often occurs in isolated or “hot spot” areas (Figure 1). One large bale may be high in nitrates while others are low because the large bale gathers and concentrates the forage from a “hot spot” into a feeding unit.

Laboratory Analysis for Nitrate

Hay samples can be accurately tested for nitrate content by the OSU Soil, Water, and Forage Analytical laboratory or by the Oklahoma Animal Disease Diagnostic Laboratory. Your local county Cooperative Extension Service office can provide information about the test and help you submit samples. They can also provide information on a qualitative test called the diphenylamine test. The diphenylamine test indicates the presence of nitrate, but not the amount. False positive results (i.e. results that raise concern about nitrate when the actual concentration is of little concern) are frequent with this test. If the diphenylamine test indicates nitrates are of concern, forage samples should be sent to the laboratory for final evaluation. False negative results with the diphenylamine test (i.e. results that indicate nitrate is not a concern when the actual concentration is high) are uncommon, and therefore, the test can be used effectively to screen samples for laboratory analysis.

For laboratory test results to be useful, forage samples must be collected properly. OSU Extension Fact Sheet PSS-2589, “Collecting Forage Samples for Analysis” discusses in detail proper sampling techniques for samples suspected of nitrate toxicity. Proper sampling is difficult since nitrate concentrations are extremely variable and only isolated areas in a field or just a few bales in a barn may be high in nitrate. As an example, the variation in nitrate concentration of samples collected from a 5-acre sorghum/sudan pasture is shown in Figure 1. Nitrate concentrations varied from 7,930 to 43,600 ppm nitrate. This map demonstrates that a nitrate test is only good for the field location or group of bales from which the sample came. Sample standing for-

Table 4. Generalized interpretation for forage nitrate test.

ppm NO_3 (dry matter basis)	interpretation
0-3,000	Generally safe for all cattle
3,000-5,000	Generally safe for non-pregnant beef cattle. Low risk of reduced breeding performance and early term abortions. Total ration for dairy cattle should be less than 2500 ppm NO_3.
5,000-10,000	Some risk for all cattle. May cause mid to late term abortions and weak newborn calves. May decrease growth and milk production.
>10,000	Potentially toxic for all cattle. Can cause abortions, acute toxicity symptoms, and death.

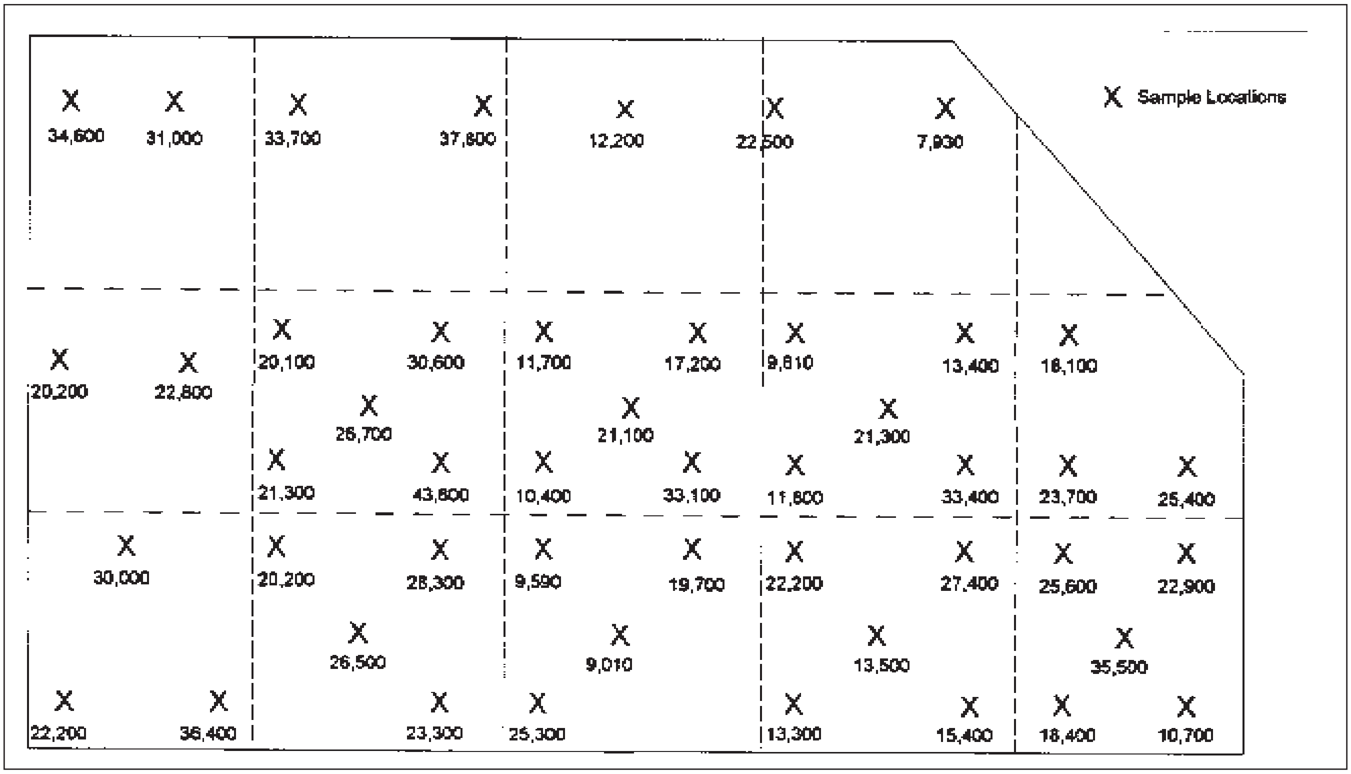

Figure 1. Nitrate concentration (ppm) of forage samples collected from different locations in a 5-acre sorghum/sudan pasture.

Quartering is used to reduce to a smaller, more manageable size in an unbiased manner. Prior to quartering, forage samples collected by hand must be cut into 2-3" pieces with shears or scissors and thoroughly mixed. Care must be taken to prevent leaf loss. Cored samples can be mixed as is. Pour the entire sample evenly into a pile on a clean surface, preferable paper, plastic, etc. Level the pile and divide into equal quarters (see diagram). Select and save two opposite quarters including the fines. If the sample is still too large, repeat the entire quartering procedure until the proper sample size is obtained. Always use the quartering method when reducing sample size to obtain a representative sample for analysis.

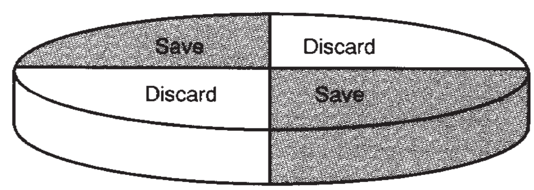

Figure 2. Quartering a Sample

age by clipping at least 20 representative plants at grazing height from the suspected area. Cut the plants into 2 to 3 inch pieces, combine, and mix thoroughly in a bucket.

Hay should be sampled based on the type of bales. The following general guidelines may be used for sampling hay: 1) for small square bales, collect one core from each of 20 suspected bales; 2) for large square bales, collect two cores each from each of 10 suspected bales; 3) for large round bales, collect two cores each from the curved side of 10 suspected bales; and 4) for loose hay stacks, collect three cores sampled diagonally along one side from each of six suspected stacks. Combine and mix cores. Reduce sample size using the quartering method (Figure 2).

Generalized interpretations for nitrate forage tests are presented in Table 4. The interpretations are based on nitrate concentrations reported as parts per million nitrate (ppm NO_3) on a dry weight basis. Both the OSU Soil, Water, and Forage Analytical Laboratory and the Oklahoma Animal Diagnostic Laboratory use these units for reporting results. Some laboratories may report results as nitrate-nitrogen (NO_3-N) or potassium nitrate (KNO_3). These values must be converted to nitrate before Table 4 applies.

To convert NO_3-N to NO_3, multiply by 4.4.

Example: 1,000 ppm NO_3-N X 4.4 = 4,400 ppm NO_3

To convert KNO_3 to NO_3, multiply by 0.61.

Example: 1,000 ppm KNO_3 X 0.61 = 610 ppm NO_3

As can be seen, it is important to use the correct units when interpreting test results.

Summary

Careful use of nitrogen fertilizer, an awareness of plant factors, the effect of weather, and cattle management can help reduce losses from nitrate poisoning. Diagnostic techniques are available to determine nitrate levels in forages. Hay which has potentially toxic levels of nitrate should be fed only as a part of the total diet.

Credits: Information for parts of this Fact Sheet was provided by C.E. Denman, W.E. Murphy, L.I. Croy, C.H. Hibberd and W. E. Edwards.

The Oklahoma Cooperative Extension Service Bringing the University to You!

The Cooperative Extension Service is the largest, most successful informal educational organization in the world. It is a nationwide system funded and guided by a partnership of federal, state, and local governments that delivers information to help people help themselves through the land-grant university system.

Extension carries out programs in the broad categories of agriculture, natural resources and environment; family and consumer sciences; 4-H and other youth; and community resource development. Extension staff members live and work among the people they serve to help stimulate and educate Americans to plan ahead and cope with their problems.

Some characteristics of the Cooperative Extension system are:

- The federal, state, and local governments cooperatively share in its financial support and program direction.
- It is administered by the land-grant university as designated by the state legislature through an Extension director.
- Extension programs are nonpolitical, objective, and research-based information.
- It provides practical, problem-oriented education for people of all ages. It is designated to take the knowledge of the university to those persons who do not or cannot participate in the formal classroom instruction of the university.
- It utilizes research from university, government, and other sources to help people make their own decisions.
- More than a million volunteers help multiply the impact of the Extension professional staff.
- It dispenses no funds to the public.
- It is not a regulatory agency, but it does inform people of regulations and of their options in meeting them.
- Local programs are developed and carried out in full recognition of national problems and goals.
- The Extension staff educates people through personal contacts, meetings, demonstrations, and the mass media.
- Extension has the built-in flexibility to adjust its programs and subject matter to meet new needs. Activities shift from year to year as citizen groups and Extension workers close to the problems advise changes.

Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, the Director of Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma. This publication is printed and issued by Oklahoma State University as authorized by the Vice President, Dean, and Director of the Division of Agricultural Sciences and Natural Resources and has been prepared and distributed at a cost of 42 cents per copy. 0313 Revised. GH