Nitrate Poisoning

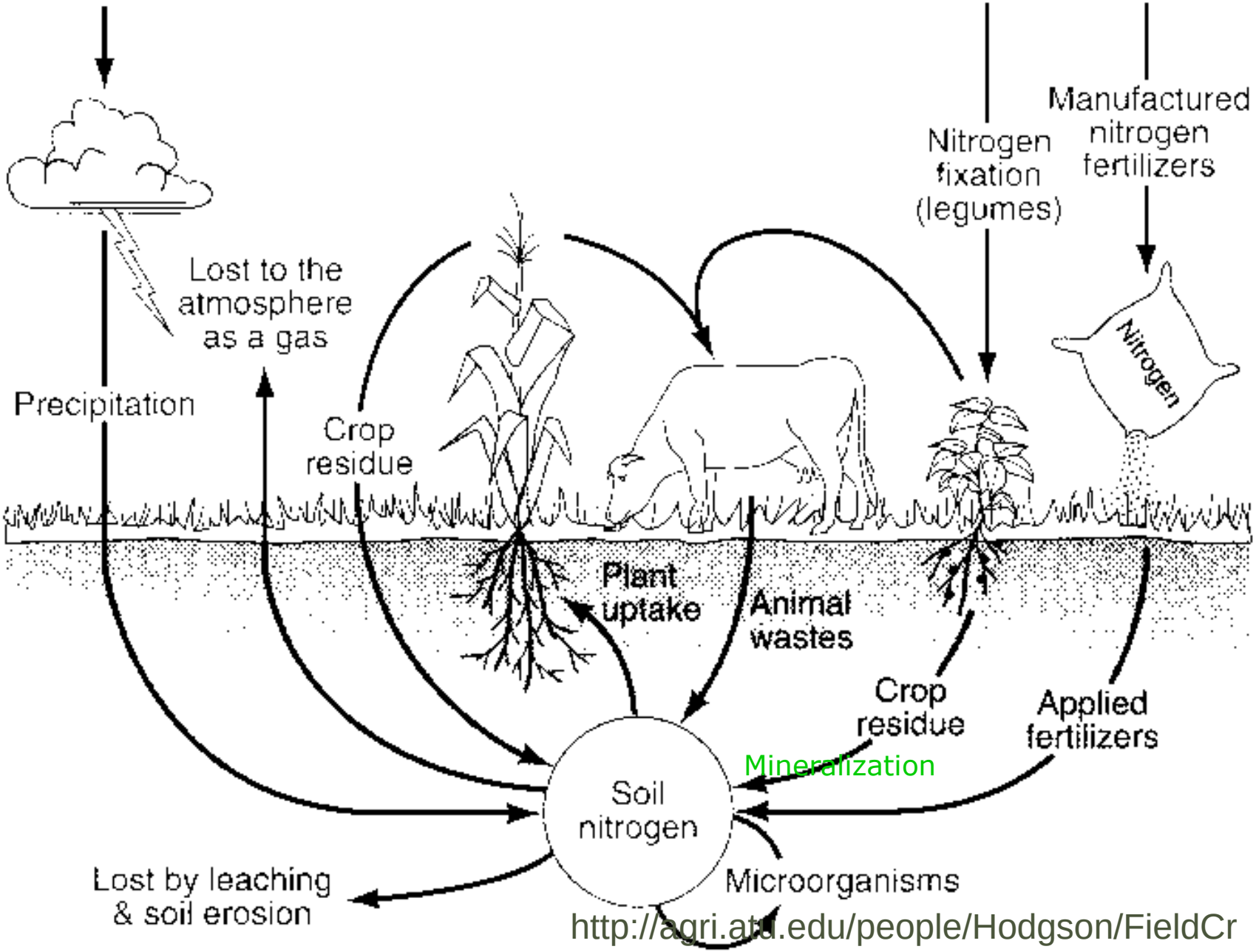
Saskatchewan Agriculture

August 17, 2021

Presented by:
Barry Yaremcio M. Sc., P. Ag.

The Nitrogen Cycle

- Nitrogen is an important nutrient
  - Integral in plant function and growth
- Availability is regulated through cycles



http://agri.atd.edu/people/Hodgson/FieldCrops/Chapt4figs/nitrocycle.GIF

Some common Nitrate accumulators

- Green feeds – oats, barley, triticale etc.
- Canola plants, mustards
- Weeds – stinkweed, lamb's quarters, smartweed, buckwheat, and many more

Plants that do not accumulate nitrate

- Legumes such as alfalfa, sainfoin, birds foot trefoil, vetches and clovers
- Crops grown in nitrogen deficient soils

Nitrate changes in the same field

- High areas of the field vs low areas
  - Elevation
  - Water availability for the crop
- Changes in organic matter
  - Residual nitrogen in the soil
- Presence of weeds that accumulate nitrate
- UNKNOWN????

Factors Affecting Plant Nitrate Level

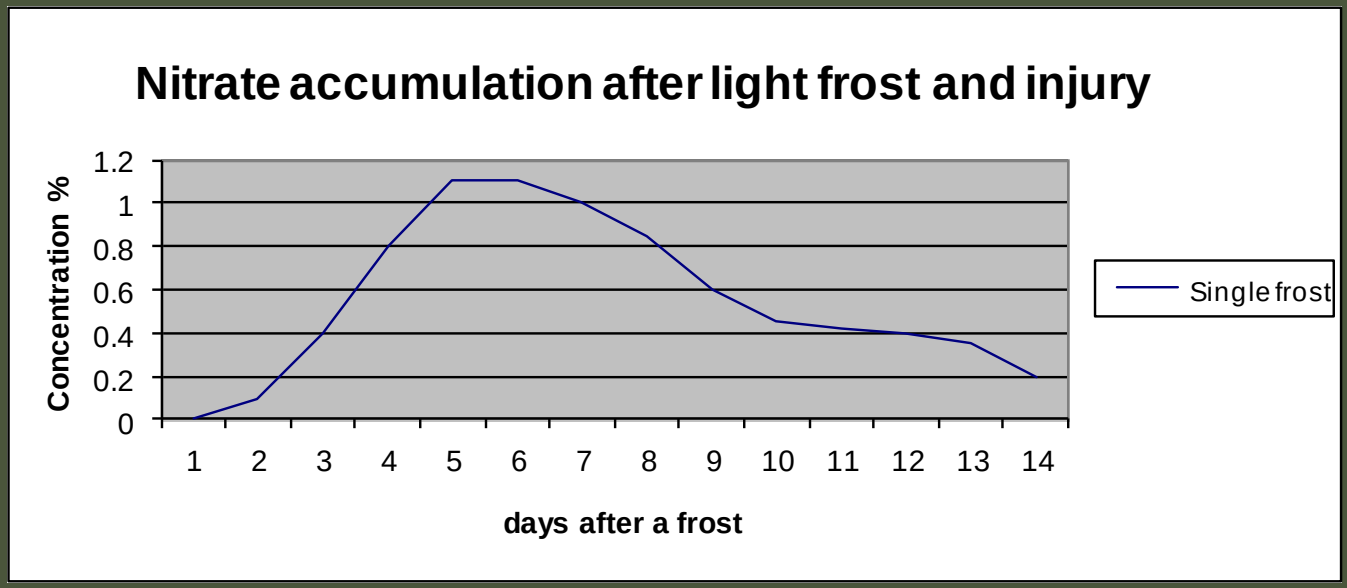
- Soil nitrate levels affect plant levels
- Large applications of manure or fertilizer increase nitrate availability to plants
- The nitrate – utilization pathway requires adequate water, sunlight and temperatures above 13^{o} C to work efficiently
- If environmental conditions not favorable, nitrates accumulate

Factors Affecting Plant Nitrate Level

- Stressed plants (hail, light frost, drought, or anything that impairs photosynthesis) can cause nitrates to accumulate
- Weeds sprayed by herbicide accumulate nitrate during the injury and dying stages
- Nitrate levels are highest in the lowest portions of the stem. Concentrations are lower in the leaves and upper plant parts
- Grain does not accumulate nitrates.

Plant recovery from frost or hail

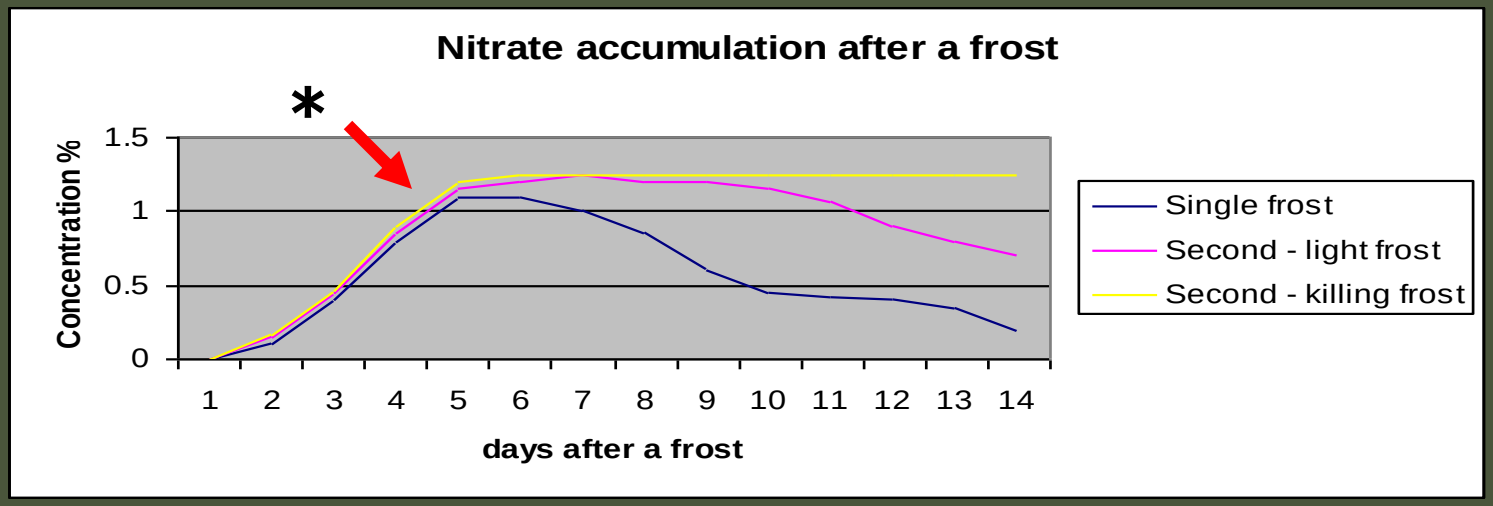
- Light frosts are the problem.
  - Nitrates accumulate with time.
  - Peak concentrations 4 – 5 days after injury
  - If plant recovers, levels will decrease and stabilize by day 14 after the frost.



Cut crop as soon as possible after injury

Multiple frost injuries to plants

- A series of frosts that are 4 – 5 days apart increases the time required for a plant to recover from the stress.
- A killing frost after the first frost "locks" nitrate into the tissue. It will not change after this point in time.



*** Time of second frost**

Conversion factors

- Mg / kg to parts per million (ppm)
  - The units are interchangeable
- Changing part per million to percent (%)
  - Move the decimal 4 places to the left
  - 385 ppm = 0.0385%

Converting to percent Nitrate (NO_3)

- Nitrate ($N0_3$) is the most common reported value (also easy to work with)
- Nitrate–nitrogen ($N0_3$-N) to nitrate
  - Nitrate-Nitrogen x 4.427 = nitrate
  - 0.12% NO_3-N x 4.427 = 0.53% Nitrate
- Potassium-nitrate (KNO_3) to nitrate
  - Potassium-nitrate x 0.62 = nitrate
  - 0.85% KNO_3 x 0.62 = 0.527% nitrate
- http://www.range.colostate.edu/nitratecalc.shtml

Susceptibility to nitrate poisoning

Highest risk

Lowest risk

- Cattle
- Sheep – ruminant 2.5 x more tolerant to nitrate than cattle
- Horse – modified ruminant is not susceptable
- Pig / chickens – monogastrics are not a concern

Ensiling process on Nitrate reduction

- During initial fermentation phase, the normal process of nitrate reduction occurs
- Enzymes (nitrate reductase) becomes less active below pH 7 and inactive below pH of 5.5
- Nitrate level in silage is highest when pH is 4.9 – 5.7
- It takes about 10 days for pH to drop below 5.0 in high quality legume silage
- Cereal crops ensile faster, less time for nitrate reduction

Final word on Silage Nitrate reduction

- DO NOT COUNT ON FERMENTATION TO REDUCE NITRATE!
- When reduction does occur
  - Silage is at an incorrect moisture
  - Packing is insufficient
  - Pile or pit is not covered in plastic
  - Aerobic fermentation occurs
  - A form of “Mustard Gas” can be produced
- **End result is that the silage is very poor quality and may not be worth feeding**

Forms of Nitrate Poisoning

- Chronic or Sub Acute
  - Reduction in performance
  - Cows less likely to become pregnant
- Acute – deaths can be rapid

https://www.dreamstime.com/royalty-free-stock-photos-dead-cow-image4665348

Nitrate Poisoning in Cattle

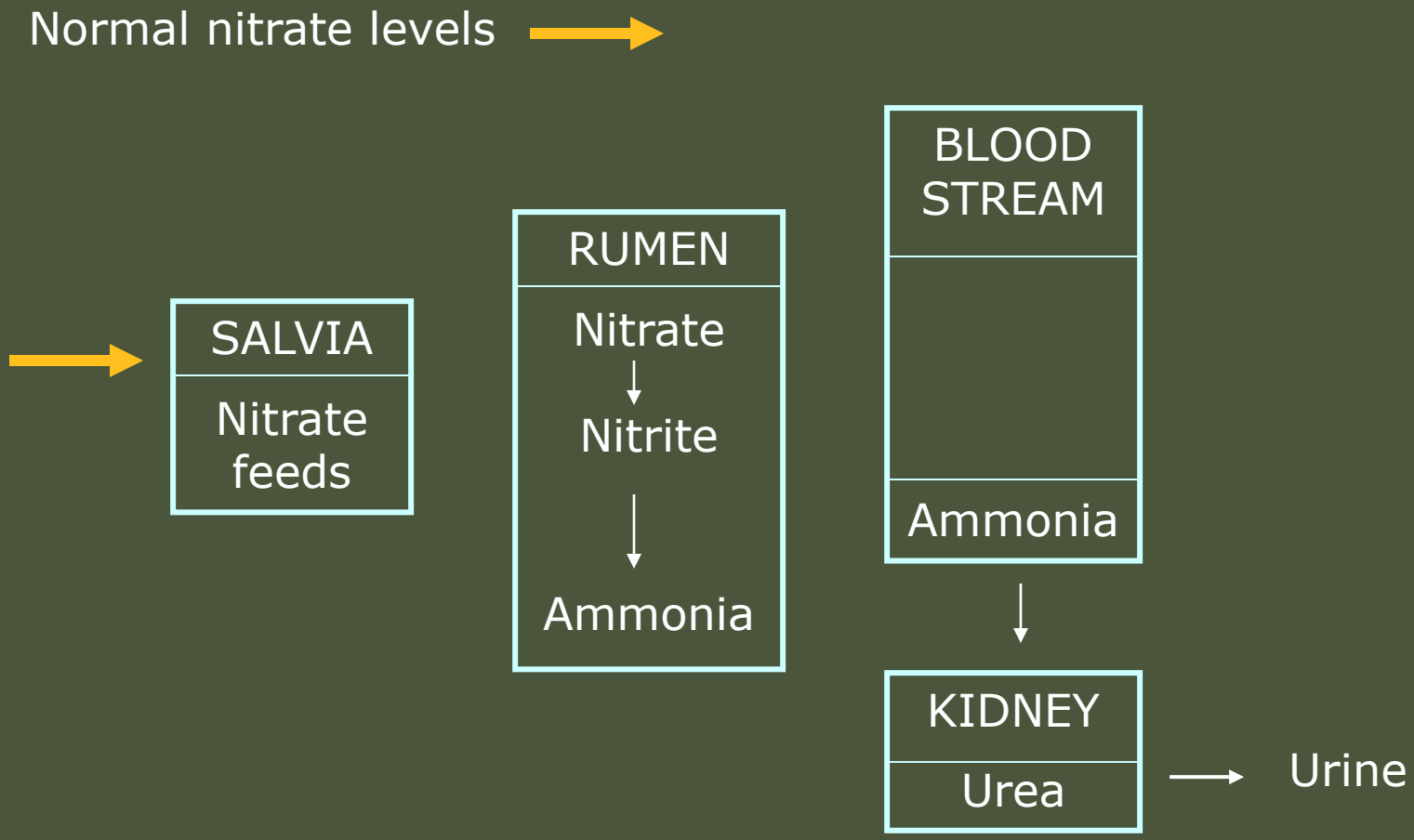


Figure 1 Nitrate pathway in ruminants

Nitrate Poisoning in Cattle

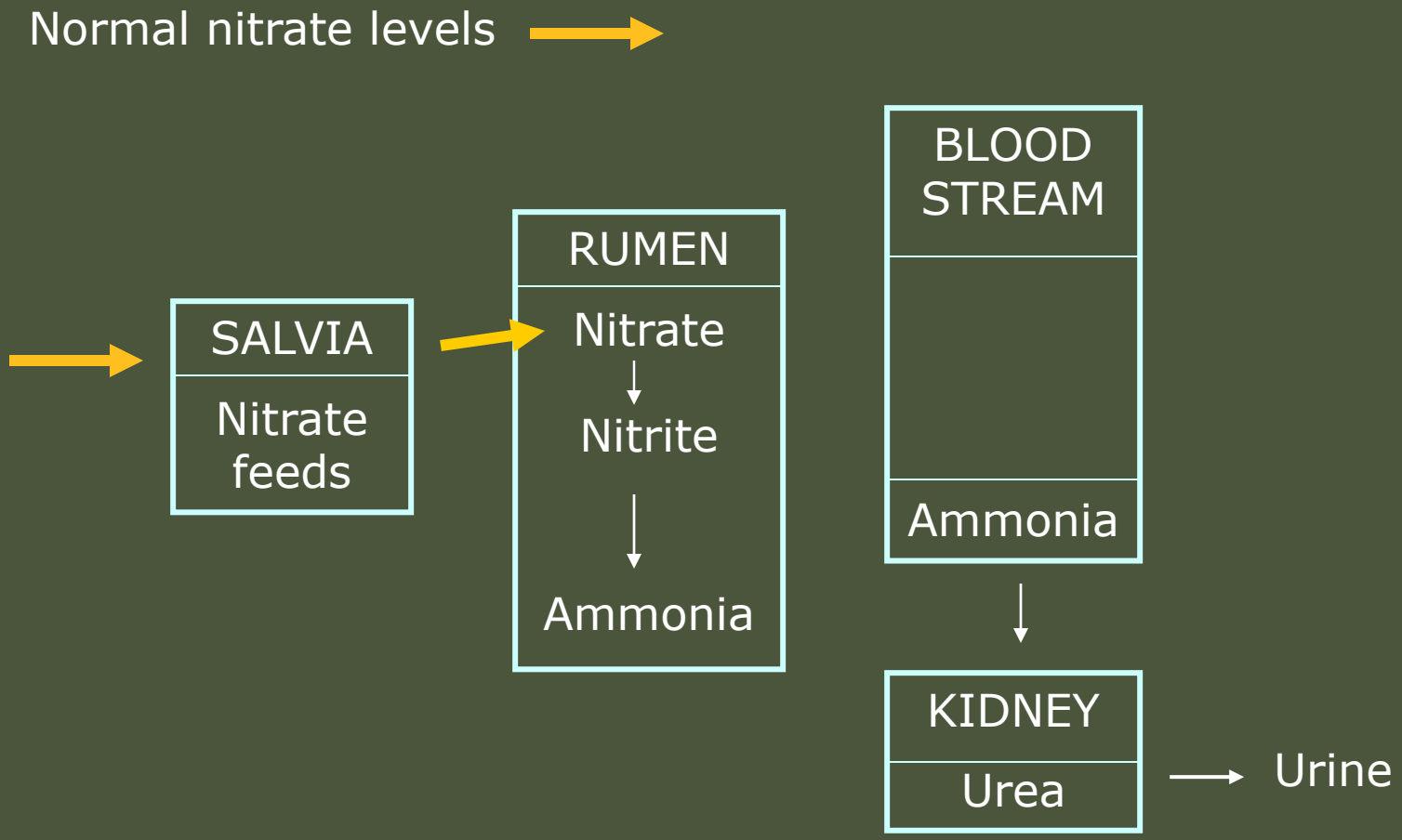


Figure 2 Nitrate pathway in ruminants

Nitrate Poisoning in Cattle

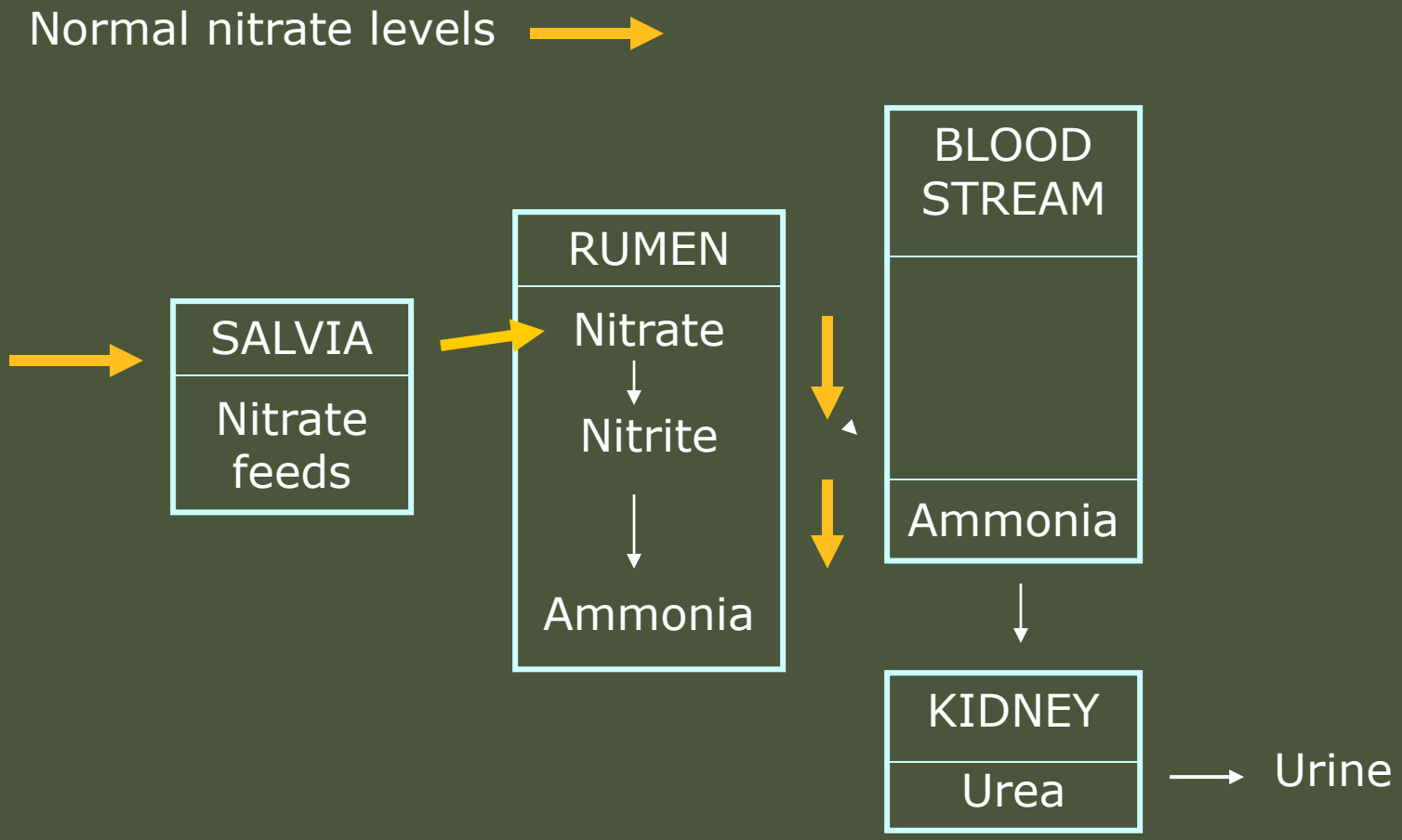


Figure 3 Nitrate pathway in ruminants

Nitrate Poisoning in Cattle

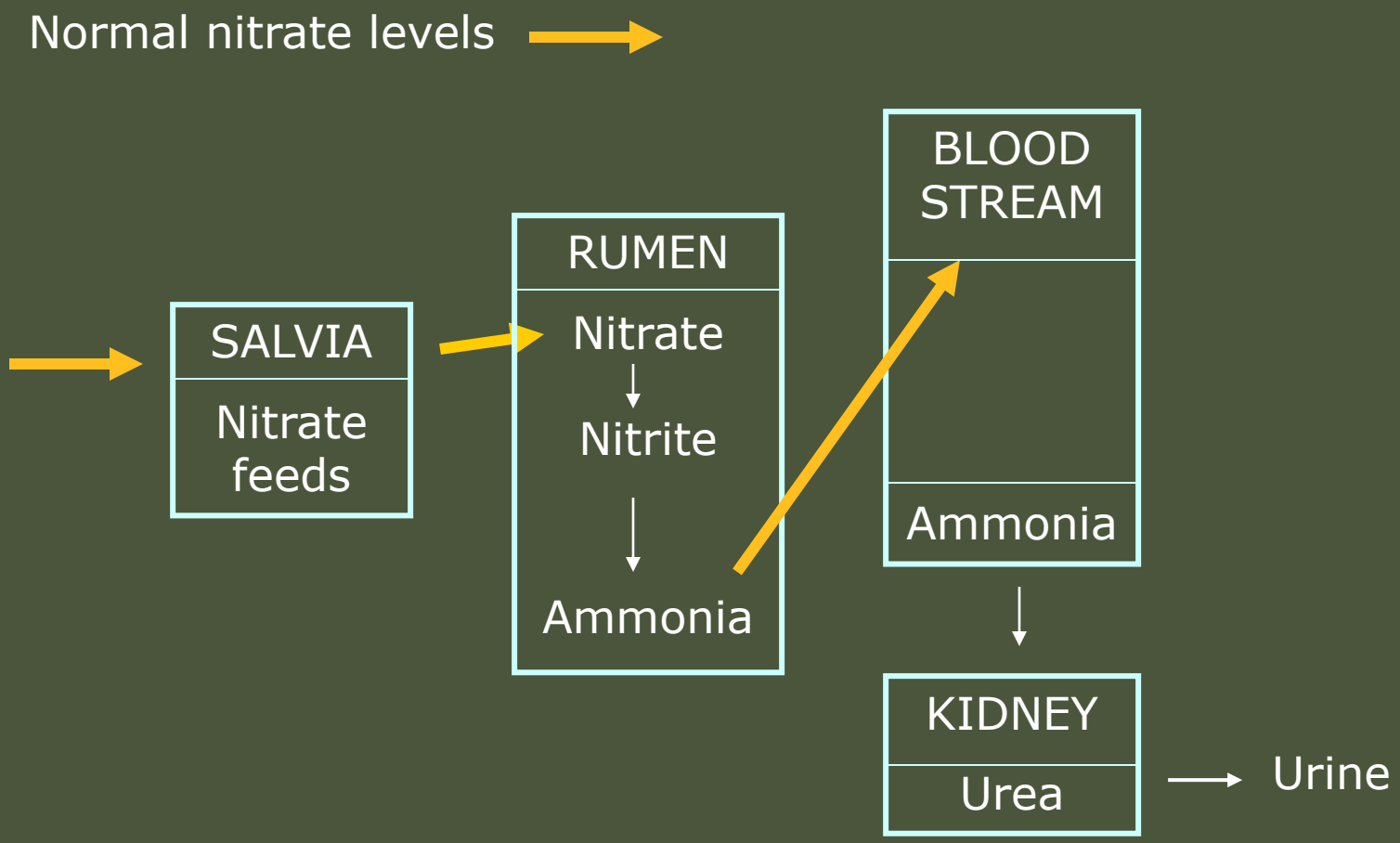


Figure 4. Nitrate pathway in ruminants

Nitrate Poisoning in Cattle

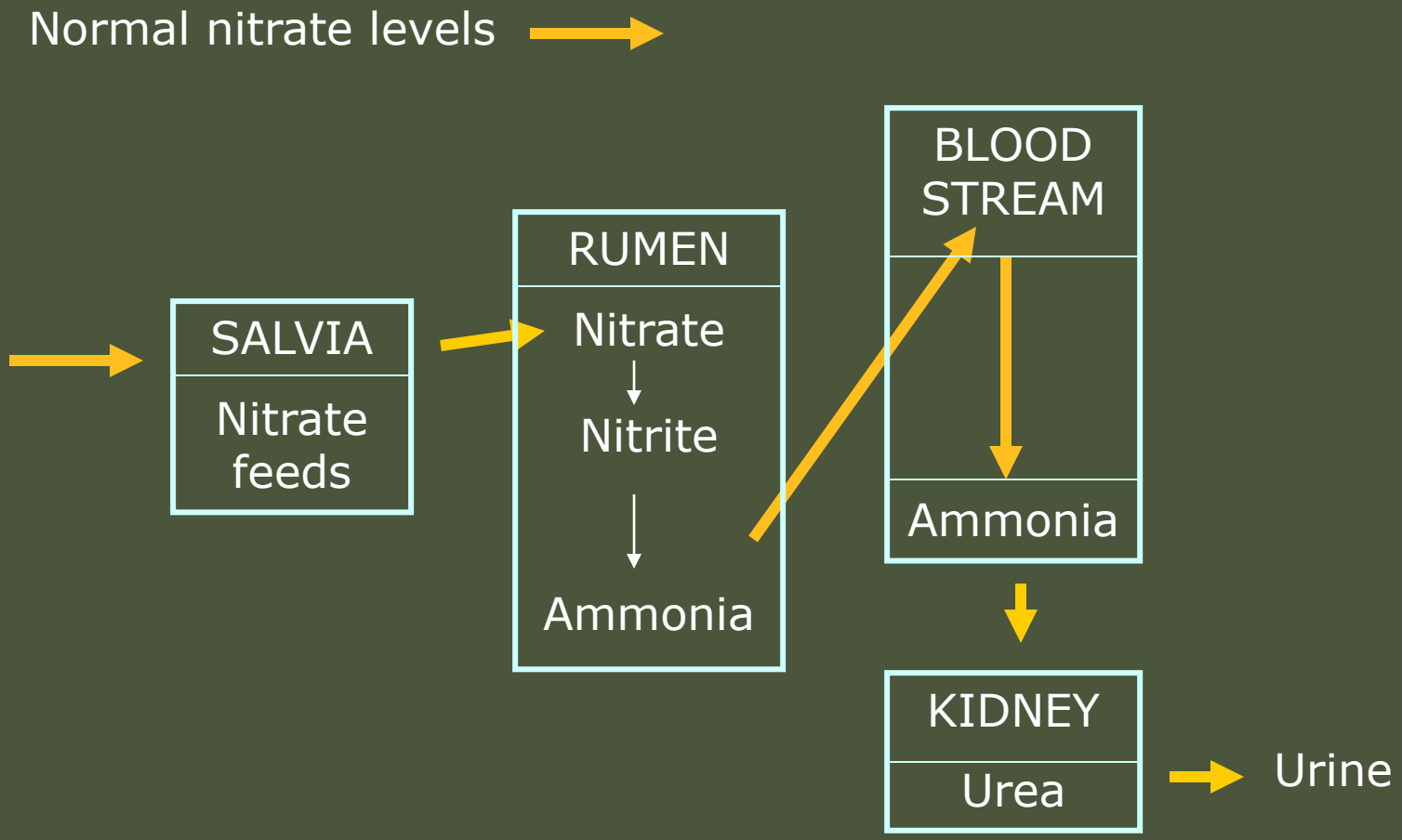


Figure 5. Nitrate pathway in ruminants

Nitrate Poisoning in Cattle

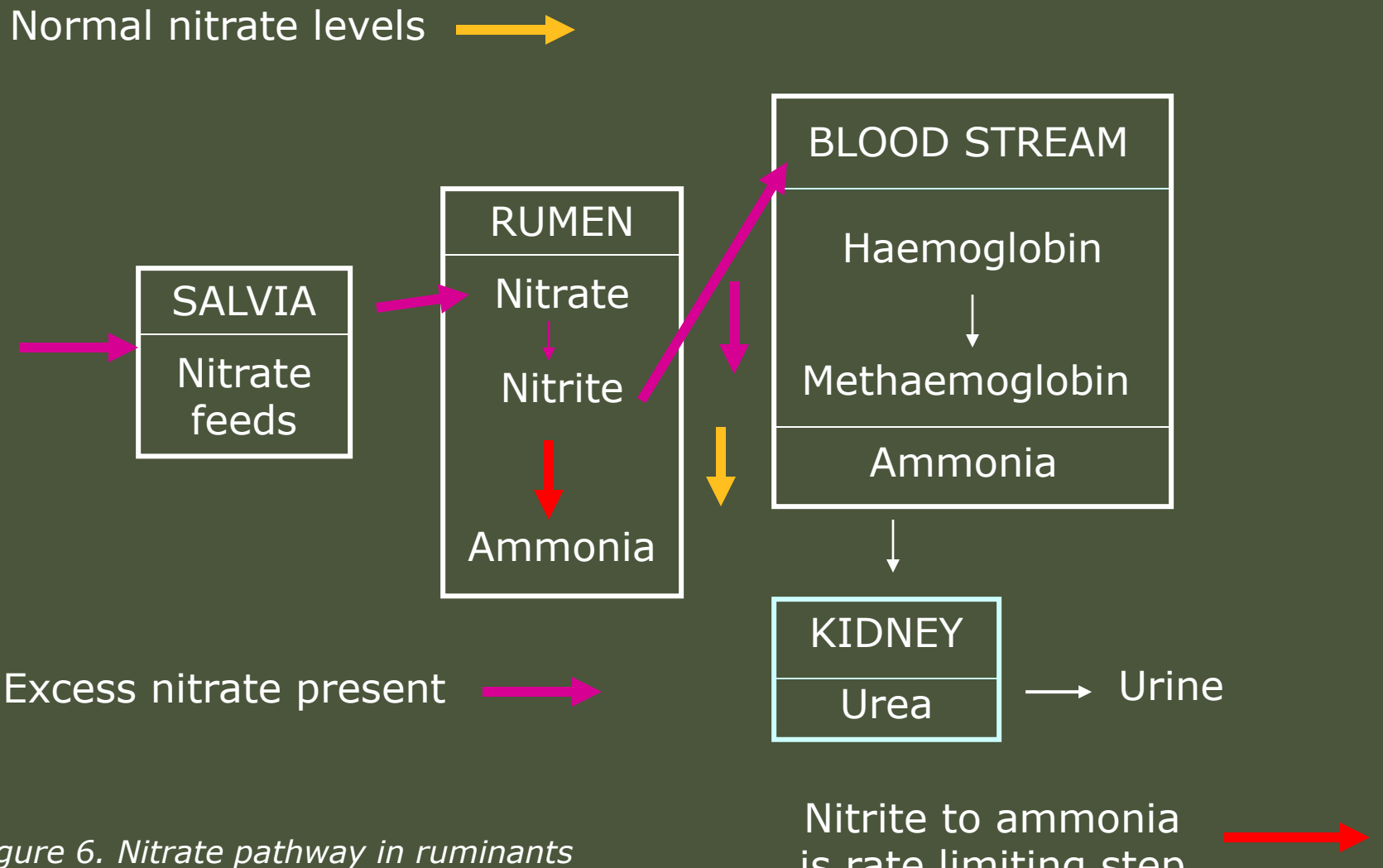


Figure 6. Nitrate pathway in ruminants

Nitrate Poisoning in Cattle

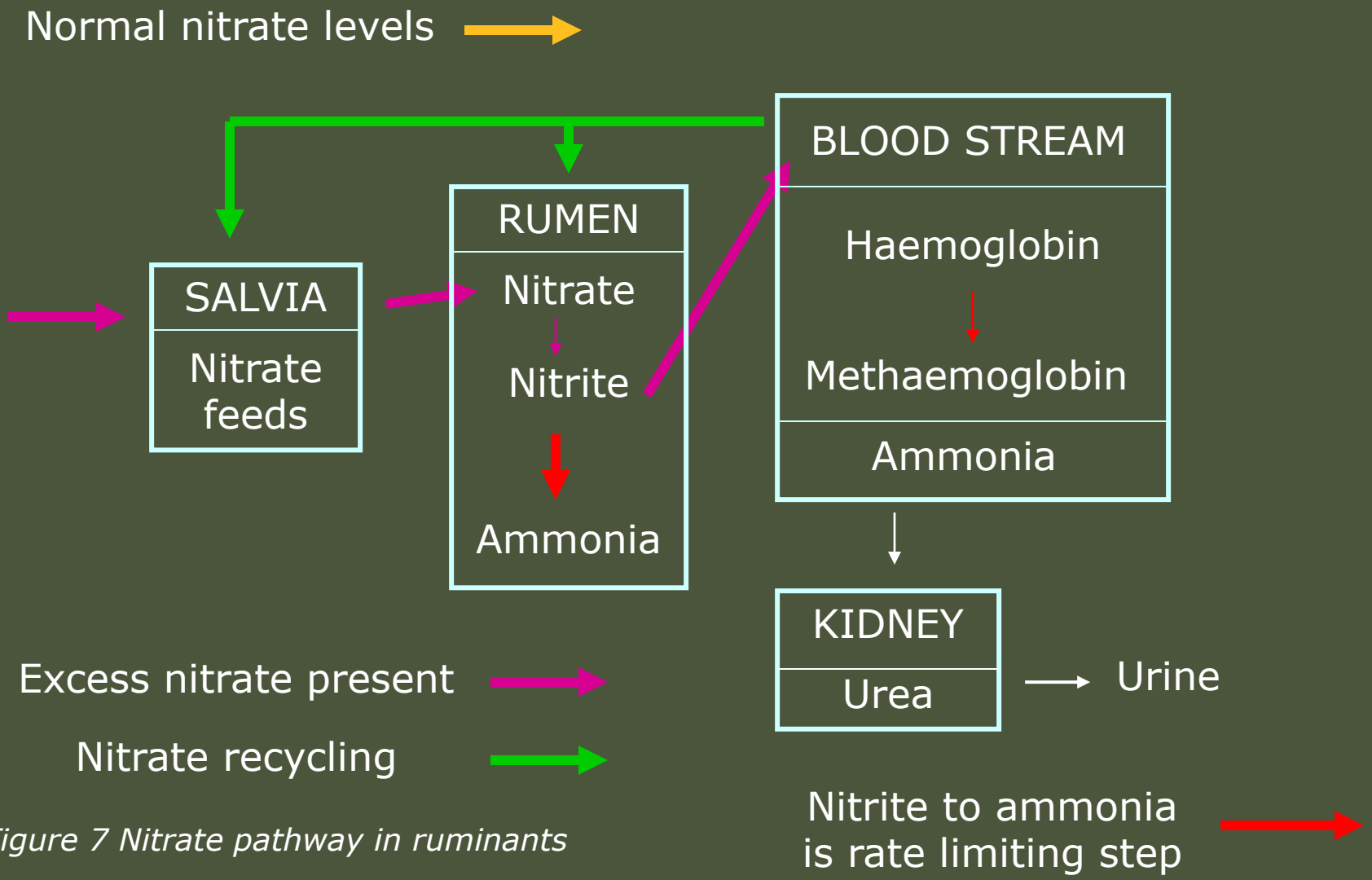


Figure 7 Nitrate pathway in ruminants

Nitrate Poisoning in Cattle

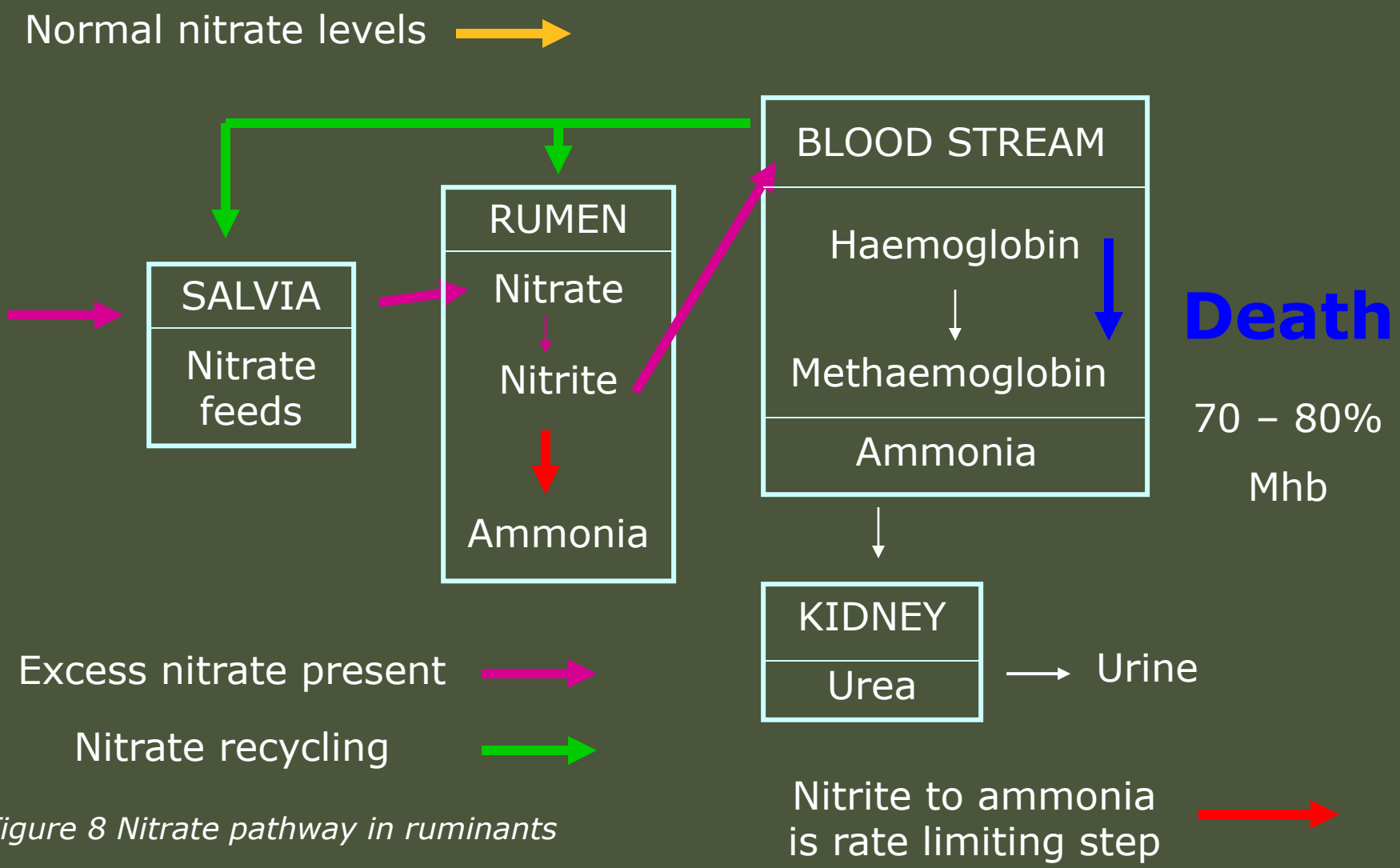


Figure 8 Nitrate pathway in ruminants

How feeding limits were established

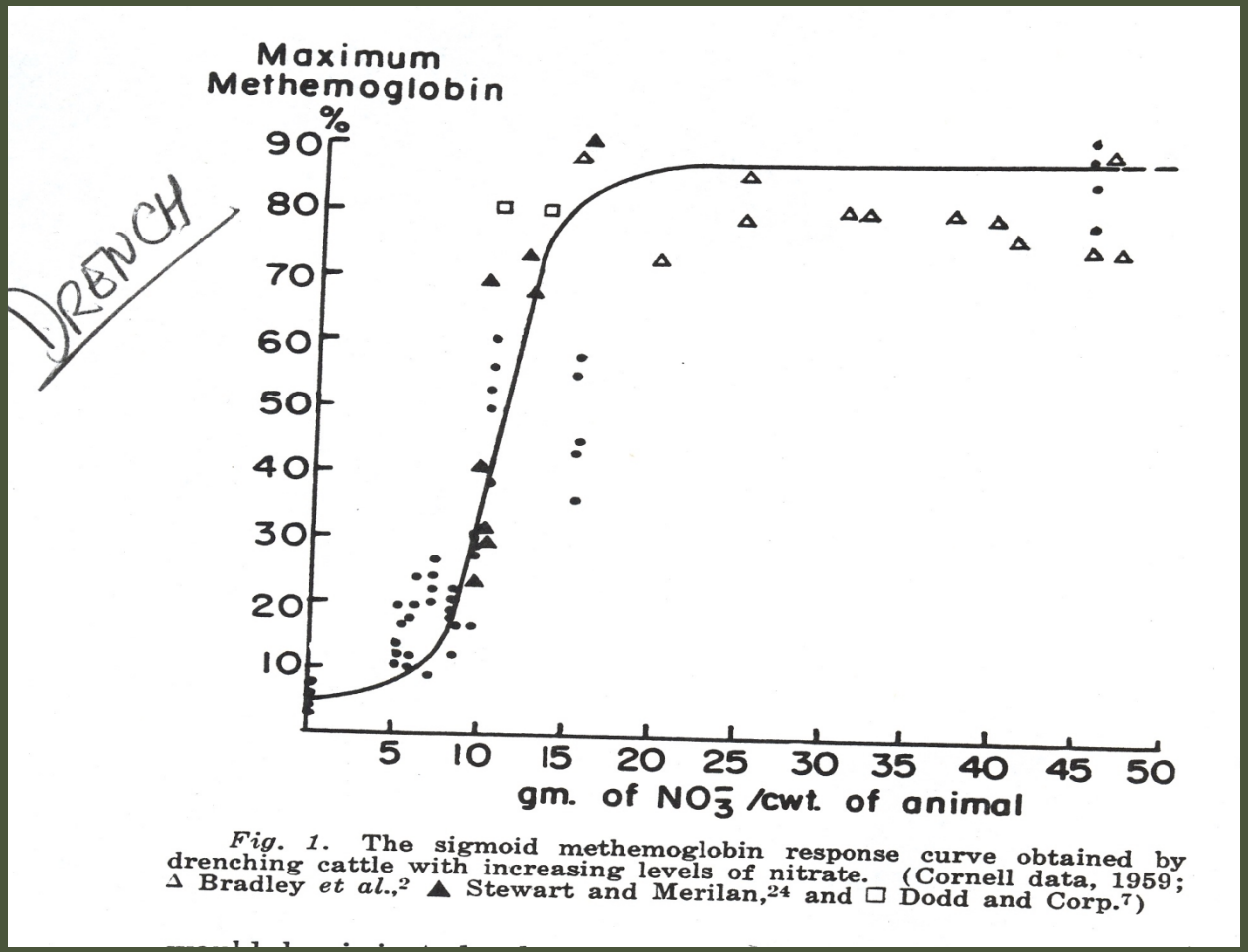


Fig. 1. The sigmoid methemoglobin response curve obtained by drenching cattle with increasing levels of nitrate. (Cornell data, 1959; Δ Bradley *et al.*,[2] ▲ Stewart and Merilan,[24] and □ Dodd and Corp.[7])

Crawford

1964

Fetal Hb more sensitive to change to Mhb than maternal blood

Feeding response vs. drench

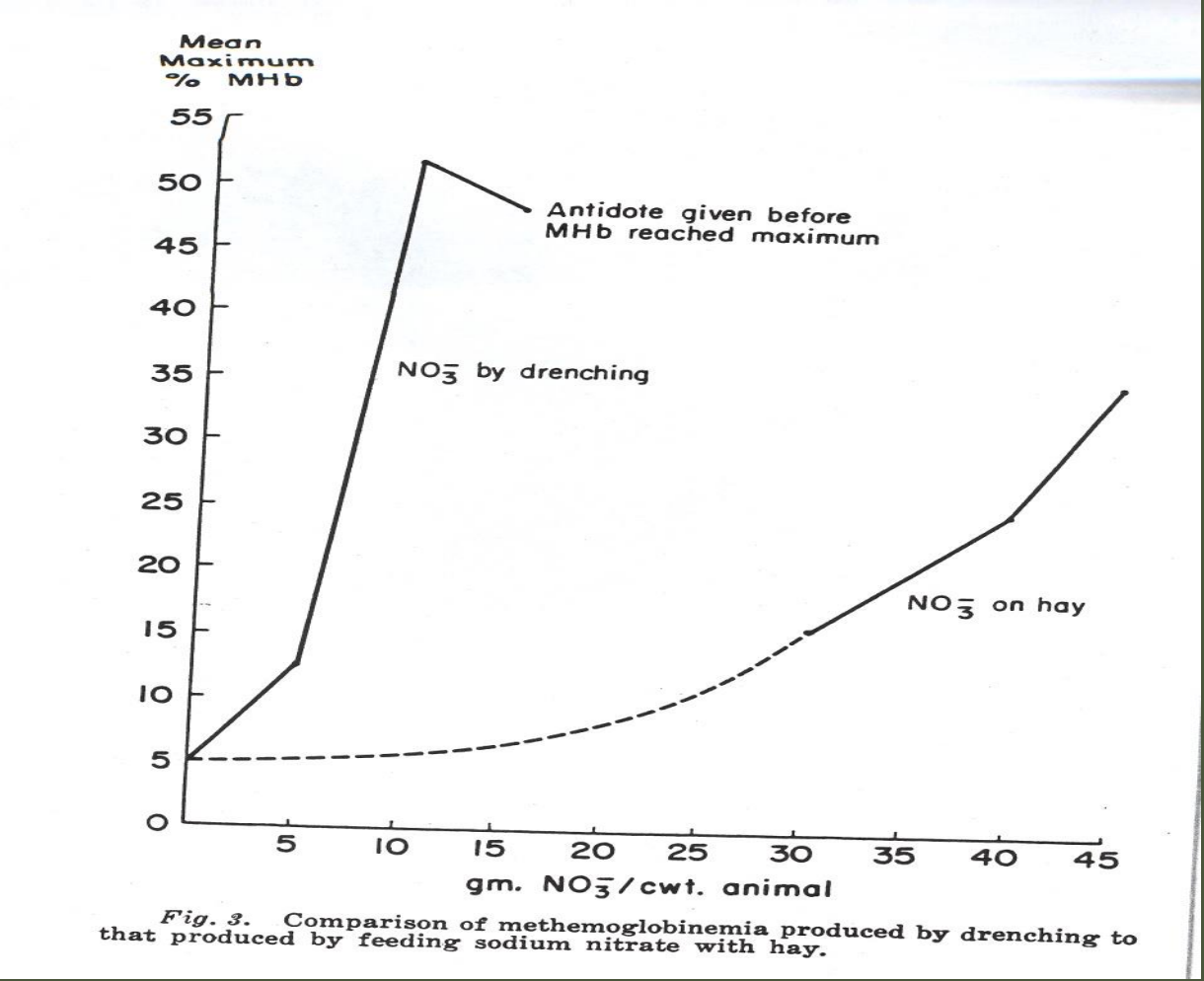


Fig. 3. Comparison of methemoglobinemia produced by drenching to that produced by feeding sodium nitrate with hay.

Crawford

1964

Crawford's conclusion:

- "The data did not establish the exact LD_{50} of nitrate in forage for cattle, but did establish that the LD_{50} was much greater, perhaps three times greater than determined by drenching. This difference was obviously due to differences in rate of nitrate intake".

Methaemoglobin levels

- Normal – 2 – 3 % Mhb.
- Moderate symptoms 20 – 40% Mhb.
- Severe symptoms 67 – 90 % Mhb.
- In-utero blood (fetus) has a higher affinity to remain as Mhb compared to maternal blood. Fetus death occurs before the cow.

The Change in Hemoglobin

Contributed by:

- Concentration of nitrate in the forage
- Presence of nitrate and nitrite in heated greenfeed / forage
- Rate of feedstuff consumption
- Rate of digestion and feed passage rate
- Conversion rate of nitrate to nitrite to ammonia
- Absorption of nitrite (10X more toxic than NO_3)

Chronic (Sub Acute) Poisoning

- **No** clinical signs
- 0.5 – 1.0 % (?) of DMI
- Symptoms
  - Reduced growth rate
  - Lower milk production
  - Depressed appetite
  - Shortness of breath
  - Grinding teeth
  - Uneasiness
  - Low blood pressure
  - Infection Susceptibility
  - Reproductive Problems

Signs of Chronic Poisoning

- Calves can be affected
  - Calf abortion - 3 days to 4 weeks after insult
  - Born 1 – 4 weeks premature
    - 25 % of maternal oxygen supply required to maintain calf last 30 days of pregnancy
  - Die within 18 to 24 hours of birth
  - If they do survive
    - Convulsions
    - Seizures
    - “Poor Doers”

Acute Poisoning

- Clinical signs **seen**
- > 1.0 % concentration DMI
- Cows are usually found dead by hypoxia (lack of oxygen)
  - Nitrate conversion to nitrite is very rapid
  - Could be from nitrite from feed

Symptoms of Acute Poisoning

- Muscle tremors
- Vomiting
- Frequent urination
- Dark brown blood (seen within 2 hours of death)
- Staggered gait, Disorientation
- Unable to get up

Treatment by Veterinarian

- Can be treated if found immediately
  - IV injection(s) with Methylene Blue
    - Restores blood hemoglobin
    - Only treatment available
      - Availability is being restricted
      - Not approved for use in food – producing animals
  - Chlortetracycline in adaptation phase
- Prevention is best to avoid animal loss!

Heated Greenfeed bales

- Maillard reaction occurs at >35^{o} C
- Conversion of nitrate to nitrate occurs at these temperatures
- Aerobic conditions needed
- Nitrate is converted to nitrite
  - NO^{3} ⟶ NO^{2}
- Nitrite is 10 x more toxic than nitrate
- Request Nitrate and Nitrite tests
- Add values together to obtain final concentration

Nitrate content in dugout water - 1990

- Cows found dead within 1.5 km of a dugout
  - 16 head dead – herd of 100 animals
  - Necropsy showed "typical" symptoms
    - **Water contained 4.8 g/L nitrate**
- Second case:
  - Animals dead within 100 m of dugout
    - **Water contained 7.0 g/L nitrate**
- **Determined cause to be nitrate fertilizer contamination**
  - **34 – 0 – 0 used to construct dugouts**

Light Frost and Nitrate accumulation

- Frost injures the upper part of the plant, reducing photosynthesis.
- Roots continue to supply nutrients to the upper plant at the same rate as before the frost.
- Severity of the frost impacts accumulation.

- **Killing frost** prevents nitrate accumulation

Reducing Nitrate Accumulation in Forages

- Cut as soon as possible after frost or hail storm
- Waiting to harvest a frosted crop
  - Problems with quality loss due to leaf drop
  - Raising the cutter head is a better option
- Highest nitrate levels occur 4 to 5 days after injury
- Wait for 10 to 14 days
  - Plants should be recovered by this time
- Better to develop a ration with a high quality forage and dilute down the nitrates

Testing for Nitrates

- Occurs only in forage – not in grain
- Silage
  - Sample in plastic bag, exclude air, seal, freeze
  - Send frozen to lab. 1 – 2 day delivery
    - Up to 20 X difference if longer to get samples to lab (520 vs. 6100 ppm).
- Hay
  - Low moisture – less chance of nitrate change because of no fermentation
  - Exclude air, seal
  - Send to lab. 1 -2 day delivery if possible

Animals can adjust to high nitrate

- Rumen bacteria change in 3 to 4 days to increase reduction of nitrates
- If nitrate present for two weeks, bone marrow will increase red blood cell production to carry more oxygen to the tissues

Prevention

- Awareness
  - Feed and water testing
- Management strategies
  - Limit N fertilizer application if using area for swath grazing
  - History of the field?
    - Manure applied
    - Used for winter feeding area
    - Used for swath grazing or bale grazing
  - Changing harvesting times to reduce risk

Prevention during feeding

- Gradual adaptation is key
- Control amount provided
  - Feed in a TMR
  - Feed high nitrate feeds mid afternoon
- Add soluble carbohydrate to the ration (grain @ 3 – 4 pounds / day)
- Trace mineral salt vs. blue salt

Conclusions and Implications

- All plants contain some nitrate
- Knowledge is the key
  - Accumulation
  - Prevention
  - Feed Testing
  - Management strategies

Management Strategies

- Test your feeds. Know what you have.
- Mix high nitrate and low nitrate feeds
  - TMR reduces risk
- Feed ration 2 - 3 times/day (first 2 – 4 days)
- Grazing management
- Adaptation is possible over time

Take Home Message

- Nitrate poisoning is preventable using proper management strategies.
- Toxicity is not usually recognized until animals are found dead.
- Test your feeds!

Questions?

- Contact Information

Barry Yaremcio

Independent Nutritionist

Stettler

403-741-6032

bjyaremcio@gmail.com

www.beefconsultant.com

Yaremcio AG CONSULTING LTD.