Managing high nitrate feedstuffs - Toxic dosage approach

Nitrate toxicity ratings are typically based on the concentration in the feedstuff being tested. Remembering that these ratings assume the forage is the sole feedstuff for the animal in question is important. Dilution with other feedstuffs, slowing the intake rate, or other management strategies can help modify the toxicity potential of a high nitrate feed.

Toxicity ratings based on feed analysis alone do not consider all factors that affect how an animal will react to nitrate. A good evaluation of nitrate toxicity potential should include the following:

1) the nitrate-nitrogen content of the entire ration,

2) feed intake (as "dry matter" consumption),

3) nitrate contributions from water or other sources,

4) body weight or animal size, and

5) previous exposure to nitrate.

"The dose makes the poison" is an old saying that applies to nitrate toxicity. Research shows that toxicity is rare if an animal consumes less than about 450 milligrams nitrate-nitrogen per hundred pounds of body weight (NO_3-N mg/cwt BW). The toxic dose can increase to about 1300 NO_3-N mg/cwt_BW if the animal is not pregnant.

The toxic dose approach considers body weight, ration composition, and other factors - not just the nitrate level of a single feedstuff. Table 1 shows the expected symptoms at different dosages of nitrate.

Different animals vary in just how they respond to elevated nitrates. Some animals can simply tolerate more nitrate in the ration than others, so no approach is absolutely foolproof. The toxic dose approach allows flexibility to help manage high nitrate forages in a feeding program.

Formulating rations based on nitrate

The forage analysis results and animal weight are used to calculate the amount of a specific feedstuff that can be tolerated in an animal diet to stay below the critical nitrate dosage. This process has four steps.

Step 1. Calculate the nitrate content of forages and ration ingredients.

ppm NO_3-N in forage x 0.4536 = mg NO_3-N/lb dry matter

Step 2. Multiply the nitrate content by the pounds of forage to be fed or consumed daily (on a dry matter basis) to find the total nitrate dosage.

*mg NO_3-N/lb DM * lb DM = mg NO_3-N*

Consumption rates are often calculated as percentages of animal body weight. For example, a young, 500-lb animal will consume about 2.5% of their body weight as dry matter (DM) or about 12 to 13 pounds of dry matter per day.

Forage type also affects intake rates. The intake rate increases as forage quality increases. Table 2 lists the estimated typical dry matter intakes for various forage qualities.

Table 3 contains the calculated total dosage of nitrate-nitrogen that would be present in various amounts of dry matter at different nitrate concentrations.

Step 3. Add the nitrate dosage of the ration ingredients to identify the total daily nitrate dosage. Divide the total daily dosage by the animal body weight as hundred-weight (cwt_BW) to find the ration nitrate dosage.

mg NO_3-N ÷ cwt_BW = mg NO_3/cwt_BW

Step 4. If the ration nitrate dosage is less than 450 mg NO_3/cwt_BW, then no adjustment should be needed for any livestock class. If the ration nitrate dosage is less than 1300 mg NO_3/cwt_BW, then no adjustment should be needed for non-pregnant livestock.

Adjust the ration ingredients as needed if the ration nitrate dosage exceeds the critical level. Divide either 450 or 1300 by the ration nitrate dosage to estimate the proportion of the high nitrate ingredients in the ration.

For example, assume a forage with 2000 ppm NO_3-N is to be fed free-choice to 500 lb calves that consume 10 lb of dry matter per day.

2000 ppm NO_3-N x 0.4536 = 907 mg NO_3-N/lb

907 mg NO_3-N x 10 lb DM = 9070 mg NO_3

9070 mg NO_3-N ÷ 5 cwt = 1814 mg NO_3/cwt_BW

In this example, the forage should not be the single source of feed because it exceeds 1300 mg NO_3-N/cwt_BW. It should only make up about 70% of the

total ration with the other 30% as very low nitrate feedstuffs, like grain or concentrate.

1300 ÷ 1814 = 0.72 = 72%

Tables 4 and 5 list the suggested maximum pounds of dry matter forage to be included in the daily ration for different body weights, forage qualities, and forage nitrate concentrations. These calculations assume that the remaining ration ingredients have very low nitrate concentrations.

Table 4 uses the critical dosage of 1300 mg/cwt_BW for non-pregnant livestock. Table 5 uses a dosage of 450 mg/cwt_BW for pregnant livestock.

The toxic dosage calculations involve the daily ration, not just the feedstuff consumed in a single "meal". A single meal is one feeding that may take a few minutes to two hours to complete, depending on the animal intake rate. The daily proportion of the feedstuff should not exceed the maximum percentage of the ration dry matter intake given in the tables. These intake rates are generally designed to keep the blood methemoglobin level at 3% or less.

Table 1. Nitrate dose and expected animal response.

milligrams of nitrate per 100 lb body weight, mg NO_3-N /cwt_BW	Expected animal response
0 - 450	Safe for pregnant cattle
450 - 1300	Potential early·term abortions Reduced breeding performance
0 - 1300	Safe for non-pregnant cattle.
1300 - 2600	Mid- to late-term abortions Weak newborn calves Decreased growth Reduced milk yields
> 2600	Abortions. Toxicity symptoms and death

Adapting to nitrate

The rumen microbes adapt to increased nitrate levels in feedstuffs by increasing the enzyme, nitrate reductase. This enzyme is used to convert nitrate to nitrite. The microbes can then convert the nitrite to ammonia or other nontoxic compounds.

This adaptation process begins within four hours or so after the animal starts consuming a high nitrate feedstuff. Full adaptation may take three to six days. Adaptation may not be rapid enough to avoid toxicity, especially if nitrate intake is too high. The microbes simply cannot detoxify the nitrate quickly enough.

Microbes will de-adapt when the ration nitrate level declines. De-adaptation may take as little as four days, so the animals are not protected if ration nitrate levels increase later.

Consumption rates

Hungry animals eat more feed. Eating more feed or eating it faster may exceed the ability of the rumen microbes to detoxify the ingested nitrate. Controlling intake rate is critical to manage high nitrate feedstuffs. Animals cannot sense the level of feed nitrate, so the forage palatability and digestibility usually govern dry matter intake.

Harvesting forage allows a producer to manage the intake rate, but livestock can consume a processed forage faster than by grazing. Regardless of harvest method, high nitrate forages must be limit-fed to reduce toxicity potential.

Followup feedings of high nitrate forage should be delayed for at least two to three hours after the animal has completed the previous feeding. Do not delay feeding to the point where the animal becomes excessively hungry and prone to eat rapidly - exceeding the rumen microbes ability to detoxify nitrate and increasing the potential for toxicity to occur.

Drinking water nitrate

Nitrate salts contained in drinking water are available more quickly than the nitrates contained in forage tissue. The toxic dosage of water alone is about 15,000 to 20,000 mg per hundred pounds of body weight. Including the nitrate contribution from water as part of the total dietary nitrate consumption may be necessary.

Water nitrate content per gallon can be calculated from lab analysis results. The nitrate content should then be multiplied by the estimated daily water consumption to find daily nitrate ingestion. This may need to be included to the daily nitrate dosage along with nitrate from the ration.

mg NO_3-N/gal = mg/L NO_3-N x 3.785

For example, assume the 500 lb calves in the earlier example consume 7 gallons of water with 35 mg/L NO_3-N.

35mg/L x 3 .785 = 132 mg NO_3-N/gal

132 x 10 gallons = 1320 mg NO_3-N

This water would supply the animal with an additional 1320 mg of NO_3-N. If added to the 9070 mg NO3-N from the forage, the total daily nitrate ingestion would be 10,390 mg NO_3-N.

10,390 mg NO_3-N ÷ 5 cwt = 2078 mg NO_3/cwt_BW

This additional nitrate from the water increases the

daily dosage by about 200 mg NO_3-N, possibly requiring additional adjustments to the ration. Table 6 contains quantities of nitrate contained in various volumes of water.

Table 7 contains typical daily water consumption rates for various types and classes of livestock. Daily nitrate intake from water can be estimated from these figures.

References

Hibberd, C.A., T. Rehberger, J. Swartzlander, and T. Parrot. 1993. Utilization of High Nitrate Forages by Beef Cows, Dairy Cows and Stocker Calves. Proc. of "Management of High Nitrate Forages for Beef and Dairy Cattle". Oklahoma State Univ., Coop. Extension Svc. Enid, Oklahoma. 04 May 1993. 12 pg.

Adams, R.S., T.R. McCarty and L.J. Hutchinson. 2010. Prevention and Control of Nitrate Toxicity in Cattle. Publ. DAS 92-107. Pennsylvania State University Penn State.

Table 2. Forage quality effect on dry matter intake

Forage quality	Dry matter intake, percent of body weight	Examples
Low quality	1.5%	dormant grass straw, stubble mature stalks
Average quality	2.0 % - 2.5%	native grass mid- to late summer, improved warm-season pasture
High quality	2.5% - 3.0%	Alfalfa Small grain pasture Spring, cool-season improved pasture

Table 3. Estimated nitrate dosage at different concentrations and dry matter intake.

Pounds of dry matter consumed	*Forage nitrate concentration, ppm NO_3-N*						
	500	1000	1500	2000	2500	3000	3500
	Total nitrate consumed in dry matter, mg NO_3-N						
1	225	450	680	910	1130	1360	1590
5	1130	2270	3400	4540	5670	6800	7950
10	2,270	4550	6800	9070	11,350	13,600	15,900
15	3400	6800	10,200	13,600	17,000	20,400	23,800
20	4540	9070	13,600	18,150	22,700	27,200	31,750
25	5670	11,350	17,000	22,700	28,350	34,000	39,700

Table 4. Maximum amount of dry matter consumption for NON-PREGNANT animals.

assumes LOW QUALITY FORAGE, 1.5% of body weight consumed									
Forage nitrate, ppm NO_3-N		500	1000	1500	2000	2500	3000	3500	4000
Max. percent of dry matter intake		100%	100%	100%	95%	75%	65%	55%	50%
Animal body weight	*lb DM intake*	----------	*Maximum lb of dry matter to be consumed*					----------	
200 lb	3.0	3.0	3.0	3.0	2.9	2.3	2.0	1.7	1.5
400 lb	6.0	6.0	6.0	6.0	5.7	4.5	3.9	3.3	3.0
600 lb	9.0	9.0	9.0	9.0	8.6	6.8	5.9	5.0	4.5
800 lb	12.0	12.0	12.0	12.0	11.4	9.0	7.8	6.6	6.0
1000 lb	15.0	15.0	15.0	15.0	14.3	11.3	9.8	8.3	7.5
1200 lb	18.0	18.0	18.0	18.0	17.1	13.5	11.7	9.9	9.0
1200 l4	21.0	21.0	21.0	21.0	20.0	15.8	13.7	11.6	10.5
assumes LOW TO AVERAGE QUALITY FORAGE, 2.0% of body weight consumed									
Forage nitrate, ppm NO_3-N		500	1000	1500	2000	2500	3000	3500	4000
Max. percent of dry matter intake		100%	100%	95%	70%	55%	50%	40%	35%
Animal body weight	*lb DM intake*	----------	*Maximum lb of dry matter to be consumed*					----------	
200 lb	4.0	4.0	4.0	3.8	2.8	2.2	2.0	1.6	*1.4*
400 lb	8.0	8.0	8.0	7.6	5.6	4.4	4.0	3.2	2.8
600 lb	12.0	12.0	12.0	11.4	8.4	6.6	6.8	4.8	4.2
800 lb	16.0	16.0	16.0	15.2	11.2	8.8	8.0	6.4	5.6
1000 lb	20.0	20.0	20.0	19.0	14.0	11.0	10.0	8.0	7.0
1200 lb	24.0	24.0	24.0	22.8	16.8	13.2	12.0	9.6	8.4
1400 lb	28.0	28.0	28.0	26.6	19.6	15.4	14.0	11.2	9.8
assumes AVERAGE TO HIGH QUALITY FORAGE, 2.5% of body weight consumed									
Forage nitrate, ppm NO_3-N		500	1000	1500	2000	2500	3000	3500	4000
Max. percent of dry matter intake		100%	100%	75%	55%	45%	40%	35%	30%
Animal body weight	*lb DM intake*	----------	*Maximum lb of dry matter to be consumed*					----------	
200 lb	5.0	5.0	5.0	3.8	2.8	2.3	2.0	1.8	1.5
400 lb	10.0	10.0	10.0	7.5	5.5	4.5	4.0	3.5	3.0
600 lb	15.0	15.0	15.0	11.3	8.3	6.8	6.0	5.3	4.5
800 lb	20.0	20.0	20.0	15.0	11.0	9.0	8.0	7.0	6.0
1000 lb	25.0	25.0	25.0	18.8	13.8	11.3	10.0	8.8	7.5
1200 lb	30.0	30.0	30.0	22.5	16.5	13.5	12.0	10.5	9.0
1400 lb	35.0	35.0	35.0	26.3	19.3	15.8	14.0	12.3	10.5
assumes HIGH QUALITY FORAGE, 3.0% of body weight consumed									
Forage nitrate, ppm NO_3-N		500	1000	1500	2000	2500	3000	3500	4000
Max. percent of dry matter intake		100%	95%	65%	50%	40%	30%	25%	25%
Animal body weight	*lb DM intake*	----------	*Maximum lb of dry matter to be consumed*					----------	
200 lb	6.0	6.0	5.7	3.9	3.0	2.4	1.8	1.5	1.5
400 lb	12.0	12.0	11.4	7.8	6.0	4.8	3.6	3.0	3.0
600 lb	18.0	18.0	17.1	11.7	9.0	7.2	5.4	4.5	4.5
800 lb	24.0	24.0	22.8	15.6	12.0	9.6	7.2	6.0	6.0
1000 lb	30.0	30.0	28.5	19.5	15.0	12.0	9.0	7.5	7.5
1200 lb	36.0	36.0	34.2	23.4	18.0	14.4	10.8	9.0	9.0
1400 lb	42.0	42.0	39.9	27.3	21.0	16.8	12.6	10.5	10.5

Table 5. Maximum amount of dry matter consumption for PREGNANT animals.

assumes LOW QUALITY FORAGE, 1.5% of body weight consumed									
Forage nitrate, ppm NO_3-N		500	1000	1500	2000	2500	3000	3500	4000
Max. percent of dry matter intake		100%	100%	100%	95%	75%	65%	55%	50%
Animal body weight	*lb DM intake*	----------	*Maximum lb of dry matter to be consumed*					----------	
200 lb	3.0	3.0	2.0	1.4	1.1	0.8	0.6	0.6	0.5
400 lb	6.0	6.0	3.9	2.7	2.1	1.5	1.2	1.2	0.9
600 lb	9.0	9.0	5.9	4.1	3.2	2.3	1.8	1.8	1.4
800 lb	12.0	12.0	7.8	5.4	4.2	3.0	2.4	2.4	1.8
1000 lb	15.0	15.0	9.8	6.8	5.3	3.8	3.0	3.0	2.3
1200 lb	18.0	18.0	11.7	8.1	6.3	4.5	3.6	3.6	2.7
1200 l4	21.0	21.0	13.7	9.5	7.4	5.3	4.2	4.2	3.2
assumes LOW TO AVERAGE QUALITY FORAGE, 2.0% of body weight consumed									
Forage nitrate, ppm NO_3-N		500	1000	1500	2000	2500	3000	3500	4000
Max. percent of dry matter intake		100%	50%	35%	25%	20%	15%	15%	10%
Animal body weight	*lb DM intake*	----------	*Maximum lb of dry matter to be consumed*					----------	
200 lb	4.0	4.0	2.0	1.4	1.0	0.8	0.6	0.6	*0.4*
400 lb	8.0	8.0	4.0	2.8	2.0	1.6	1.2	1.2	0.8
600 lb	12.0	12.0	6.0	4.2	3.0	2.4	1.8	1.8	1.2
800 lb	16.0	16.0	8.0	5.6	4.0	3.2	2.4	2.4	1.6
1000 lb	20.0	20.0	10.0	7.0	5.0	4.0	3.0	3.0	2.0
1200 lb	24.0	24.0	12.0	8.4	6.0	4.8	3.6	3.6	2.4
1400 lb	28.0	28.0	14.0	9.8	6.9	5.6	4.2	4.2	2.8
assumes AVERAGE TO HIGH QUALITY FORAGE, 2.5% of body weight consumed									
Forage nitrate, ppm NO_3-N		500	1000	1500	2000	2500	3000	3500	4000
Max. percent of dry matter intake		80%	40%	25%	20%	15%	15%	10%	10%
Animal body weight	*lb DM intake*	----------	*Maximum lb of dry matter to be consumed*					----------	
200 lb	5.0	4.0	2.0	1.3	1.0	0.8	0.8	0.5	0.5
400 lb	10.0	8.0	4.0	2.5	2.0	1.5	1.5	1.0	1.0
600 lb	15.0	12.0	6.0	3.8	3.0	2.3	2.3	1.5	1.5
800 lb	20.0	16.0	7.9	5.0	4.0	3.0	3.0	2.0	2.0
1000 lb	25.0	20.0	9.9	6.3	5.0	3.8	3.8	2.5	2.5
1200 lb	30.0	24.0	11.9	7.5	6.0	4.5	4.5	3.0	3.0
1400 lb	35.0	28.0	13.9	8.8	6.9	5.3	5.3	3.5	3.5
assumes HIGH QUALITY FORAGE, 3.0% of body weight consumed									
Forage nitrate, ppm NO_3-N		500	1000	1500	2000	2500	3000	3500	4000
Max. percent of dry matter intake		65%	35%	20%	15%	15%	10%	10%	10%
Animal body weight	*lb DM intake*	----------	*Maximum lb of dry matter to be consumed*					----------	
200 lb	6.0	3.9	2.1	1.2	0.9	0.9	0.6	0.6	0.6
400 lb	12.0	7.8	4.2	2.4	1.8	1.8	1.2	1.2	1.2
600 lb	18.0	11.7	6.3	3.6	2.7	2.7	1.8	1.8	1.8
800 lb	24.0	15.6	8.4	4.8	3.6	3.6	2.4	2.4	2.4
1000 lb	30.0	19.5	10.5	6.0	4.5	4.5	3.0	3.0	3.0
1200 lb	36.0	23.4	12.6	7.2	5.4	5.4	3.6	3.6	3.6
1400 lb	42.0	27.3	14.7	8.4	6.3	6.3	4.2	4.2	4.2

Table 6. Estimated nitrate dosage in animal drinking water.

Gallons of water consumed.	----- *Drinking water nitrate concentration, mg/L NO_3-N* -----						
	10	25	50	75	100	200	400
	---------- *Nitrate consumed in water, mg NO_3-N* ----------						
0.5	19	47	95	140	190	380	760
1	38	95	190	285	380	760	1510
2	76	190	380	570	760	1500	3000
5	190	475	950	1400	1900	3800	7600
10	380	950	1900	2800	3800	7600	15,150
20	760	1900	3800	5700	7600	15,150	30,300
40	1500	3800	7600	11,350	15,150	30,300	60,600

Table 7. Estimated average water consumption for different animal types.

Animal type	Description		Gallons per day	
			40˚ - 70˚F	75˚ or more
Beef	cow with calf/lactating	900 - 1200 lb	12 - 17	15 - 22
	dry cow/mature cow	900 - 1200 lb	7 - 10	10 - 15
	bred cow/heifer	900 - 1200 lb	7 - 10	10 - 15
	calf	2 - 4 months	1½ - 3	2½ - 5
	calf	3 - 6 months	2 - 5	3 - 7
	feeder -growing	400 - 800 lb	6 - 9	9 - 15
	feeder - finishing	600-1200 lb	8 - 13	11 - 23
	bull	1400 - 1600 lb	9 - 12	12 - 18
Dairy	milking*	small breeds, 30 lb/day	13 - 15	18 - 23
	milking*	larger breeds, 30 lb/day	15 - 17	20 - 25
	milking*	large breeds/ 50 lb/day	24 - 27	32 - 40
	dry cow	pregnant, 6 - 9 months	9 - 13	12 - 19
	heifer	12 - 18 months	6 - 8	9 - 12
	heifer	16 - 24 months	7 - 10	10 - 15
	calves	2 to 6 months	2 - 5	3 - 6
Sheep, goats	ewe/doe		2 - 2½	---
	milking ewe/doe		2½ - 3	---
	feeder lamb/kid		1 - 1½	---
	ram/billy		2	---
Horses	maintenance	1100 lb	6 - 8	8 - 15
	working	1100 lb	10 - 12	12 - 18
	mare, lactating	1100 lb	10 - 15	13 - 20
	colt	650 lb	6 - 8	8 - 11
Mule, bison			12	---
Deer, llama, alpaca			2½	---
Elk, donkey			6	---

** typically 4½ to 5 lb water (0.5 to 0.6 gal) per lb milk produced minus water in feed*