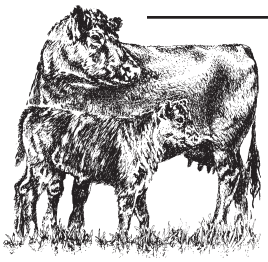

Western Beef Resource Committee

Cattle Producer's Library

Nutrition Section CL355

Nitrates in Cattle Feed and Water

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Nitrate poisoning is a noninfectious disease that occurs when cattle consume forages or water containing large amounts of nitrate. Each year in range cattle producing areas conditions occur which cause plants and water to accumulate nitrate that increases the likelihood of nitrate poisoning.

Nitrate itself is not particularly toxic to animals. Nitrates consumed by ruminants are normally reduced to ammonia and then absorbed and excreted, thus converted by bacteria into bacterial protein.

Nitrite, one intermediate product, is the actual cause of "nitrate poisoning." Some of the nitrate is absorbed into the blood, where it changes the hemoglobin to methemoglobin. Hemoglobin carries oxygen from the lungs to other tissues, but methemoglobin cannot carry oxygen.

Nitrate becomes toxic when methemoglobin production is high enough that the oxygen-carrying capacity of the blood is reduced to a critical level. If enough methemoglobin is produced, the animal with that condition will die. The toxic level depends both upon how much and how fast nitrate was consumed. Immature ruminants are more susceptible to nitrate toxicity than more mature animals.

Symptoms of Nitrate Toxicity

Nitrate levels from 15 to 45 grams per 100 pounds of body weight are considered toxic in feed and water sources. Nitrate in water sources is more rapidly available than in feed sources. Nitrite is 10 times more toxic than nitrate and should be watched more carefully.

Nitrate poisoning can be rapidly fatal. When nitrate poisoning is suspected, a veterinarian should be called immediately to confirm the diagnosis and start treatment. Since death comes from oxygen insufficiency, cattle should be handled as little and as quietly as possible to minimize their oxygen needs.

Symptoms appear when 30 to 40 percent of the hemoglobin has been converted to methemoglobin, with death occurring at 70 to 80 percent methemoglobin levels. Symptoms may not develop until 3 to 4 days after daily feeding of moderate nitrate feedstuffs. Respiratory distress, incoordination, weakness, muscle tremors, and collapse occur. Forced movement may trigger the onset of symptoms.

Terminal convulsions due to suffocation occur in untreated animals in 12 to 25 hours. In the non-acclimated cow, acute poisoning can occur as soon as 1/2 to 4 hours after abrupt feeding of high-nitrate feed and/or water. If pregnant animals recover abortion usually follows.

Postmortem Lesions

Mucous membranes appear gray (cyanotic) or dark brown. Blood obtained within a couple of hours after death is chocolate brown in color. This blood changes back to dark red within a few hours. Hemorrhages may be in the lungs and on the heart.

Common toxicants that may be confused with nitrates and nitrites are silo gases (slight brown-colored blood), cyanide (cherry red), carbon dioxide (dark blue), and carbon monoxide (bright red). Acute poisonings in cattle most commonly occur with nitrate concentration exceeding 1 percent NO_3 (approximately equivalent to 1.5 percent KNO_3) in forage dry matter or 1,500 mg NO_3/m1 (ppm) in water. Irritation may be found in the stomach and intestines (if the source of nitrate is from eating fertilizer).

Chronic Toxicity

Subacute or chronic nitrate poisoning causes poor growth, abortion, repeat breeding, Vitamin A deficiency, goiter, and increased susceptibility to infection. Such problems may occur when high-nitrate forages or waters are fed to animals in poor condition, but controlled

experiments with well-fed animals failed to substantiate nitrate as the specific causative agent.

Drought-damaged (high-nitrate) feeds have a high nonprotein nitrogen value, elevated crude protein value, but reduced bypass protein. Carotene is lower in drought-stressed corn silage than in normal corn silage, because the amount of grain is lower. Problems attributed to chronic nitrate toxicity may in reality be due in part to nutritional deficiencies.

The level of nitrate that reduced performance while not causing acute symptoms is controversial. There appears to be several factors that affect the animal's ability to tolerate higher than normal levels of nitrates that are individually variable. Much of the data have been collected from diagnostic evaluations after an animal developed toxicity symptoms.

Generally, the circumstance surrounding an illness that is caused by nitrate poisoning is hypothetical. Postmortem data have increased our understanding of the topic, however, definite conclusions are difficult to reach. The exact level of nitrate intake is unknown and symptoms are difficult to duplicate under controlled research conditions.

Weak calves, abortions, stillbirths, and related reproductive disorders have been linked to excessive dietary nitrate. A study in Wyoming did not show any effect on pregnancy when mature cows were fed oat hay containing up to 1.4 percent KNO_3. The cows carried fetuses to term with no effects on parturition.

The effect of nitrates on fertility also has been researched extensively. This effect is difficult to document because nitrate intake levels are not documented until symptoms are observed. A non-return to heat of A.I. cattle from 58 herds indicated a non-significant negative correlation coefficient of -.18 between NO_3 and fertility. Reduced milk production has also been described.

Reduced growth rates have been reported as a chronic nitrate effect. Feedlot cattle fed sodium nitrate at 1.16 percent of the diet had decreased feed intake, weight gain, plasma Vitamin A level, and feed efficiency. Other researchers have reported reduced liver stores of Vitamin A and feel that supplemental Vitamin A will reduce the toxic effect. However, further research shows no effect of dietary NO_3 on Vitamin A status in ruminants.

Non-pregnant ruminants can adapt to higher levels of nitrate feeding over time. Researchers have increased the intake of steers up to .39 gram nitrate per kilogram body weight over a period of several weeks without any problems. However, increasing doses to .49 gram resulted in death.

Nitrate Levels in Plants

All plants contain some nitrate, but excessive amounts occur in some forage grown under stress conditions. 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 up take by the plant's root system. Under certain conditions, roots take up nitrate faster than the plant can convert it. 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 tissue. The nitrate-to-protein cycle in a plant depends on three major factors:

1. Adequate water.
2. Energy from sunlight.
3. A temperature conductive to plant growth.

Plant stress is the major cause of nitrate accumulation and is caused by factors such as (a) detrimental weather—drought, frost, hail; (b) shading—low light intensity; (c) herbicide application; and (d) diseases.

The following are some conditions that may cause high nitrate in forage:

- **Plant Species**—Plants like pigweeds, lambsquarters, oats, millet, sorghum, sudangrass, and corn are often high in nitrate, but other grasses and legumes can have excessive levels under extreme conditions.
- **State of Growth**—The nitrate level is usually higher in young plants and decreases as the plant matures.
- **Plant Parts**—Various parts of the plant contain different levels of nitrate. A Wisconsin study of drought-stressed corn found nitrate levels in plant parts as follows: total plant, 978 ppm nitrate nitrogen; bottom one-third stalk, 5,524 ppm nitrate nitrogen; middle one-third stalk, 803 ppm nitrate nitrogen; top one-third stalk, 153 ppm nitrate nitrogen; leaves, 64 ppm nitrate nitrogen, and ear, 17 ppm nitrate nitrogen.
- **Weather**—Nitrates accumulate in plants during periods of hot, dry weather. In plants that survive drought, nitrates are especially high for several days after a break in the dry weather.
- **Frost, Hail, and Low Temperatures**—These all interfere with normal plant growth and can cause nitrate accumulation. Frost and hail may damage, reduce, or completely destroy the plants' leaf area, thus limiting photosynthetic activity. Also, plants require temperatures above 55°F for active photosynthesis. Under either condition, nitrates absorbed by the roots may not be converted to plant protein and, therefore, 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 will be higher in the morning than in the mid-afternoon. It also will be higher on cloudy days.

- **Herbicide**—Spraying with herbicides that disrupt the plant's 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 by removing weed species that are normally high in nitrates.
- **Disease**—Plant disease can cause nitrate accumulation by interfering with normal plant growth and development.
- **Nitrogen Fertilization**—Nitrates in the soil are the source of nutrients in the plant. Nitrogen fertilization adds to the supply of soil nitrate and 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 of the other factors causing high nitrate in forages.

Nitrates in Water

Normally, water sources of nitrates will not cause problems (Table 1). However, high nitrate feed levels with elevated water levels contribute to the total nitrate intake of an animal. Well water is usually safe. Nitrate toxicity from water is most likely to occur when livestock drink water from ponds, road ditches, or other surface impressions (drainage from feedlots, fertilized fields, silos, or manure disposal lagoons).

Water (aqueous solution) sources are more dangerous (almost twice) than food sources in causing toxicity. Nitrites can be found in water, but the level is usually below 1 to 2 ppm (maximum level is 50 ppm of nitrite nitrogen). Microbial growth in water troughs can convert nitrates to nitrites, but the effect is small.

Testing for Nitrate

The only way to determine if nitrates are a problem is through a diphenylamine test as a field screen. The **test solution** consists of 0.5 gram (g) of diphenylamine dissolved in 20 milliliters (ml) of water. Add sulfuric acid to a total volume of 100 ml. Cool the solution, store in a brown bottle, and keep refrigerated.

Split the stem of a fresh plant to expose the inside, add one to two drops of the reagent to the cut surface, and note any immediate color change. An intense blue or black indicates more than 2 percent nitrate. Reactive samples should be submitted for quantitative analysis at a laboratory.

Many commercial laboratories will run a nitrate test for a minimal fee, however, terminology may vary. Common terms are shown in Table 2, and Table 3 shows the formulas to convert lab reports to a standard measure.

Table 1. Guidelines for nitrites in water.

ppm of NO_3	Estimated effect
0 to 44	Not harmful
45 to 120	Slight possibility
121 to 220	Risky, especially over long period
221 to 440	Interference syndrome likely
441 to 660	More serious, possible acute losses
661 to 880	Increased, acute losses, secondary diseases
881 and over	Heavy acute losses

Table 2. Methods of expressing nitrate and nitrite contents of feeds and water, atomic weights of the various substances, and a conversion factor.[1]

Nitrogenous substance	Chemical formula or designation	Atomic, molecular, ionic weight	Multiplication factors
Nitrate nitrogen	NO_3-N	14	4.4
Nitrite nitrogen	NO_2-N	14	4.4
Nitrite	NO_2	46	1.3
Nitrate	NO_3	62	1
Sodium nitrate	$NaNO_3$	85	0.73
Potassium nitrate	KNO_3	101	0.61

[1]To convert parts per million (ppm) to percent, divide by 10,000 (e.g., 1,500 ppm is .15%).

Table 3. Conversion table.

% KNO_3	=	% nitrate (NO_3) x 1.6
% KNO_3	=	% nitrate nitrogen (NO_3N) x 7.0
% NO_3	=	% KNO_3 x .6
% NO_3N	=	% KNO_3 x .14
% NO_3N	=	% NO_3 x .23
parts per million (ppm)	=	percent (%) x 10,000
percent (%)	=	ppm ÷ 10,000

Feeding Strategies with Higher Nitrate Forage

In general, feed nitrate levels less than 1 percent, or 10,000 ppm, are not toxic. Diets of pregnant beef cows should not exceed 5,000 ppm nitrates on a dry basis. The most commonly accepted levels of nitrate that can be fed before you can expect problems are listed in Table 4.

Management Guidelines for High-Nitrate Feeds and Water

- Leave drought-damaged feeds in the field as long as practical since nitrate will diminish as plants mature.
- Cut suspected forages at higher than usual heights to avoid the higher nitrate-containing portions of the stalks.
- Avoid use of drought-stricken forage for 3 to 5 days after a rain.
- Control weeds closely to avoid nitrate from weed sources.
- Run an analysis on suspect feed to determine nitrate level.

Table 4. Guidelines for nitrate in feedstuffs (expressed on 100% dry matter basis).

Nitrate content (%)	Comment
0.0 to 0.44	This level is considered safe to feed under all conditions.
0.44 to 0.66	This level should be safe to feed to nonpregnant animals under all conditions. It may be best to limit its use to pregnant animals to 50 percent of the total ration on a dry basis.
0.66 to 0.88	Feeds safely fed if limited to 50 percent of the total dry matter in the ration.
0.88 to 1.54	Feeds should be limited to about 35 to 40 percent of the total dry matter in the ration.
1.54 to 1.76	Feeds containing more than 0.88 percent nitrate should not be used for pregnant animals. Feeds should be limited to 25 percent of total dry matter in the ration. Do not use these feeds for pregnant animals.
over 1.76	These feeds are potentially toxic. Do not feed.

- Feed a balanced nutrient ration, high in energy and undegradable protein.
- Avoid changes in forage ration and other situations that may impair rumen function.
- Observe good herd health practices. Healthy animals are better able to handle nitrates.
- Avoid unnecessary handling and excitement of animals during feeding of high-nitrate feeds.
- Check water as a source of nitrates.
- Avoid mold formation in high-nitrate forages that can convert nitrates to nitrites.
- Mix high nitrate feed with low nitrate feed sources, preferably a ground or chopped ration. If this is not possible, feed several times per day rather than a large amount once a day.
- Feeding limited concentrates (grains) with high nitrate forages may assist the conversion of nitrate to bacterial protein in the rumen minimizing nitrite production likely to occur when roughage is fed alone.
- Offering a low nitrate forage before grazing high nitrate forages can be beneficial since the quantity of NO_3 consumed in a short period of time effects the animal's chance of toxicosis.
- Feed forages containing over .5 percent NO_3 or .75 percent KNO_3 to non-pregnant cattle.
- Cattle should be gradually adapted to higher nitrate forages.
- Some evidence may suggest that excess Vitamin A protects animals for nitrate toxicity. This practice has not been documented in the scientific field.
- Some new commercial products are now on the market that may alter rumen microorganisms and decrease toxic effects of nitrate feeds. Limited research is available to support or refute these results. Proper diet management is effective and is the recommended method to avoid toxic problems from nitrates.

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