



# Prevention and control of nitrate toxicity in cattle

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## Topics Include:

Complexity

Effects on animals

Guidelines

General recommendations

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Issued in furtherance of Cooperative Extension Work, Acts of Congress May 8 and June 30, 1914, in cooperation with the U. S. Department of Agriculture and the Pennsylvania Legislature. T. R. Alter, Director of Cooperative Extension, The Pennsylvania State University.

# INTRODUCTION

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Nitrate intake is closely related to the levels found in forage and drinking water. Forages may contain elevated levels of nitrate when fields are heavily fertilized with manure and nitrogen-containing fertilizer, crops are environmentally stressed by cold, rainy weather with a lack of sunshine in the spring or fall, and drouth. Drouth-stricken forage may be highest in nitrates for a period of three to seven days following appreciable rainfall. While corn silage often is associated with nitrate problems, high levels may occur in other forages such as sorghum, sudan-grass, perennial grasses, and legumes. Sometimes alfalfa may have a higher nitrate content than corn silage. Annuals grown on heavily fertilized fields which were intended for corn and were plowed down due to drouth, or silage made from drouth-stricken corn or sorghum are the most frequent offenders. Certain weeds such as pigweed and lambsquarter are nitrate accumulators and may increase levels in forage even under normal growing conditions.

Water may contribute considerable nitrate or the more toxic nitrite to the diet. Acute toxicity from water alone is rare and may result when levels approach 1500 to 3000 ppm nitrate ion ( $\text{NO}_3$ ) or 340 to 680 ppm nitrate nitrogen ( $\text{NO}_3\text{-N}$ ). Subclinical toxicity in the form of reduced reproductive efficiency may result from water containing 374 ppm  $\text{NO}_3$  or 85 ppm  $\text{NO}_3\text{-N}$  when fed with a diet with relatively normal nitrate content. Weight gains in calves may be

reduced on a normal diet when water contains 150 to 300 ppm  $\text{NO}_3$  or 34 to 68 ppm  $\text{NO}_3\text{-N}$ . Nitrate levels in water often may be reported as mg/l as well as ppm. These units are synonymous.

See **Table 1** for a guide to possible toxicity of nitrate in water. Nitrate tests can vary according to moisture conditions. Because definitive calibration studies with graded levels of nitrate in water have not been conducted and rations may vary appreciably in nitrate content, it is recommended that water contain less than 100 ppm  $\text{NO}_3$  or 23 ppm  $\text{NO}_3\text{-N}$ , unless total nitrate intake is determined using forage and feed analysis and animal performance is closely observed. Some researchers feel that a nitrate level as high as 400 ppm  $\text{NO}_3$  or 91 ppm  $\text{NO}_3\text{-N}$  should not appreciably affect performance under normal conditions. The average content of farm water supplies in Pennsylvania is 34 ppm  $\text{NO}_3$  or 7.7 ppm  $\text{NO}_3\text{-N}$ . Nitrate contents over 100 ppm  $\text{NO}_3$  or 23 ppm  $\text{NO}_3\text{-N}$  rarely are encountered. High levels generally are associated with leaching of nitrate through soils that have received heavy applications of manure and nitrogen-containing fertilizer or with contamination of water sources by septic systems. Some discrepancies in the literature on toxic levels of water may be due in part to a greater proportion of total nitrate being in the more toxic nitrite form in some studies. Continuous access to water also reduces risky toxicity.

# COMPLEXITY

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Any discussion or guidelines relating to nitrates are complicated by several factors. A number of recommendations and guidelines still found today are based largely on early field observations and limited research data obtained in the late 50s and early 60s, and have not been updated to more recent research and field experiences. For example, many people indicate that vitamin A status of animals may be adversely affected by elevated intakes of nitrate. However, many well-controlled studies indicate that little or no appreciable effects occur. In addition,

nitrate intakes necessary to produce a harmful degree of methemoglobinuria (lack of oxygen-carrying capacity in the blood) are much higher than previously thought. Most studies show little or no adverse effects on feed intake or milk production in dairy cows. In fact increased milk production has occurred in some trials when appreciable levels of nitrate and thus more soluble N were present in the diet. A decrease in feed intake and gains have been noted in some research with growing animals, especially young calves when water was the source of nitrates.

## COMPLEXITY (continued)

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Numerous studies indicate that there is a wide variation in the response to high nitrate intake among animals on a given diet and among trials due to apparent differences in environment, diet, and feeding practices. Nitrate problems may occur when these compounds are converted to the more toxic nitrite (NO<sub>2</sub>) form via rumen metabolism. Conditions, which limit the reduction of nitrate to ammonia (NH<sub>3</sub>) in the rumen, or tax this system and allow for a buildup of nitrite, make animals more susceptible to nitrate toxicity. For example, animals on a high forage or forage alone ration may be at greater risk due to lack of readily available carbohydrates in the rumen. At least three to five pounds of grain intake may be necessary to minimize toxic nitrite production.

Some minerals such as molybdenum, copper, iron, magnesium, and manganese are involved in the complete reduction of nitrate to ammonia, which avoids nitrite accumulation. Cattle on some rations, especially all-forage diets in some areas, may lack some of these or other minerals that are important for normal rumen metabolism. Rumen microorganisms often adapt to higher nitrite levels over a period of time. Thus the rate at which higher nitrate feeds or water are introduced to the diet may considerably influence the effects noted. Most important, the rate at which even adapted animals consume nitrate is the critical factor. Rate of nitrate intake is a function of both forage nitrate content and the rate of forage dry matter consumption. Thus less dry matter from high nitrate forage can be eaten in a single meal.

Grazing animals often are at less risk than those consuming dry or ensiled forages because they eat less dry matter per unit of time, and may have less buildup of nitrite in the rumen and, consequently, the blood stream. There also may be differences in effects between species of grass or possibly annual hybrids at similar nitrate intakes. Methods of feeding also may influence effects. The TMR system of feeding may be less risky at a given nitrate intake than conventional feeding which results in several peak intakes of forage during the day.

Numerous factors beyond those discussed here are known to affect the reduction of protein degradation and other nitrogen-containing compounds to ammonia, and the synthesis of microbial protein in the rumen. For example rumen by-pass protein is needed in the diet. It is likely that many of these same factors affect nitrate reduction and levels of nitrite that may accumulate.

Some research indicates that substantial amounts of endogenous nitrate and nitrite may be produced in the animal. This may be recycled and may contribute to an accumulation of NO<sub>2</sub> in the blood stream. Animals appear to vary considerably in the amount of endogenous nitrate and nitrite produced. Endotoxins present due to infection or stress enhance this endogenous production and may make animals more susceptible to toxicity. Animals usually are under more stress during hot, humid weather, at calving time, and during major ration changes (such as type of forage fed and levels of concentrate intake).

A lot of confusion or misunderstanding also results from differences in expressing nitrate levels. Some laboratories and researchers indicate nitrate levels as nitrate ion (NO<sub>3</sub>) while others use nitrate nitrogen (NO<sub>3</sub>-N). Some do not indicate which unit is being used in analytical reports, research, or guidelines. This problem in itself has given rise to many conflicting recommendations and guidelines, as well as misinterpretation of test reports. Some laboratories report in parts per million which results in a much larger figure than the percentage basis used by others. Furthermore, some people indicate levels in feeds on an *as fed* basis rather than the preferred *dry matter basis* as used in this presentation. Conversions that may be used regarding nitrate and nitrite content are found in **Table 2**. Many analytical methods result in a nitrate content that includes the nitrite present. Since nitrite is more toxic than nitrate, nitrate content is not always a good indicator of potential toxicity due to possible variations in the proportion of nitrite present. Fortunately most nitrogen oxide is present as nitrate, not nitrite, in plant material and water.

## EFFECTS ON ANIMALS

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Acute toxicity may result in serious illness or death due to a lack of oxygen in body tissues. Nitrate is reduced to nitrite in the rumen. Nitrite, which is absorbed into the bloodstream, combines with hemoglobin to form methemoglobin, which cannot carry oxygen to the tissues. Thus the animal may die from suffocation. When methemoglobin levels reach 50 to 65 percent of hemoglobin content, acute symptoms or death may occur. Symptoms include muscular weakness, incoordination, convulsions, accelerated heart rate, rapid breathing, and cyanosis or a discoloration of mucous membranes. Vaginal and other mucous membranes may turn from pink to a gray-brown at methemoglobin contents of over 20 percent, while other symptoms may not result until methemoglobin reaches 50 percent or higher. Normal methemoglobin values range from 1 to 3 percent. Thus mucous membranes should be checked closely when feeding a ration suspected to contain elevated nitrate content.

Unfortunately, symptoms of prussic acid (cyanide) poisoning are similar to nitrate toxicity. When sorghum, sudangrass, or their hybrids, Johnson grass, or pasture containing access to cherry are involved in an acute problem, one must determine whether nitrate or prussic acid is involved. Freshly drawn blood from an animal afflicted with nitrate poisoning often is a dark chocolate-brown color, while that from prussic acid toxicity often may turn a brilliant cherry red upon exposure to air. Forages may be tested for nitrate and prussic acid (cyanide) to help with later confirmation. Prussic acid testing is available at the Summerdale Diagnostic Laboratory of the Pennsylvania Department of Agriculture, Bureau of Animal Industry.

## GUIDELINES

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The information and precautions presented earlier must be taken into account when using any guidelines on safe levels of nitrate content in the diet. It is important to use caution in feeding forages that are suspect in regard to possibly high nitrate or prussic acid levels.

Nitrate testing is available from most laboratories testing forages and feeds.

Subclinical toxicity from nitrates may be reflected as reduced reproductive efficiency in adult cattle and lower weight gains with or without decreased feed intake in young stock. Research has shown that serum progesterone concentrations may be decreased greatly in open animals (50 percent), more moderately in early pregnancy (25 percent), and very little, if any, in mid- or later pregnancy. Late-term abortions rarely occur. Services per conception and percentage first service conception may be most noticeably affected and result in more repeat breedings.

Fortunately acute nitrate toxicity rarely occurs under normal conditions. It is most apt to occur when cattle suddenly are allowed access to large amounts of high nitrate forage. (Generally this is an annual grown on highly fertilized fields, especially when the crop is weather-stressed.) Nitrate content of forages causing acute toxicity (on a dry matter basis) generally ranges from 1 to 3 percent or 10,000 to 30,000 ppm  $\text{NO}_3$ ; or .23 percent to .68 percent  $\text{NO}_3\text{-N}$ ; or 2,300 to 6,800 ppm  $\text{NO}_3\text{-N}$ . Methylene blue may be used in treating animals for nitrate poisoning, while a sodium thiosulfate-sodium nitrite solution is used for prussic acid (cyanide) toxicity. Subclinical nitrate toxicity is more apt to occur than acute, especially when drouth or otherwise stressed forages are fed. Even subclinical toxicity occurs infrequently in well-fed, well-managed herds. This results in part from a dilution effect when several forages and at least moderate amounts of grain or concentrate are fed, as often practiced with feeding dairy cows.

Weather-stress and fertilization practices must be considered. Before feeding, test suspected forages for nitrates using representative samples obtained as you would for other nutritional evaluation. If such tests indicate a nitrate level for a single forage in excess of .44 percent  $\text{NO}_3$  or 1000 ppm  $\text{NO}_3\text{-N}$  on a dry matter basis, test

## GUIDELINES (continued)

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all forages, water, and possibly concentrates for nitrate content. Pending test reports on other feeds, use the information in **Table 3** as a rough guide for using high nitrate forage(s). It is important, however, to limit meal size as shown in **Table 4** for any forage containing .50 percent NO<sub>3</sub> or 1100 ppm NO<sub>3</sub>-N or more. These maximums on forage dry matter intake in a single meal are those which research has shown to maintain methemoglobin levels at a normal level of 3 percent or less.

Upon completion of testing other forages and water, determine the NO<sub>3</sub>-N content of the total ration dry matter for the average animal in the herd or group. If necessary, alter forage intakes to keep the NO<sub>3</sub>-N content at not over .04 to .09 percent of the total ration dry matter including NO<sub>3</sub>-N contribution from all feeds and drinking water. The lower value should prevent all appreciable adverse effects, provided maximum single meal intakes are not exceeded. The upper value should prevent acute and chronic toxicity with the exception of a moderate increase in reproductive problems.

Use the information and worksheets as illustrated in **Table 5** for these calculations and

possible ration adjustments. Blank worksheets at the end of this publication also may be used to make preliminary adjustments in the NO<sub>3</sub>-N content of the overall diet, pending tests of non-suspected feeds and water. Expected nitrate contents for various feeds and water under usual conditions are given in **Table 6**. Water intakes may be estimated using information found in **Table 7**.

While it is prudent to maintain a NO<sub>3</sub>-N content in the total ration dry matter—including contributions of drinking water at not over .04 percent for reproducing animals—a lower or higher level may be chosen based on information presented in **Table 8**. For example, if no reproductive impairment is desired, a level somewhat under .04 percent or 400 ppm NO<sub>3</sub>-N may be used. If one is willing to accept a slight to moderate rise in infertility, then a level of NO<sub>3</sub>-N as high as .09 to .13 percent NO<sub>3</sub>-N might be considered in order to use more high-nitrate forage. This assumes that amounts of dry matter intake per single meal from high-nitrate forage will not exceed limits indicated in **Table 4**.

## GENERAL RECOMMENDATIONS

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1. Test suspected forages for nitrate content, preferably before feeding them.
2. Introduce suspected or high-nitrate forages gradually into the ration over a period of two to three weeks to allow for adaptation and reduce risks.
3. Feed another forage prior to feeding suspected or high-nitrate forage to help limit meal size.
4. Feed forages and TMRs more frequently, when suspected or high nitrate forage is used or silo gas is present, to reduce meal size.
5. Feed at least three to five pounds of grain per head daily to cattle fed suspected forages or high nitrate forages to reduce possible toxic effects.
6. Limit dry matter intake per single meal if stored forage contains 1100 ppm NO<sub>3</sub>-N or more on a dry matter basis. See **Table 4**. Allow a delay of two to three hours after completion of a meal before feeding high nitrate forage(s) again.
7. Re-test suspected and high nitrate forages periodically, due to large variations which often occur in forages.

## GENERAL RECOMMENDATIONS (continued)

8. Test all forages and water for nitrates if one stored forage contains over 1000 ppm NO<sub>3</sub>-N.
9. Consider blending high-nitrate silage or haylage with those containing lower amounts before feeding to provide less than 1100 ppm NO<sub>3</sub>-N in the blend dry matter and thus enabling free-choice feeding.
10. Restrict the NO<sub>3</sub>-N content of the total ration dry matter, including contribution from water to not over .04 to .09 percent when using stored forage in addition to meeting any maximum forage dry matter intake for a single meal. See **Tables 5 and 8**.
11. Observe animals closely for symptoms of toxicity. Check the color of mucous membranes in the vagina, mouth, or eyes two hours following the start of a meal consisting of a suspected or high nitrate forage (over 1100 ppm NO<sub>3</sub>-N).

Membranes will turn from pink to a grayish-brown at a methemoglobin content of 20 percent or higher. This is the earliest sign of a possible toxicity occurring with slight to acute symptoms. Acute symptoms may include rapid breathing, incoordination or staggering, and signs of suffocation.

Usually stored forages with less than 1100 ppm NO<sub>3</sub>-N may be fed free choice to cattle. Alternative levels are indicated in **Table 8** and the text. Use precautions against silo gas poisoning with suspected or known high nitrate forages, including the possible development of nitrogen oxide gases in silage or total mixed rations that heat appreciably in the bunk or manger. Cows are very sensitive to silo gas. Do not fill silage carts or TMR mixers and feeders appreciably in advance of feeding. Aerate and feed gas-producing silages in a well-ventilated place, preferably outside. When silage is not well preserved, nitrogen oxide gases may continue to be produced for considerable periods after ensiling, rather than for a few weeks after harvest.

**Table 1. Guide to Toxicity of Nitrates in Water for Cattle<sup>a</sup>**

<i>Nitrate level as NO<sub>3</sub></i> <i>ppm<sup>b</sup></i>	<i>Nitrate level as NO<sub>3</sub>-N</i> <i>ppm<sup>b</sup></i>	<i>Possible effects</i>
0-100	0-23	None
101-500	23+-114	Reduced gains, more infertility
501-1000	114+-227	Gray-brown mucous membranes distress symptoms <sup>c</sup>
over 1000	over 227	Acute symptoms, deaths <sup>d</sup>

<sup>a</sup>Assumes normal or close to average nitrate levels in forages and feeds. Test forages and complete a nitrate worksheet when water contains over 100 ppm NO<sub>3</sub> or 23 ppm NO<sub>3</sub>-N. See Table 5.

<sup>b</sup>ppm=mg/l    mg/l x .454 = mg/lb

<sup>c</sup>Shortness of breath, rapid breathing

<sup>d</sup>Suffocation signs, incoordination, or staggering

**Table 2. Factors for Converting Various Expressions of Nitrate Content**

Method of expression	Molecular or ionic weight	Factors converting from one designation to another based on relative weights			
		N	NO <sub>2</sub>	NO <sub>3</sub>	KNO <sub>3</sub>
Nitrate nitrogen	14	1.0	0.30	0.23	0.14
Nitrite nitrogen	14	1.0	0.30	0.23	0.14
Nitrite	46	3.3	1.00	0.74	0.46
Nitrate	62	4.4	1.34	1.00	0.61
Sodium nitrate	85	6.1	1.85	1.37	0.84
Potassium nitrate	101	7.2	2.20	1.63	1.00

*Examples:*

- Percentage: 1.0% nitrate nitrogen is equivalent to 4.4% nitrate or 7.2% potassium nitrate
- Parts per million: 1 ppm potassium nitrate is equivalent of 0.61 ppm nitrate or 0.14 ppm nitrate nitrogen

*Conversion to and from parts per million:*

- (1) To convert parts per million to percent, move the decimal point four places to the left  
*Example:* 10 ppm = .0010% or  $10 \div 10,000$
- (2) To convert percent to parts per million, move the decimal point four places to the right  
*Example:* 0.01% = 100 ppm or  $.01 \times 10,000 = 100$

ppm = mg/kg      mg/lb = mg/kg x .454

*Conversion of nitrate ion (NO<sub>3</sub>) to nitrate nitrogen (NO<sub>3</sub>-N):*

$NO_3-N = NO_3 \div 4.4$

*Conversion of nitrate nitrogen to nitrate ion:*

$NO_3 = NO_3-N \times 4.4$

**Table 3. Guide to Using Stored Forages with Various Nitrate Contents<sup>a</sup>**

Forage nitrate content - dry matter basis				Comments
—as Nitrate Ion— (NO <sub>3</sub> )		—as Nitrate-Nitrogen— (NO <sub>3</sub> -N)		
%	ppm	%	ppm	
0.0-.44	0-4400	0-.10	0-1000	Safe under most conditions
.45-.75	4500-7500	.10+-.17	1000+-1700	Gradually introduce to ration Feed some concentrate Test all feeds and water Dilute to .40% NO <sub>3</sub> or .09% NO <sub>3</sub> -N or less in total ration dry matter Restrict single meal size <sup>b</sup>
.76-1.00+	7600-10,000+	.17+-.23	1700+-2300+	Possible acute toxicity Feed in a balanced ration with concentrate included Dilute to .40% NO <sub>3</sub> or .09% NO <sub>3</sub> -N or less in total ration dry matter Restrict single meal size <sup>b</sup>

<sup>a</sup>If one forage contains over .44% NO<sub>3</sub> or 1000 ppm NO<sub>3</sub>-N test all forages, water, and possibly concentrates. Include nitrate intake from water as part of dietary intake. Use work sheets and information in guideline section to determine and adjust nitrate intake and meal size. Somewhat higher levels of nitrate may be tolerated when pasture is the sole source of forage. See Table 8.

<sup>b</sup>See Table 4 to determine safe intake of forage dry matter with a given nitrate content in a single meal.

**Table 4. Maximum Intake of Stored Forage Dry Matter in a Single Meal at Various Forage Nitrate Contents to Avoid Nitrate Toxicity<sup>a</sup>**

(A) Forage NO <sub>3</sub> -N DM Basis	(B) Single Meal Max Intake of Forage NO <sub>3</sub> -N	(C) Single Meal Maximum Forage DMI <sup>b</sup>	(D) Interpolation Factors for Forage NO <sub>3</sub> -N Intake <sup>c</sup>
ppm (mg/kg)	mg/cwt BW	lb/cwt BW	mg/ppm change in (A)
1100	574	1.15	---
1700	517	.67	.095
2300	423	.41	.157
2800	388	.31	.070
3400	367	.24	.035
4000	356	.20	.018
4500	346	.17	.020
5100	341	.15	.008
5700	336	.13	.008
6300	331	.12	.008
6800	325	.11	.012
8000	318	.09	.006
9100	315	.08	.003
10200	313	.07	.002
11400	310	.06	.003

<sup>a</sup>A single meal refers to the amount of stored forage dry matter consumed during one episode of eating, which may require a few minutes to two hours, depending upon the rate of forage dry matter intake per cwt of BW as indicated in the table. Delay feeding high nitrate forage again for two to three hours after completion of intake at its previous feeding. Maximum intakes given are designed to keep methemoglobin level at 3% or less.

<sup>b</sup>FDMI = forage dry matter intake BW = bodyweight

<sup>c</sup>Factors for use only when desired with intermediate NO<sub>3</sub>-N contents in forage. Maximum levels of NO<sub>3</sub>-N intake per cwt of BW may be calculated for forages of intermediate NO<sub>3</sub>-N content by using these factors. Example for a forage with 3100 ppm NO<sub>3</sub>-N: the overage is 3100 - 2800 or 300. Thus the maximum is 388 - dx 300 or 388 - .035 x 300 or 388 - 10.5 equals 378 mg/cwt BW (B) in a single meal. Maximum FDMI may then be calculated: B ÷ (A x .454). *Example:* 378 ÷ (3100 x .454) or 378 ÷ 1407 = .269 or .27 lb of FDMI per cwt BW in a single meal.

**Table 5. Example of Nitrate Intake Worksheet for Ruminants**

	<i>A</i> <i>Daily Intake As Fed</i>	<i>B</i> <i>% Moisture</i>	<i>C</i> <i>% Dry Matter</i>	<i>D</i> <i>Lb DM Intake Daily</i>	<i>E</i> <i>Lb Feed Water</i>	<i>F</i> <i>Feed NO<sub>3</sub>-N Content</i>	<i>G</i> <i>Content Factor</i>	<i>H</i> <i>mg of NO<sub>3</sub>-N Intake</i>
<i>Calculation:</i>	<i>Lb</i>	<i>Test</i>	<i>100-B</i>	<i>AxC/100</i>	<i>AxB/100</i>	<i>PPM</i>	<i>Given</i>	<i>DxFxG</i>
<b>A. Feed Item<sup>a</sup></b>								
Corn silage	28.6	65	35	10.0	18.5	1700 <sup>b</sup>	.454	7718
MML haylage	26.8	50	50	13.4	13.4	460	.454	2798
Grain mix	20.0	12	88	17.6	2.4	48	.454	384
_____							.454	
_____							.454	
_____							.454	
_____							.454	
_____							.454	
_____							.454	
<b>Feed Total</b>				<b>41.0</b>	<b>34.3</b>			<b>10900</b>

<sup>a</sup>Include expected pasture intake in all diets using such

<sup>b</sup>Amount in a single meal must be limited due to a content of 1100 ppm or higher. See Table 4 for details.

**B. Drinking water contribution (for average cow at 1300 lb BW and producing 60 lb of 3.7% milk)**

Expected total water intake <sup>a</sup>	<u>270</u>	(I) [60 x 4.5]
Feed water (Total E)	<u>34</u>	(J)
Drinking water (I-J)	<u>236</u>	(K)
Mg NO <sub>3</sub> -N from drinking water:		(L)
K x Water NO <sub>3</sub> -N as ppm or mg/l		
Example: <u>236</u> x <u>8</u> x .454 = <u>857</u>		(L)

**C. Total mg NO<sub>3</sub>-N intake daily** (M)

Total H + L  
 Example: 10900 + 857 = 11757 (M)

**D. NO<sub>3</sub>-N content of total diet as % DM<sup>b</sup>** (N)

[(M/454,000) ÷ Total D] x 100  
 Example: .0259 ÷ 41 x 100 = .063 (N)

<sup>a</sup>See Table 7 for expected water intakes.

<sup>b</sup>See Table 8 and the text for interpretation

(continued on next page)

**Table 5. Example of Nitrate Intake Worksheet for Ruminants** (continued)

E. Adjustment of ration to control NO<sub>3</sub>-N content of diet<sup>b</sup>

Desired level in TRDM, including water: \_\_\_\_\_% (P) —see Table 8 for guide

Assumed desired level in this example .05% (P)

Current content (N) .063% (Q)

Content to be reduced (R)

$$Q - P = R$$

Example:  $.063 - .050 = .013\%$  (R)

Amount to be reduced (S)

$$D \times R/100 = S$$

Example:  $41 \times .00013 = .00533$  (S)

Difference in content of NO<sub>3</sub>-N of high and low forage (T)

High forage (F) - Low forage (F) / 10,000

Example:  $(1700 - 460) / 10,000 = .1240$  (T)

Lb forage dry matter to be exchanged (U)

$$S \div T/100 = U$$

Example:  $.00533 \div .00124 = 4.3$

New high NO<sub>3</sub>-N forage DMI (V)

(Old) D - U = V

Example:  $10 - 4.3 = 5.7$

New as fed amount of high forage

$$V \div C/100$$

Example:  $5.7 \div .35 = 16.3$  for corn silage

New low NO<sub>3</sub>-N forage DMI (W)

(Old) D + U = W

Example:  $13.4 + 4.3 = 17.7$  (W)

New as fed amount of low forage

$$W \div C/100$$

Example:  $17.7 \div .50 = 35.4$

Restriction on single meal dry matter intake for high NO<sub>3</sub>-N forage<sup>c</sup>:

Corn silage @ 1700 ppm content

Maximum intake = .67 ÷ cwt BW (X) —from Table 4

Single meal max in lb FDMI (Y)

$$\text{Max} \times \text{cwt BW} = Y$$

Example:  $.67 \times 13 = 8.7$  (Y)

Comparison

Y vs V

8.7 max is larger than V (5.7) — Thus, corn silage could be fed in one meal.

If daily amount V is greater than Y, then corn silage should be fed in more than one meal.

Choose a desired risk level of NO<sub>3</sub>-N in total ration dry matter that enables removal of silages or haylages at a rate that prevents molding and heating in the silo. When this is not feasible, it may not be possible to feed the high nitrate forage.

<sup>a</sup>See Table 7 for expected water intakes

<sup>b</sup>See Table 8 and the text for interpretation

<sup>c</sup>See Table 4 for possible need for maximum single meal intakes for forages containing 1100 ppm NO<sub>3</sub>-N or higher

**Table 6. Expected Nitrate Content of Feeds Grown Under Normal Weather Conditions**

	<i>NO<sub>3</sub> range</i>	<i>Nitrate content—dry matter basis</i>	
		<i>NO<sub>3</sub> mean</i>	<i>NO<sub>3</sub>-N mean</i>
	<i>ppm</i>	<i>ppm</i>	<i>ppm</i>
Water	0 - 44	34	8
Dairy grain mix	111 - 400	209	48
Corn grain	139 - 188	164	37
Protein concentrate	105 - 120	113	26
Corn silage	440 - 2200	1365	310
Grass, MMG <sup>a</sup> forage	46 - 1600 <sup>c</sup>	1003 <sup>c</sup>	228
Legume, MML <sup>b</sup> forage	490 - 4100 <sup>c</sup>	2025 <sup>c</sup>	460

<sup>a</sup>Mixed mainly grass

<sup>b</sup>Mixed mainly legume

<sup>c</sup>Ensiled forage may contain about 30% less nitrate than hay or fresh forage of the same nitrate content at harvest.

**Table 7. Expected Water Intakes for Dairy Cattle<sup>a,b</sup>**

Milk Cows—4.5 to 5.0 lb<sup>c</sup> per lb milk produced minus feed water

Dry Cows—75 to 108 lb<sup>d</sup> for small and large breed animals, respectively

Calves, 6 months—37 lb<sup>d</sup>

Heifers, 12 months—45 lb<sup>d</sup>

Heifers, 18 months—61 lb<sup>d</sup>

<sup>a</sup>See other sources for beef cattle, sheep, and goats. As a rule of thumb, beef cattle may need water at the rate of 1% of BW in gallons daily.

<sup>b</sup>One gallon of water = 8.34 lb

<sup>c</sup>Use higher values given during hot weather

<sup>d</sup>Drinking water, not total water intake as with milk cows

**Table 8. Possible Effects of Various Contents of NO<sub>3</sub>-N  
in the Total Ration Dry Matter<sup>a</sup>**

<i>Possible toxicity</i>	<i>Stored forage and concentrate<sup>b</sup> ppm<sup>d</sup></i>	<i>Pasture alone<sup>c</sup> ppm<sup>d</sup></i>
None	up to 400	up to 800
Impaired fertility <sup>e</sup>	401-1300	801-2600
Reduced gains	1301-1700	2601-3400
Clinical symptoms <sup>f</sup>	over 1700	over 3400

<sup>a</sup>Includes NO<sub>3</sub>-N from water. Nitrate intake per meal also must be limited by restricted intake of forage dry matter, as indicated in Table 4, to make a ration safe or low risk.

<sup>b</sup>Refers to rations containing 60% or less concentrate dry matter and those containing a combination of stored forage and pasture or green chop as well as concentrate.

<sup>c</sup>No appreciable amount of concentrates or other forage being consumed.

<sup>d</sup>Percent NO<sub>3</sub>-N equals ppm ÷ 10,000, or move decimal point four places to the left.

<sup>e</sup>Refers to a slight to moderate increase in services required per conception and repeat breedings. Abortions generally do not occur until content of NO<sub>3</sub>-N in the ration dry matter reaches 1400 ppm, or more commonly 2300 ppm, when feeding stored forages. No aborted fetuses have occurred in some research at even higher levels of nitrate intake when meals have been spaced, such as in feeding a TMR.

<sup>f</sup>A change in color of mucous membranes of the vagina, mouth, or eye (from pink to a grayish-brown) may be noted at levels of intake near this level. Respiratory and other distress symptoms or death may occur at high levels, particularly if dry matter intakes per meal exceed those indicated in Table 4 for high nitrate forages.

**Dietary Nitrate Intake Worksheet for Ruminants**

	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>F</i>	<i>G</i>	<i>H</i>
	<i>Daily</i>	<i>%</i>		<i>Lb DM</i>	<i>Lb</i>	<i>Feed</i>		<i>mg of</i>
	<i>Intake</i>	<i>Moisture</i>	<i>% Dry</i>	<i>Intake</i>	<i>Feed</i>	<i>NO<sub>3</sub>-N</i>	<i>Content</i>	<i>NO<sub>3</sub>-N</i>
	<i>As Fed</i>		<i>Matter</i>	<i>Daily</i>	<i>Water</i>	<i>Content</i>	<i>Factor</i>	<i>Intake</i>
<i>Calculation:</i>	<i>Lb</i>	<i>Test</i>	<i>100-B</i>	<i>AxC/100</i>	<i>AxB/100</i>	<i>PPM</i>	<i>Given</i>	<i>DxFxG</i>
A. Feed Item <sup>a</sup>								
_____							.454	
_____							.454	
_____							.454	
_____							.454	
_____							.454	
_____							.454	
_____							.454	
_____							.454	
Feed Total				_____	_____			_____

<sup>a</sup>Include expected pasture intake in all diets using such)

**B. Drinking water contribution**

- Expected intake<sup>a</sup> \_\_\_\_\_ (I)
- Feed water (Total E) \_\_\_\_\_ (J)
- Drinking water (I-J) \_\_\_\_\_ (K)
- Mg NO<sub>3</sub>-N from drinking water: \_\_\_\_\_ (L)

K x Water NO<sub>3</sub>-N as ppm or mg/l  
 \_\_\_\_\_ x \_\_\_\_\_ x .454 = L

## Dietary Nitrate Intake Worksheet for Ruminants (continued)

C. Total mg NO<sub>3</sub>-N intake daily (M)

$$\begin{array}{l} \text{Total H + L} \\ \text{_____} + \text{_____} = \text{M} \end{array}$$

D. NO<sub>3</sub>-N content of total diet as % DM<sup>b</sup> (N)

$$\begin{array}{l} (\text{M}/454,000) \div \text{tTotal D} \times 100 \\ \text{_____} \div \text{_____} = \text{_____} \text{ (N)} \end{array}$$

E. Adjustment of ration to control NO<sub>3</sub>-N content of diet<sup>b</sup>

Desired level in TRDM, including water: \_\_\_\_\_% (P) —see Table 8 for guide

Assumed desired level in this example \_\_\_\_\_ (P)

Current content (N) \_\_\_\_\_ (Q)

Content to be reduced (R)

$$Q - P = R$$

Amount to be reduced (S)

$$D \times R/100 = S$$

Difference in content of NO<sub>3</sub>-N of high and low forage (T)

$$\text{High forage (F) - Low forage (F)}/10,000$$

Lb forage dry matter to be exchanged (U)

$$S \div T/100 = U$$

New high NO<sub>3</sub>-N forage DMI (V)

$$(\text{Old}) D - U = V$$

New as fed amount of high forage

$$V \div C/100$$

New low NO<sub>3</sub>-N forage DMI (W)

$$(\text{Old}) D + U = W$$

Restriction on single meal dry matter intake for high NO<sub>3</sub>-N forage<sup>c</sup>: —see Table 4

Maximum intake = \_\_\_\_\_/cwt BW (X) —from Table 4

Single meal max in lb FDMI (Y)

$$\text{Max} \times \text{cwt BW} = Y$$

Comparison

Y vs V—If daily amount V is greater than Y, it must be fed in more than one meal.

Choose a desired risk level of NO<sub>3</sub>-N in total ration dry matter that enables removal of silages or haylages at a rate that prevents molding and heating in the silo. When this is not feasible, it may not be possible to feed the high nitrate forage.

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<sup>a</sup>See Table 7 for expected water intakes.

<sup>b</sup>See Table 8 and the text for interpretation

<sup>c</sup>See Table 4 for possible need for maximum single meal intakes for forages containing 1100 ppm NO<sub>3</sub>-N or higher