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Nitrates and Dairy Cattle: Cause for Concern ?

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There is a consensus amongst dairy cattle nutritionists that nitrate levels of forages in California have been rising steadily for several years. There is also a recognition that in several areas of California often, but not always, associated with high animal densities that nitrate levels in the groundwater that provides drinking water for dairy cattle are also increasing. Is this cause for concern?

Where do Nitrates Come From ?

Nitrates on dairy ranches come from several sources. In some cases nitrates occur naturally in groundwater due to leaching from adjacent rock formations. Nitrates also make up a significant form of nitrogen (N) in many commercial fertilizers. Thus heavy use of commercial fertilizers may lead to increased levels of nitrates in the plants being fertilized. In addition, some of this nitrate may percolate through the soil to groundwater. This process is slow, generally measured in months, and the buildup of nitrates in groundwater may take years to reach levels that can significantly affect animal performance. However in most parts of California the most significant new source of nitrate in the environment, and the probable cause for much of the increase noted in forages and groundwater, is from the N in animal excreta. When animal wastes are repeatedly used as organic fertilizer on limited expanses of land, nitrates will tend to build up in the soil, leach to groundwater at increasing rates, and be taken up in higher quantities by plants.

How do Plants use Nitrates ?

Nitrates are taken up by the roots of plants and deposited in plant tissues. Under many conditions, nitrates are degraded by plant enzymes to forms of N that pose little hazard to either the animal or the environment in general. However any process which increases soil nitrate levels and/or reduces plant growth will lead to elevated levels of nitrates in the plant itself. Thus, when soil nitrate levels are increased, due to heavy use of either N-rich fertilizers or animal wastes, the ability of plant enzymes to break them down may be overwhelmed and nitrate levels in the plant tissues may rise. In addition, the activity of these plant enzymes are reduced by low temperatures as well as cloudy weather. Drought has also been shown to decrease the activity of these enzymes and result in increased plant nitrate levels. Nitrates tend to be highest in plant parts nearest the ground as well as in stalks and stems, which contain less of the enzyme that breaks it down.

What Happens to Nitrates in the Rumen ?

Nitrates in plants are a normal situation for rumen microorganisms and they are well equipped to break down the nitrate to ammonia, which is then used by other rumen microorganisms as a source of N for their growth. However heavy dietary loads of nitrate may overwhelm the ability of rumen microorganisms to completely degrade nitrate to ammonia and levels of nitrite, an intermediate compound, may increase. Nitrite is the real problem as it is toxic to cellulolytic bacteria (i.e. those that digest fiber). This can result in reduced digestibility of fiber in the rumen, which in turn, will result in reduced feed intake and milk production. Fortunately the ability of microorganisms to completely break down nitrate to ammonia increases as the nitrate load it faces increases. Thus, over time, the nitrate level of the diet can be increased slowly without detrimental effects on animal performance.

However if nitrite is produced so quickly that the rumen microorganisms that break it down to ammonia are overwhelmed, it will accumulate in the rumen. This nitrite will pass through the rumen wall to the blood where it combines with hemoglobin, by substituting for oxygen, to create methemoglobin. Methemoglobin has a lower oxygen carrying capacity than hemoglobin and this reduces oxygen delivery to all tissues, including foetal membranes. This is the reason nitrate toxicity has often been associated with increased incidence of abortion. In cases of acute poisoning, the animal will exhibit aberrant behavior, often referred to as ‘bovine bonkers’. This violent behavior makes the condition worse, as tissue oxygen requirements increase to support greater muscle activity and the animal may collapse and die of oxygen deficiency.

What to Watch For in the Herd.

The first, and most subtle, signs of nitrate toxicity will be reduced feed intake and milk production caused by the toxic effects of nitrite on the rumen microorganisms that digest fiber. These symptoms may occur well in advance of subsequent effects, which may never develop at all. However, subsequent sub-acute signs are an increase in spontaneous abortions including reproductive failure caused by early embryonic death caused in turn by oxygen deprivation of these tissues. Acute symptoms, which exhibit the effect of more serious oxygen deprivation to the tissues, include rapid breathing through the mouth, elevated heart rate, and blue coloration of mucous membranes due to oxygen deficiency.

How to Prevent a Problem.

There are a number of management practices that dairy producers can follow to prevent both sub-acute and acute nitrate toxicity. However, it is arguable that the most important management practice that should be followed is to analyze all diet components and drinking water for their nitrate levels well before they are to be fed, and then seek out professional help to interpret the nitrate assay results and to formulate the diet to avoid nitrate toxicity. Other management practices to consider include:

Reduce Nitrate Leaching to Groundwater

- Limit the utilization of N-rich pond waters, manure, and N-rich commercial fertilizers to the soil holding capacity (i.e., do not run pond waters onto soils saturated with water or fertilize immediately before heavy rains).

Reduce Soil Nitrate Accumulation

- Limit utilization of N-rich pond waters, manure, and N-rich commercial fertilizers to the ability of the plants to break down the nitrate (i.e., track the nitrate levels of the forage crops on specific fields over time and reduce N fertilization as plant nitrate levels increase to unacceptable levels).

Reduce Plant Nitrate Levels Before Feeding

- Ensiling is the most effective method to reduce plant nitrate levels post-harvest. The extent of the reduction in nitrate concentration will vary with crop, but factors which will increase nitrate degradation in the silo include increased time in the silo and higher levels of fermentable carbohydrates in the forage being ensiled. High N (crude protein) levels of the plant, often caused by excessive fertilization, will reduce the extent of nitrate destruction during ensiling.

Consider the Time of the Year

- Remember that lack of sunshine and cool growing conditions will limit the activity of the plant enzymes that break down nitrate in the plant. Thus for winter cereals and grasses it is advisable to keep fertilizer use as low as possible.
- Delay harvest until winter crops have had two days of full sun exposure. Nitrate levels that have increased during cool and cloudy growing conditions will decline rapidly as the enzymes that break down nitrate become more active in sunny weather.

Consider the Crop

- In general, corn and alfalfa plants break down nitrates taken up by their roots from the soil more effectively than do winter cereals. Sudangrass, which is becoming more popular is California, appears to have inefficient nitrate reducing enzymes in its tissues often leading to high levels of nitrate in the conserved crop.

Let the Rumen Microorganisms Work for You

- Formulate high nitrate feedstuffs into total mixed rations, or overall diets, in combination with low nitrate feedstuffs in order to keep the overall nitrate level of the diet as low as possible over time.
- Increase the nitrate level of the diet slowly in order to allow microorganisms to adapt and more effectively degrade nitrate to ammonia without accumulation of the toxic nitrite intermediate.
- Feed the microorganisms. Work with your nutritional advisor to maximize rumen microbial growth by providing sufficient degradable carbohydrate and protein. If the

microorganisms are deficient in either, or both, of rumen fermentable carbohydrate or rumen degradable protein, their growth rate will be reduced thereby reducing their ability to completely convert nitrate to ammonia.

- Don't overfeed the microorganisms with protein! High levels of dietary N (crude protein), which is rapidly solubilized in the rumen, may depress microbial growth. High levels of rumen fermentable carbohydrate will cause excess production of lactic acid (lactic acidosis), which will reduce bacterial growth. Lactic acidosis also kills off protozoa, which have been suggested to be effective degraders of nitrate to ammonia.

How High is Too High ?

This is a difficult question to answer. It seems clear that levels up to about 3500 ppm of total dry matter intake as nitrate N from both feed and water sources are not toxic to animals if toxicity is defined as acute symptoms followed, generally, by death. However nitrate levels that could cause sub-acute problems are less clear. There is very little data upon which guidelines can be formulated. However it is probable that levels under 1000 ppm of total dry matter intake as nitrate N from both feed and water sources are safe for all classes of dairy animals. As levels increase from 1000 to 3500 ppm the risk of sub-acute symptoms will increase.

Overall, the best course of action is to:

- manage to reduce nitrate levels in farm grown feeds and drinking water
- assay all feedstuffs and drinking water to know their nitrate levels
- balance the ration to maximize microbial growth
- increase total diet nitrate levels as slowly as possible
- maintain animal nitrate intakes that are as low as possible

So, is There Cause for Concern ?

It would appear that levels of nitrates in both drinking water and feedstuffs consumed by dairy cattle in California have been rising for several years. This pattern may continue. Regardless, California dairy producers should be sufficiently concerned to take action to reduce nitrate levels in farm grown feedstuffs and groundwater. As well, they should institute management practices that both reduce the probability of sub-acute nitrate toxicity in their cows and alert their dairy facility managers that problems may be occurring that can be attributed to excessive nitrate intake.

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