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Nitrates in Livestock Feeding: A Problem in Drought Conditions

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Nitrate poisoning is a noninfectious disease that occurs when cattle consume forages containing large amounts of nitrate. Both death loss and fetal abortions are caused by nitrate poisoning.

The occurrence of nitrate poisoning is difficult to predict because it is influenced by many circumstances. These include the rapid change of nitrate levels in plants and the wide range in the quantity of nitrate levels in plants and the wide range in the quantity of nitrate which sheep and/or cattle can tolerate under various conditions.

Excess accumulations of nitrate in plants generally result from extreme stress caused by environmental factors such as drought, frost, hail, disease, etc. Consequently, when plants are stressed particular precautions must be taken to avoid possible nitrate poisoning, especially when feeding those forages that accumulate nitrate fairly readily.

Cause of Nitrate Poisoning

Nitrate is not particularly toxic to animals. Nitrates eaten by ruminants are normally broken down to nitrite and then to ammonia that is converted by the rumen microbes into bacterial protein.

This process may be diagramed as follows:

Nitrate -> Nitrite -> Ammonia -> Amino acid -> Protein

In the ruminant animal nitrate is broken down to nitrite faster than nitrite is converted to ammonia. Consequently, when high levels of nitrate are present in the ruminants diet, nitrite accumulates and is absorbed into the blood stream. Once in the blood stream it combines with hemoglobin, which in turn reduces the oxygen carrying capacity of the blood. Toxic level depends on how much and how fast nitrate is consumed. A brownish discoloration of blood is evidence of nitrate poisoning. Both death loss and fetal abortions are common results of nitrate poisoning.

Nitrate Levels in Plants

Nitrates in the soil are the primary source of nitrogen, an essential nutrient for growing plants. Under normal growth conditions nitrates are converted to plant protein at about the same rate as they are taken up by the plant's root system. However, when certain conditions disrupt this balance, roots take up nitrate faster than the plant can convert it to plant protein. This results in excess plant accumulations of nitrate. The primary site for converting nitrates to plant proteins is in the green leaves that are actively engaged in photosynthesis. Consequently, the highest concentrations of nitrate are found in the stalks, stems and other conductive tissues.

The nitrate-to-protein cycle in a plant is dependent on three major factors:

- Adequate water.
- Energy from sunlight.
- A temperature conducive to plant growth--rapid chemical reactions.

If any of these factors is inadequate, plant will convert nitrate to plant protein at a much

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slower rate than normal. Because the roots still absorb the nitrate at normal rates the plant accumulates excess nitrate. Plant stress is the major cause of nitrate accumulation. It is caused by factors such as 1) detrimental weather, drought, frost, hail, etc., 2) shading--low light intensity, 3) herbicide application and 4) diseases. The amount of nitrate accumulation in plant tissue also depends upon 5) plant species, 6) stage of maturity, 7) part of the plant, 8) nitrogen fertilization, and 9) method of harvest.

Weather

Nitrates may accumulate in plants during periods of hot, dry weather. In plants that survive drought nitrates are likely to be especially high for several days following a break in the dry weather.

Frost, hail and low temperatures all interfere with normal plant growth and can cause nitrate accumulation. Frost and hail may damage, reduce, or completely destroy the plants' leaf area. This reduction of the leaf area limits photosynthetic activity of the plant. Also, plants require temperatures of above about 55°F for active photosynthesis. At lower temperatures, photosynthetic activity is severely reduced. Under either condition, nitrates absorbed by the roots may not be converted to plant protein and accumulate in the stems or stalks.

Shading

The reduction of nitrates to plant protein is closely linked to photosynthesis. Light provides the source of energy for both processes. Consequently, shaded plants may be higher in nitrates than plants grown under adequate light.

Under normal growing conditions, the nitrate content usually will be higher in the morning than it is in the mid-afternoon. It also will be higher on cloudy days. For instance, wheat hay harvested after cloudy weather often will be much higher in nitrate content than that harvested during sunny periods.

Herbicide

Spraying with herbicides which disrupt the plants growth process may result in temporary high nitrate levels in plants. However, this usually is just temporary. In fact, proper application of herbicides to control weeds in forage crops actually may reduce the nitrate poisoning hazard in the long run because weed species that are normally high in nitrates are killed.

Disease

Disease conditions can cause nitrate accumulation by interfering with the normal plant growth and development.

Plant Species

Plant species vary in the amount of nitrate they will accumulate (Table 1). Generally, crops such as corn, sorghum, sudangrass, oat and other small grains, when used for forage are the most dangerous.

Table 1. Guide to relative danger of nitrate poisoning by forage type and feeding method

Crops for Forage		***Method of Feeding***
Corn, sorghum & sudangrass	**Most dangerous**	Green-feeding
Oats & other small grains		Pasturing
Forage Grasses	↓	Hay
Legumes	**Least Dangerous**	Silage

Stage of Growth

Stage of growth markedly affects the nitrate content of forages. The nitrate level usually is higher in young plants and decreases as plants mature.

Plant Parts

Various parts of plants contain different levels of nitrates. The highest concentrations are found in stalks, stems and other conductive tissues. Most of the nitrate is found in the bottom third of the stalk or stem.

Nitrogen Fertilization

Nitrates in the soil are the source of nutrients in the plant. Nitrogen fertilization adds to the supply of soil nitrate available and, therefore, affects the nitrate content of the plant. Although a positive relationship exists, the direct effect of nitrogen fertilization appears to be less important than many other factors causing high nitrate in forages.

Method of Harvest

The most dangerous method of feeding is green-feeding or pasturing, followed by hay. Silage is the least dangerous (Table 1). Although hay and pasturing of forages apparently is somewhat safer than green-feeding, one usually cannot expect much risk reduction. Also, once the hay is harvested, nitrate levels remain fairly constant. On the other hand, ensiling usually lowers the nitrate content by 10 to 60 percent.

Feeding Forage High in Nitrate

If you suspect drought or frost-stressed forage might contain nitrates, it is a good idea to have it tested. Most County Extension Service offices have field test kits to determine whether nitrates are present in forage or in hay. If the field test shows that nitrates are present, and there is a good chance that weather or other factors causing the stress will improve, one may want to wait a couple of days before harvesting the forage. Generally, once the stress is removed and normal plant growth has resumed, nitrate accumulation disappear fairly quickly. Periodic testing may be necessary to assure that the nitrate accumulations has disappeared.

In some cases, such as when drought stress causes nitrate accumulation and there is little chance of rain, it may be necessary to harvest the forage although it contains nitrates. It generally is recommended to mow higher than normal because nitrate accumulations are greater in the lower parts of the plant and in regrowth. Also, postponing harvest until afternoon will allow sunlight to convert as much of the nitrate to plant protein as possible. Also, ensiling sometimes can reduce nitrate levels by 40 percent or more compared to haying. Whenever the field test indicates a possible nitrate problem a quantitative analysis from the MSU Chemistry Laboratory or another chemistry laboratory should be run before feeding to determine the actual amount of nitrate present.

Because the nitrate concentration is fairly stable in harvested forages, it generally is recommended that a quantitative test be run on those samples. Although the field test can be used as a screening device it can only provide a general indication that nitrate is present. It does not quantify the amount of nitrate. Also, a "field test" is more subject to error than the more controlled laboratory analysis. Field tests, however, are extremely useful when making harvesting decisions or when immediate results are necessary.

Livestocks' tolerance to nitrate depends on species, age, pregnancy and other factors. Ruminants such as sheep and cattle are more susceptible to nitrate poisoning than horses or swine.

Toxic levels of nitrate can be found in fresh or dry forages and/or contaminated water. Nitrate content can be reported several different ways (Table 2). A trend in recent years is toward simply reporting the nitrate (NO_3) content. The amount of nitrate in water is usually expressed as parts per million (ppm) of nitrate or nitrate-nitrogen (NO_3-N). Be sure to note how the information was reported whenever a laboratory analysis is received. Conversion factors comparing different expressions of nitrate are given in Table 2.

Table 2. Conversion factors for comparing different types of nitrate*

Method of Expression	*Chemical Designation*	*Convert to Nitrate, by multiplying by*
Nitrate	NO_3	1.0
Nitrate-nitrogen	NO_3-N	4.4
Potassium nitrate	KNO_3	0.6
Sodium nitrate	$NaNO_3$	0.7

***Nitrate levels in feed and water are frequently reported in parts per million (ppm). To convert to percent, move the decimal point four places to the left. Example: 5500 ppm - .55%.**

Exact recommendations for feeding forages high in nitrate are difficult to determine because they can vary greatly depending on the rate of NO_3 intake, amount consumed and the nature of the diet. Nitrate poisoning has been reported with rations as little as 0.9 percent nitrate. On the other hand, rations containing substantially more than 0.9 percent nitrate have been fed without harmful effects. Research has shown that a source of readily available carbohydrate in ration enhances the conversion of nitrate to ammonia, thus reducing the risk of nitrate poisoning.

Frequent intake of small amounts of a high nitrate feed increase the total amount of nitrate that can be consumed daily without toxic effects. More of a high nitrate forage can be fed without harmful effects by feeding it in limited amounts several times daily rather than feeding large amounts once or twice daily. Similar results can

be obtained by using it in a complete self-fed ration rather than feeding the roughage free-choice separate from the other ration components. With frequent intake of limited amounts of high nitrate feed, the concentration of nitrate in the rumen does not become extremely high at any one time.

Hay, straw or fodder that is suspected of being high in nitrate should not be fed when damp. Damp feed seems to be more toxic. The probable explanation is that some of the nitrate is converted to the more toxic nitrite in the blood. Nitrite is oxygen "starved" and therefore picks up oxygen from the blood.

Even if the forages are high in nitrates, they often can be diluted to a safe level with other forages that are low in nitrate or with grain. Some dietary guidelines for feeding forage with different levels of nitrates are shown in Table 3.

Whenever the possibility of nitrate poisoning exists special precautions should be taken to assure that individual animals do not consume excess amounts of the forages high in nitrate.

Table 3. Nitrate levels in forages for cattle and sheep*

Content of Nitrate (NO_3) % (DM Basis)	***Comment***
<0.3	This level is considered safe to feed.
0.3 to 0.4	Can usually be fed safely if limited to 75% of the total dry matter in the ration.
0.4 to 0.6	Can usually be fed safely if limited to 50% of the total dry matter in the ration.
0.6 to 1.2	Can usually be fed safely if limited to 25% of the total dry matter in the ration. *Do NOT use for pregnant animals.*
>1.2	*Potentially toxic. Do NOT feed.*

***Feeds used to dilute high nitrate forages must be nitrate free.**

If diluting forages, make sure that each individual animal gets the proper dilution of feeds at each feeding. Do not just put out the calculated number of bales of each feed and expected individual animals to consume the proper amounts of each. Also, do not feed the low nitrate forage at one feeding -- say in the evening (or visa-versa). If turning livestock out on forage suspected of high nitrate content, do so at mid-afternoon when the concentration tends to be lowest. Livestock should not be hungry when fed forages suspected of being high in nitrate. If is generally recommended that they be fed just prior to turnout.

Avoid Nitrate Poisoning Through Preventative Management

Nitrate poisoning, especially under drought situations, can be a very serious problem. However, the risk of an unwelcome experience with nitrate poisoning can be minimized by using the following preventative management precautions:

Understanding the essential elements necessary to produce a potentially dangerous situation is the first step in preventing a problem. Remember, conditions capable of nitrate buildup are:

- restricted water
- long period of cloudy water
- damage to plants (e.g. trampled, blown down in a storm, hail)
- cold temperatures
- plants growing in shade

If there is a problem or a potential problem:

- check feed, hay and/or water for nitrate concentration
- feed a ration high in carbohydrate
- remember that high levels of non-protein nitrogen--urea, etc., have the potential of aggravating the condition
- remember that high-nitrate feeds can be diluted with low-nitrate feeds

If you have any specific questions concerning nitrate poisoning, contact your local extension county agent or local veterinarian.