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MANAGEMENT OF HIGH NITRATE FORAGES

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Each year various regions of western range country are affected by weather and other environmental conditions that stress growing plants, causing them to accumulate nitrates. Of 183 forage samples analyzed for nitrates at the Wyoming State Chemical Lab from July 1 to December 31, 1989, 27% had potassium nitrate levels of 1.5% or greater. At these levels, when ingested by livestock and particularly cattle, the possibility of nitrate toxicoses are highly probable. In this paper, an attempt will be made to review the literature in order to give the producer a better understanding of potential problems and precautions necessary to utilize high nitrate forages.

Under normal growing conditions, stems and leaves of plants convert nitrate to protein about as fast as it is absorbed through the roots. However, this process does fluctuate and under certain environmental conditions, the speed of this conversion process is inhibited. This reaction is dependent on adequate water, energy from sunlight and a temperature conducive to rapid chemical reactions. If any one of these factors is inadequate while soil temperature is reasonably warm, the root continues to absorb nitrogen at a similar rate while storing it unchanged in the stalk and lower leaves. When these conditions exist, nitrates have accumulated in the plant (1,2).

Under normal feeding conditions, nitrate consumed by cattle is converted to nitrite and then ammonia by bacteria in the rumen. The rate at which nitrate is converted to nitrite, exceeds the conversion rate of nitrite to ammonia. Therefore, when higher than normal levels of nitrate are consumed, an accumulation of nitrite may occur in the rumen. Nitrite will then be absorbed into the bloodstream. When this takes place, hemoglobin which normally transports oxygen, is converted to methemoglobin. Methemoglobin is unable to transport oxygen to body tissues. If the amount of nitrate consumed is great enough and the animal is not treated, it will die of anoxia or lack of oxygen. However, there is also some indication that sublethal levels of higher than normal nitrate ingestion may affect growth, reproduction, milk production, in addition to vitamin A and iodine status of the animal (2).

The occurrence of nitrate poisoning is difficult to predict because it is influenced by many circumstances. Nitrate levels change rapidly in the plant (1). In addition, there appear to be large differences in the levels of nitrate that individual cattle can tolerate.

Environmental factors that affect nitrate accumulation in the plant include fertilization practices, light intensity and drought. Generally, the higher the level of nitrogen (N) fertilizer, the greater the potential for nitrate accumulation in the plant (1). The potential also appears to be greater when N is furnished by nitrate fertilizers rather than ammonium sulfate or urea.

In western range areas, lack of adequate water often increases the accumulation of nitrates by various plants. Cloudy (low light intensity) and cool days may further compound this

situation. Plant species differ markedly in their ability to accumulate nitrates. Cereal grain plants, especially oats and corn, tend to be accumulators. Ryegrass, sorghum and sugar-beet tops can also cause nitrate problems. Oat hay and cornstalks cause many nitrate concerns. In addition, certain wild grasses and weeds such as pigweed, kochia, carelessweed, lambsquarter, sunflower, bindweed and many others may accumulate nitrate when the plants are stressed. Under high levels of fertilization, forage species commonly used for pasture and hay production can even develop nitrate levels potentially hazardous to animals' health. High levels of nitrogen fertilization have also been attributed to increasing levels of nitrogenous compounds in surface and ground water. Effects of nitrate from multiple sources are additive and both feed and water should be considered when evaluating a problem (3).

Toxic Levels

Levels of nitrate that can be hazardous to cattle may be found in fresh forage, dry forage or contaminated water. Most laboratories report nitrate levels in the forage as a percent of the dried sample. Nitrate in water is reported in parts per million (ppm).

The Wyoming State Chem Lab reports its nitrate levels as percent potassium nitrate (KNO_3). Their recommendations cite Missouri research suggesting that 1.5% KNO_3 is potentially lethal. This would be equivalent to .9% nitrate or NO_3^- . Other laboratories might report nitrates in other forms. The following table will allow an individual to convert laboratory reports to the standard measure to which they are most familiar.

Table 1. Conversion Table (2)

$\% \text{KNO}_3 = \% \text{Nitrate } (\text{NO}_3^-) \times 1.6$
 $\% \text{KNO}_3 = \% \text{Nitrate nitrogen } (\text{NO}_3\text{N}) \times 7.0$
 $\% \text{NO}_3^- = \% \text{KNO}_3 \times .6$
 $\% \text{NO}_3\text{N} = \% \text{KNO}_3 \times .14$
 $\% \text{NO}_3\text{N} = \% \text{NO}_3^- \times .23$
Parts Per Million (PPM) = Percent (%) $\times 10,000$
Percent (%) = PPM $\div 10,000$

Acute Nitrate Toxicity

Clinical signs of acute NO_3 poisoning usually occur within 4 hours after ingestion of a toxic amount of nitrate. Symptoms usually appear when methemoglobin levels approximate 30% or more of total hemoglobin. Death usually occurs when methemoglobin levels reach in excess of 80% (4). Typical symptoms associated with high nitrate consumption are those related to anoxia or lack of oxygen. This includes rapid pulse and increase respiration rate, followed by labored breathing, muscle tremors and general weakness. Membranes of the mouth, nose and eyes become darker colored due to lack of oxygen and the blood is typically a dark brown, chocolate color. If death occurs, it will usually be expected within 10-12 hours.

Type and quantity of high nitrate forage and the time period over which it is consumed all play a role in determining whether the beef animal will show symptoms of nitrate toxicity. NO_3^- is released more slowly into the rumen from fresh forage than from dry forages (4). It's also suggested that readily available carbohydrates have been shown to increase tolerance to NO_3^- , due to more rapid utilization of the NO_3^- and NO_2^- by rumen microbes.

Acute poisonings in livestock most commonly occur with nitrate concentrations exceeding 1% NO_3^- (approximately equivalent to 1.5% KNO_3) in forage dry matter or 1500 $\mu\text{g NO}_3^-/\text{ml}$ (ppm) in water (5).

Treatment

NO_3^- toxicity is typically recognized after the fact. In other words, some deaths have usually occurred before nitrate toxicity is diagnosed. However, prompt action may save those that show outward symptoms. A slow I.V. injection of a 1% solution of methylene blue in isotonic saline at the rate of 9 mg/kg of body weight in ruminants, generally causes a rather rapid reduction of methemoglobin (6).

Subacute or Chronic Effects of Nitrate

There is considerable lack of agreement in regard to the levels of nitrate that cause some reduction in performance while not being high enough to initiate the acute symptoms previously described. There are probably several reasons for the uncertainty. First, there appears to be several factors or variables that affect the animal's ability to tolerate higher than normal levels of nitrates. This leads to the fact that there may be considerable individual variation among ruminant animals in their ability to tolerate nitrates. In addition, much of the information and data has been collected upon diagnostic evaluation after an animal has died or developed toxicity symptoms. Most generally the circumstances that led to the condition have to be reconstructed. This source of information has certainly increased our information base on the topic. However, from this information it is often difficult to formulate a definite conclusion. Generally the exact level of nitrate intake is not known. Adding to the confusion, is the fact that the symptoms are often difficult to produce under controlled research conditions.

Of reported effects of nitrates, there are probably none more controversial than abortions, stillbirths and related reproductive disorders. Excessive dietary nitrate in feed and forage has been implicated with third trimester bovine abortions and other reproductive problems. Researchers at the Veterinary Science Laboratory at North Platte, NE, evaluated 277 fetuses, stillborn and weak calves that were submitted to their laboratory during January to March calving seasons in 1982 and 1983 (7). Ocular fluids from all submissions were qualitatively examined. Thirty percent of the samples exhibited NO_3^- levels $\geq 10 \mu\text{g}/\text{ml}$. Of these, 65% of the associated plasma and serum samples indicated levels $> 20 \mu\text{g}$ of NO_3^-/ml , suggesting that excessive nitrate exposure had occurred. Normally expected values are 0-10 $\mu\text{g NO}_3^-/\text{ml}$, with 10-20 $\mu\text{g NO}_3^-/\text{ml}$ considered suspect and nitrate concentrations above 20 $\mu\text{g NO}_3^-/\text{ml}$ considered diagnostic significant (8). Other field case reports (9,10,11) also suggest nitrate/nitrite to be a ruminant abortifacient. However, other investigators have not seen this effect in controlled research trials

(12,13). In addition, a University of Wyoming trial in 1991 did not show any effect on pregnancy when mature commercial beef cows received their NRC requirements from oat hay containing up to 1.4% KNO_3 . Cows carried fetuses to term with no obvious effects on parturition nor the calf through 45 days post parturition. The associated blood work has not been completed at the time of this writing.

If one accepts the premise that nitrate does cause abortions, the theory by some researchers to explain this phenomena is that the $\text{NO}_3^-/\text{NO}_2^-$ may cause a rapid decrease in transplacental oxygen transfer to fetal blood by other than excessive fetal methemoglobinemia (5). Intrauterine death and resulting abortion could result if oxygen transfer to fetal blood decreases too rapidly. This would be especially important during the last trimester of pregnancy where rapid rate of nitrogen (protein) retention occurs in both fetal and uteroplacental tissues (2). It has also been suggested that fetal hemoglobin may be more readily oxidized by nitrite than maternal hemoglobin and lethal fetal methemoglobinemia could develop in utero with no apparent maternal effects (7). Another explanation offered is that maternal nitrate ingestion is thought to reduce transplacental oxygen transfer to fetal blood by other than excessive fetal methemoglobin formation. A potential hypothesis is that continued exposure to nitrates has an additive effect on the fetus.

At the Veterinary Diagnostic Center, University of Nebraska-Lincoln, concurrent nitrate accumulation and congenital bacterial infection have been observed in aborted bovine fetuses (5). Biosynthesis of nitrate and nitrite by mouse macrophages stimulated by bacterial products has been demonstrated in vivo and in vitro (14). Bovine alveolar macrophages also appear to be capable of endogenous nitrate and nitrite production (5).

Others (4) suggest that NO_3^- and NO_2^- induced abortions in ruminants occur only under conditions approaching those required for manifestation of near fatal methemoglobinemia in the dam.

Concerns in regard to nitrates effects on fertility have also been suggested in the literature. Again, this is difficult to document because until symptoms are observed, nitrate levels are typically not documented. However, a summary of artificially inseminated cattle from 58 herds found a non-significant negative correlation coefficient of only -.18 between NO_3^- and fertility based on non-returns (4).

Reduced growth rates (15,16) have also been reported as a chronic nitrate effect. Sodium nitrate was added to feedlot diets at 1.16% of the diet and decreased feed intake, weight gain and plasma vitamin A levels as well as feed efficiency. Reduction in milk production has also been described in the literature (2,17,18).

Non-pregnant ruminants can adapt to higher levels of nitrate feeding over time. Researchers (19) have increased intake of steers up to .39 nitrate per kg body weight over a period of several weeks without any problems. However, increasing dose to .49 resulted in death. Sheep have also been acclimated to levels of 2.5 g KNO_3 per kg body weight without any clinical signs of toxicosis (20).

Negative effects of high nitrogen fertilized forages on vitamin A liver stores have been reported in steers. However, reports of no effect of a range of dietary NO_3^- levels on vitamin A status of ruminants have been more common (4).

Feeding Strategies

Hay with excessive nitrate is more hazardous than green chop or pasture with similar nitrate content. High nitrate hay stacked outside, may be of increased concern since precipitation can leach and subsequently concentrate the majority of the total nitrate present into the lower one-third of the stack.

Even though there is disagreement in the literature on abortifacient effects of high nitrate forages, diets of pregnant beef cows should not exceed 5,000 ppm NO_3^- on a dry basis. High nitrate feed may be diluted or mixed with low nitrate feed sources to achieve appropriate concentrations. Safest conditions would exist if the forages were ground and mixed. 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.

In summary, the literature contains several conflicting viewpoints regarding the effects of high nitrate forages. Until further investigations delineate some of these controversies, one should be cautious when using high nitrate forages. Knowing the plants and conditions that typically cause NO_3^- accumulation, one can be aware of potential problems and sample and test when appropriate. It is critical to obtain representative samples when testing. This is a potential problem when sampling standing forages since soil fertility might cause problems in one area but not another. Use non-pregnant cattle to utilize forages containing over .5% NO_3^- or .75% KNO_3 . Cattle should be gradually adapted to higher nitrate forages to lessen chances of toxicity. 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 affects the animals chances of toxicosis.

By knowing when a potential problem exists and working with your veterinarian and extension agent to develop feeding strategies, precautions can be followed to effectively utilize high nitrate forages while avoiding animal losses.

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