

Animal Considerations for Nitrate Toxicity When Using Whole Plant Corn as a Feed

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Introduction

Cattle producers are often confronted with difficult choices. Drought-stressed corn that is to be utilized as a forage presents yet another challenge for dairy and beef farmers. Often, during times of poor growing conditions, it becomes necessary to utilize all forages available for feeding livestock, yet forage produced from drought-stressed corn presents the potentially dangerous problem of nitrate toxicity.

Nitrate is the primary nutrient form of nitrogen in most soils and is a normal constituent of plants. Normally nitrate is assimilated so rapidly following absorption from soil that its concentration in plant tissues is low. If plant uptake of nitrate from the soil continues, but plant growth is reduced because of an environmental stress, such as during a drought, plants can accumulate dangerous levels of nitrates. The most notorious accumulators of nitrate are in the corn and sorghum families. Some perennial grasses (fescue and Johnson grass) and weeds (pigweed, mustard, kochia, nightshade and lamb's quarters) also can also accumulate dangerous levels under certain conditions. In some cases, the corn may be safe, but the weeds harvested with it may be poisonous. Stinging nettle, elderberry, burdock and Canadian thistle are a few other known nitrate accumulators.

Effects in Cattle

Nitrate toxicity occurs in ruminants after the consumption of forages or water in which nitrates have been concentrated in higher than normal levels. After being consumed, the nitrate is reduced to nitrite in the rumen. Nitrite converts hemoglobin, the oxygen carrying protein in red blood cells, to methemoglobin. Methemoglobin does not bind oxygen so oxygen is not carried to tissues, leading to the clinical signs of nitrate toxicity (much like Blue Baby Syndrome in humans). The clinical signs observed in cattle from acute nitrate toxicity include difficulty breathing, increased respiratory rate, increased heart rate, weakness, tremors, and convulsions. Additionally, mucous membranes may be discolored, turning from a normal pink to a blue-brown color. If the toxicity is severe enough, death will follow these clinical signs. Subclinical nitrate toxicity is a more common occurrence and may manifest itself as decreased intakes, weight gains and production, and decreased reproductive efficiency in the form of decreased conception rates, embryonic death, and occasionally abortions. When diagnosing nitrate toxicity in affected cattle it must be differentiated from prussic acid poisoning seen after the consumption of Johnson grass, cherry, sorghum, sudangrass, or their hybrids. Clinical cases of nitrate toxicity may be treated by a 5 to 15ml intravenous injection of a 1% solution of methylene blue by a veterinarian.

Factors Causing High Nitrate Levels in Corn Plants

A number of factors can increase the amount of nitrate accumulated in corn plants. Generally higher nitrate accumulation is due to stressful growing conditions, but other factors may also play a role.

1. Drought

Drought conditions are most commonly implicated as the cause of increased nitrate accumulation in corn plants. Drought causes poor growth of the plant yet does not inhibit nitrate uptake, thereby increasing nitrate levels in the plant and the resulting silage. Timing of the drought can also be important as severe, brief drought seems to cause more problems than long-term droughts. Additionally, drought following adequate early rains may cause more concerns, as dry weather during pollination will lead to poor kernel development and therefore less grain to dilute the nitrates accumulated in the stem of the plant. Finally, a recovery rain will cause the increased movement of nitrates into the plant. Nitrates may take 3-4 days to be converted to proteins, resulting in high nitrate levels in plants for 3-4 days following the rain.

2. Available Nitrogen

Forages may contain higher levels of nitrate when there is more available nitrogen in the soil due to manure or nitrogen fertilizer application. A solid knowledge of field fertility will help minimize this concern.

3. Cloudy Weather

Cloudy, cool weather may environmentally stress plants and cause plants to convert less accumulated nitrates into protein.

4. Poor Soil Fertility

Nutrient deficiencies in soil limit plant growth but not nitrate uptake, leading to higher relative levels of accumulated nitrates.

5. Portion of Plant

Nitrates tend to accumulate in the bottom third of the plant with greater concentrations in the stalk than in the leaves shuck, or grain.

Strategies for Dealing with Possible High Nitrate Corn Plants

1. Reduce Plant Nitrate Levels at Harvest

- a. Because nitrate levels will be greater in the stalk and will also tend to be greater closer to the soil, plant nitrate levels can be reduced by cutting the corn plant at a higher than normal cut height. It is generally recommended to chop the corn plant at 10-12 inches of height or only cut the top two-thirds of corn shorter than 3 feet tall. While this will reduce tonnage, it will also reduce the risk of nitrate toxicity.
- b. If it rains, wait to harvest for 3-5 days as nitrate levels will be elevated in drought-stressed corn immediately following a soaking rain. This delay provides an opportunity to the plant to convert nitrate to plant protein.

2. Allow Fermentation

Complete fermentation will reduce nitrate levels by 30-50%. Fermentation should be relatively complete by 3-4 weeks after harvest. This recommendation assumes that the crop is ensiled at the correct whole-plant moisture levels (30-45% dry matter) to allow good fermentation (i.e. a rapid drop in pH). Corn that is harvested too dry may only remove 20% of the nitrates during the ensiling process and may not ferment normally. Corn harvested too wet will undergo butyric acid fermentation rather than the normal lactic acid fermentation. A butyric acid fermentation is often referred to as a “sour” fermentation and it is more prone to clostridial growth which collectively has a negative impact on animal health and productivity.

3. Analyze Forage Before Feeding

- a. To make an informed decision when there is concern about the possibility of high nitrate levels in corn plants the first strategy is to have the corn silage tested for nitrate content prior to feeding. Work with your nutritionist, Extension educator, or veterinarian to submit samples for laboratory analysis. Laboratories report nitrate content of feed and water in different forms. Consider the form for expressing nitrate levels to avoid errors in determining the potential for toxicity. For aid in interpreting laboratory results see Tables 1 & 2.
- b. The level of nitrate that causes toxicity in ruminants varies depending on rate of intake, diet, acclimation to nitrate and nutritional status. As a rule of thumb, forages containing less than 5,000 ppm NO_3 on a dry matter basis are considered safe for all beef and dairy animals. Forages containing 5,000 to 10,000 ppm NO_3 are considered potentially toxic when provided as the only feed. Forages containing over 10,000 ppm NO_3 are considered dangerous. The only way these higher nitrate containing feeds can be fed safely is to limit their intake by diluting them with low nitrate feeds.
- c. A test called the diphenylamine test can be performed for quick results, if necessary. A positive result (a blue color) seen when the test solution is applied to various locations of the inner areas of the plant stem indicates possibly dangerous levels of nitrates. This test will not provide an absolute nitrate level, but will aid in determining the need for further lab testing.

4. At Feedout

- a. Introduce high nitrate forages gradually into a ration over a two to three week timespan.
- b. Feed in smaller more frequent meals if possible.
- c. Feed low nitrate forage before feeding high nitrate forage to limit meal size.
- d. Dilute high nitrate feeds with low nitrate feeds.

5. Be Careful!

- a. High nitrate silage is capable of producing high levels of nitrogen dioxide in silos. Nitrogen dioxide is heavier than air and will displace oxygen in and around silos and

silage piles. High levels of nitrogen dioxide can cause people, livestock, and pets to be overcome by the lack of oxygen, potentially causing death.

- b.** Low levels of nitrogen dioxide may only cause respiratory tract irritation initially, yet result in death hours later. In people this can lead to the condition known as “silofiller’s disease”.
- c.** Relapses similar to pneumonia may be noted months after exposure to nitrogen dioxide.
- d.** Cattle are also very sensitive to nitrogen dioxide – aerate and feed gas producing forages in a well-ventilated area
- e.** To avoid nitrogen dioxide poisoning:
 - i. Be alert for odors or reddish to yellowish-brown fumes.
 - ii. Avoid exposure for at least 10 days after filling the silo.
 - iii. Ventilate feed areas.
 - iv. Run silo bowers for 15-45 minutes before entering the silo.
 - v. Never enter a silo when alone.

6. If feeding potentially high nitrate corn as a greenchop:

- a.** Harvest with the same precautions as mentioned for harvesting as silage (higher chop height, etc.).
- b.** Chop only what will be used immediately. Do not chop a two day supply and store on the wagon because nitrates can be converted to nitrites which are more toxic.
- c.** Adapt livestock to high-nitrate forages gradually over the span of 2-3 weeks.
- d.** Feed forage in more frequent, smaller meals.
- e.** Dilute feed with known low-nitrate forages.

7. If considering making hay from potentially high nitrate corn plants:

- a.** Unlike ensiling, corn harvested as a hay crop will not have a lower nitrate concentration than the original standing plant on a dry matter basis.
- b.** Test forage for nitrate levels before harvest.
- c.** If nitrate analysis is high, delay cutting and test again later.
- d.** If hay contains high concentrations of nitrate, be very careful. This hay must be limit fed, or blended with low nitrate feeds to dilute the concentration. Do not allow free-choice access.

8. Summary

High nitrate corn forage presents dilemmas to livestock farmers. With proper caution, the corn forage can be used as livestock feed, but it is essential that the producer have the forage analyzed for nitrate levels and follow guidelines recommended to them by nutritional experts.

Table 1. Cattle Feeding Guidelines for Forages Containing Varying Levels of Nitrate¹		
Method of Reporting Nitrate Level		Recommendations For Feeding
Nitrate Ion (NO₃)	Nitrate Nitrogen (NO₃-N)	
Percent of Forage Dry Matter		
0.0 - 0.44	0.0 - .10	Safe to feed in all situations.
0.45 - 0.66	0.11 - 0.15	Safe for non-pregnant animals. Limit to 50% of diet dry matter for pregnant animals.
0.67 - 0.88	0.16 - 0.20	Limit to 50% of diet dry matter.
0.89 - 1.54	0.21 - 0.35	Limit to 35-40% of diet dry matter. Avoid feeding to pregnant animals.
1.55 - 1.76	0.36 - 0.40	Limit to 25% of diet dry matter. Avoid feeding to pregnant animals.
over 1.76	over 0.40	DO NOT FEED

To convert from parts per million (ppm) to percent, move the decimal point four places to the left (i.e. 8800 ppm = 0.88%). To convert to ppm from percent, move the decimal point four places to right.

¹Source: Sniffen, C.J. and L.E. Chase. 1981. Nitrates in Dairy Rations, Department of Animal Science, Cornell University.

Table 2: Equivalent levels of nitrate.

Nitrate		Nitrate-nitrogen (NO ₃ -N)		Potassium nitrate (KNO ₃)	
ppm ¹	%	ppm	%	ppm	%
200	.02	46	.0046	326	.0326
5,000	0.5	1,150	.115	8,150	.815
10,000	1.0	2,300	.23	16,300	1.63

¹parts per million

Formulas for converting different methods of reporting nitrates.

Potassium nitrate (KNO₃):
= Nitrate x 1.6
= Nitrate nitrogen x 7.0

Nitrate (NO₃):
= Potassium nitrate x 0.6
= Nitrate nitrogen x 4.4

Nitrate nitrogen (NO₃-N):
= Potassium nitrate x 0.14
= Nitrate x 0.23