Anti-Quality Factors in Forages

Physical plant features
Nutrient / mineral related excesses and deficiencies
Naturally occurring plant metabolites & toxins
Others

It is assumed that plants with various defenses against herbivory, or consumption of herbage, have an ecological survival advantage.

‘Physical’ plant features

Herbaceous plants in our pastures with thorns, prickles, thistles, buffalo bur, horse nettles, etc.

More locally

Woody species that are in pastures

Mineral-related animal disorders:

Nitrate Toxicity

Most often associated with grasses:
Summer annuals: sorghums, corn, millet
Winter annuals: winter wheat
Some weeds: kochia, lambsquarters, sunflower, pigweed

Occasionally – not expected in almost any plant type under extreme conditions

Cause: ‘carbohydrate ‘backbones’

Normal, Metabolism

Incomplete nitrate reduction

• Nitrate accumulates when plants have excess available Nitrogen and under stress conditions for the plants from inhibited normal nitrogen metabolism and/or conversion to protein N and N-containing organic compounds

In livestock... Normal metabolism

When nitrate is high, nitrite (NO₂) is elevated and interferes with normal transport of oxygen in the bloodstream

Symptoms: labored breathing, rapid pulse, staggering

[if acute, ending in collapse and death]

• chocolate – brown blood color
Occurrence:
- high soil nitrate (excessive fertilization, manure, feedlots, runoff areas)
- during drought
- during extended periods of cool, cloudy weather

“Quick Tests” for nitrate in plant tissue
Apply reagent to fresh plant material or to fresh ‘plant juice’ -- look for color change

Qualitative at best!

Semi-quantitative Testing
Laboratories can more accurately analyze for nitrate in hay, silage and fresh forage

Interpretation of Laboratory Results
Nitrate can be reported as KNO3, NO3-N, or NO3, each requiring different interpretation.

<table>
<thead>
<tr>
<th>Form of Nitrate Reported</th>
<th>Recommendations for Feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>KNO3</td>
<td>NO3-N</td>
</tr>
<tr>
<td>0 - 1%</td>
<td>0 - 0.15%</td>
</tr>
<tr>
<td>0-10,000 ppm</td>
<td>0-1500 ppm</td>
</tr>
<tr>
<td>1 - 1.6%</td>
<td>0.15 - 0.23%</td>
</tr>
<tr>
<td>10,400-1600 ppm</td>
<td>1495-2300 ppm</td>
</tr>
<tr>
<td>&gt;1.6%</td>
<td>&gt;0.23%</td>
</tr>
<tr>
<td>&gt;16,000 ppm</td>
<td>&gt;2300 ppm</td>
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</table>

Management:
- Avoid excessive N application (including manure)
- Be cautious during droughts and the first week (or so) following rainfall
- During & immediately following drought, wait 3 to 5 days after an appreciable rain before harvesting.
- Leave more stubble with droughty corn silage
- Nitrate remains in dry hay and crop residues;
- NO3 concentration diminishes during the ensiling process (50-60%); is highest in fresh ‘green chop’.
- Test forages!! And water sources!!
- ‘Dilute’ the daily diet with low N ingredients

Magnesium deficiency is called Grass Tetany ‘ hypomagnesemia’

Cause: low serum Mg, < 1.2 mg/100 ml

Occurrence:
- Highest in spring and fall (cool weather)
- Cattle more susceptible than sheep
- Lactating females more susceptible than males
- Older animals more susceptible
Managing Grass Tetany: Mineral Interactions

- Nitrogen fertilization decreases plant Mg content
- Potassium (K) fertilization decreases Mg uptake (A concern in heavily manured pastures)
- Maintaining higher soil P increases plant Mg
- Use dolomitic lime (contains CaCO3 and MgCO3)
- Feed hay on pasture (during high risk periods)
- Use mixtures of grass and legumes (legumes have higher Mg levels) (?? Use ‘HiMag’ tall fescue ??)

Milk Fever (hypocalcaemia -- low blood serum Ca++)

Most often a condition in late-gestation dry cows & heifers, and cows during very early lactation

High cation / anion balance causes problems

Implications of dietary K+ (too high) and anions (Cl- and SO4²⁻) too low

Management
- Harvest later maturity forage
- Feed low K+ forages to the susceptible animal group
- Use appropriate rates of K+ fertilizer
- Research is pending on increasing dietary Cl- and SO4²⁻

Selenium Deficiency

- Causes ‘white muscle’ / ‘stiff lamb’ disease
  Nutritional muscular dystrophy; lameness

  Occurrence:
  - Low feed and forage Se conc., < 0.06 ppm
  - U.S. soils low in Selenium: Pacific NW, NE, SE

  Prevention:
  - Se supplement
  - Se fertilization (?)

Prevention:

Se fertilization (?)

Pasture forage selenium concentrations compared to dietary requirements. (Oregon)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Average Forage Se (ppm)</th>
<th>Adequate Dietary Se Levels (ppm)</th>
<th>Toxic Dietary Se Level (ppm)</th>
<th>Long Term</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 1</td>
<td>Year 2</td>
<td>0.1 – 0.3</td>
<td>3.0</td>
</tr>
<tr>
<td>Control</td>
<td>0.09</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>½ lb Se as Selenite</td>
<td>1.17</td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 lb Se as Selenite</td>
<td>3.11</td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 lb Se as Selenite</td>
<td>4.24</td>
<td>0.51</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Selenium Toxicity

- ‘Alkali disease’ or ‘blind staggers’ – ‘chronic selenosis’

  Occurrence:
  - High forage concentrations (cattle, sheep, horses) > ~ 3 ppm (about half that for swine)
  - Most frequent in forages on soils high in Se: U.S Great Plains
  - Some plants accumulate Se
    - Milkvetch (some)
    - Locoweed

  In Iowa ???

ISU Vet College case study – SW Iowa (loess and higher Se underlying till soils)
http://jvdi.org/cgi/reprint/5/1/128.pdf
Naturally Occurring Plant Metabolites and Toxins

**Phytoestrogens**
Can cause temporary to permanent infertility in sheep and cattle
Resemble animal estrogens and bind to receptors causing an estrogen-like response
Many common legumes implicated (alfalfa, white clover, red clover, subterranean clover, BFT)
Activity of some phytoestrogens can be elevated by legume leaf diseases and decreased by rumen microbes

**Misc. ‘Clover’ compounds**
Slaframine produced by fungi (*Rhizoctonia leguminicola*)
- ‘Black patch’ in red clover and some other clover
- eye discharge
- excessive slobbering !!!!
- watery diarrhea

**Sorghums/Sorghum-Sudangrass**
**Hydrocyanic acid (HCN) poisoning (Prussic acid)**
(Also in johnsongrass, wilted cherry leaves, & other obscure species - flax?)
Cyanogenic glucosides in the plant epidermal cells mix with ‘converting’ enzymes in mesophyll cells – cyanide released in the reaction
Cyanide inhibits respiratory process:
- labored breathing, excitement,
  (acute cases - convulsions and death)
- Blood is ‘bright, cherry red’

**Sorghums/Sorghum-Sudangrass hybrids**
**Hydrocyanic acid (HCN) (Prussic acid) poisoning**
Youngest tissues have highest HCN potential
- new leaves
- new tillers
HCN in leaves > stems
Seedheads and mature stems are low in HCN potential
HCN potential decreases with maturity
High Nitrogen status will increase the risk

**Light Freeze**
Frozen tissue can cause high HCN in ‘frosted leaves’
Frosted leaves ‘safe to graze’ within 5 – 6 days.
*If new tillers form after frost* (these will be high in cyano-glycosides too!)
Do Not Graze!

**Hard Freeze**
Plasmolysis occurs - HCN released into the plant
HCN volatilizes as plants dry
Do not graze for 5 – 6 days or more
HCN dissipates in dry hay!
‘Quick Tests’ for prussic acid in plant tissue

Fresh plant material exposed to the reagent …
Look for color change
Qualitative at best!

Laboratories will more accurately analyze for prussic acid in fresh forage
HCN is volatile, so fresh samples for lab analyses should be shipped ‘on ice’; but not frozen!

Alkaloids in Forage Grasses

Alkaloids are generally uncommon in grasses.

• Found in 21 out of 8,000 species

Important in three temperate forage grasses:
• Tall fescue
• Phalaris spp. (Reed canarygrass)
• Perennial ryegrass

Phalaris (Reed Canarygrass)

Alkaloid classes:

Indole
• Gramine
• Tryptamines
• Carbolines

Phenol
• Hordenine

‘Old varieties’ have all 4!

Phalaris (Reed Canarygrass)

Forage breeders have selected several reed canarygrass varieties low in all 3 of the indole alkaloids.

• ‘Venture’
• ‘Palaton’
• ‘Chiefton’
• ‘Marathon’
• ‘Rival’

(there may be others)

Animal performance is improved with these low-alkaloid reed canarygrasses, but there is not much evidence that they are particularly more palatable!

Tall Fescue

plant-related alkaloids

• perloline
• loline
• perlolidine

-- reduce microbial digestion of fiber and animal performance

Note! Other anti-quality alkaloids are also associated with tall fescue, those implicated with fungi and have a vaso-restriction mode of action.

Tall Fescue Endophyte

Endophyte fungus: (fungus growing within the plant)

Can lead to an animal condition ‘Fescue Toxicosis’

• produces ergovaline alkaloid(s)
• alkaloids act as ‘vaso-constrictors’
• similar endophytes can be in ryegrasses !!!

The presence of the endophyte is beneficial to the plant!

Imparts:
more tolerance to environmental stresses
some disease and insect resistance / tolerance
Tall Fescue Toxicosis

But is often a disadvantage for livestock eating it!

Common Symptoms:
“Summer Slump / Summer Syndrome”
- rough hair coats
- high core body temperatures
- poor rates of gain
- poor conception rates

Winter conditions
- loss of ear tips and tails
- ‘fescue foot’ (lameness, loss of hooves)

In mares
- retained placentas
- extended gestations
- agalactia, lack of milk

Fescue Toxicosis

Endophyte fungus mycelia concentrate in seedstem, seedhead, and in seed

In vegetative regrowth, endophyte and alkaloids most concentrated in lower stem bases.

- Some alkaloid in leaf blade

With maturity, the alkaloid concentration is greatest in seedstem, seedhead, and seed

Test for the Endophyte

Staining plant tissue or seed

The laboratory staff will inspect the sample for presence of endophyte fungus and report % of plants that are infected.

Newer ‘anti-body reaction’ test - sometimes called an ‘immuno-blot test’ or an ‘ELISA’ test

Tall Fescue Endophyte ‘Life Cycle’

Grass Vegetative Stage:
Most Active Fungus Growth in Leaf Sheaths

Fungal Mycelium invades the developing seed

Seed-borne Tall Fescue Endophyte

Fungus infects new grass seedling

Active endophyte fungus infects new grass seedling

Sampling and Testing for the Endophyte

Collect tillers in summer from representative plants in representative areas of the field (max 10 Ac areas)

Sample: 30-50 random stem pieces per sample area

Trim to 2-inch lower stem segments

Managing the Endophyte

Don’t plant (or feed) endophyte infected fescue

Clip seedstems in May and June

Test for the endophyte

Avoid grazing infected pastures in mid-summer

Dilute the infected pasture with other grasses and/or legumes

In extreme cases, renovate to:
- other forage species
- endophyte free tall fescue variety
- novel endophyte tall fescue variety

Toxin levels are reduced by half or more, but still present in dry hay!
**‘Novel endophyte’**

“Friendly endophyte”

Recall that the endophyte increases the pest resistance & stress tolerance of fescue plants

E- (endophyte-free / low-endophyte) varieties are:

--- beneficial to livestock

-- but have less persistence in the southern U.S. states – similar persistence in Iowa

Selection of endophyte strains from ‘wild-type’ fescue plants has produced endophyte strains that impart stress tolerance to the plants but without the alkaloids that cause problems for livestock

**Pennington Seed Co. (Georgia) markets**

‘Jessup MAXQ’; (& now maybe U. of Arkansas and other sources) (No data to say that we need Novel endophyte in Iowa – Endophyte-free varieties persist well here)

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**Ergot** *(Claviceps sp.)*

Affects many forage grasses and cereal grains

- Fungi (‘external’- air & water borne) infect developing seedhead florets prior to pollination

- Fungal mass grows, replacing seed with an ‘ergot body’, contains alkaloids

- Produces ergotamine alkaloids
  
  - Vasoconstriction = reduced blood supply
  
  - Hyperexcitability, abortion, convulsions

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**Oxalate Poisoning**

- High oxalate in some tropical grasses

- Oxalate reacts with Calcium

- Calcium and Phosphorous metabolism disrupted
  
  - excessive bone demineralization
  
  - lameness, crooked limbs, “bighead” in horses

- urinary calculi, calculi (stones), usually comprised of phosphate salts, lodge in the urinary tract and prevent urination

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**Photosensitization**

Greatest concern for white-skinned animals (or white patches)

A physiological condition of the liver causes animals to become hypersensitive to sunlight -- can ‘sunburn’

alsike clover

buckwheat

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**Other ‘Forage’ Metabolites**

**Tannins**

--- Phenolic compound (with aromatic rings and hydroxyxyl groups)

- Bitter taste -- decreased intake

- Very reactive; complex with peptides
  
  -- improve ‘by-pass’ protein (less soluble)

- At low concentrations, prevent bloat (it) (birdsfoot trefoil, lespedeza, sanfoin)

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**Other ‘Forage’ Toxins**

‘Poisonous’ weeds

Many weeds have other types of minor to ‘acute’ forms of reactive metabolites

Effects vary with the type of toxin, the amount ingested, and type of animal consuming it

‘Browsing animals’ are generally more tolerant of plant toxins
Some lupines and milkvetches (including ‘locoweed’)

- Found on western rangelands
  - contain alkaloids
  - brain effects
  - feed refusal (or the opposite, feeding preference – loco weed)

Pasture Bloat, Frothy Bloat (Acute Tympany)

- Rapid cell wall breakdown releasing soluble proteins and carbohydrates. Proteins form stable foam trapping fermentation gases resulting from the rapidly fermented carbohydrates
- Normal rumen 'Stable forth' fluid vs. 'Foamy' fluid
- Greatest problem when ruminant animals graze young, succulent legumes (alfalfa and clovers)

Pasture Bloat, Frothy Bloat

- foam prevents eructation (belching / gas release)
- animal “balloons” up on left side
- lung capacity reduced
- animal dies of asphyxiation.

Reducing Bloat

- 50% or more grass in pasture
- Let legumes reach early flower stage before grazing
- Turn "full" cattle onto ‘new’, bloat-prone pastures
- Provide a source of dry hay for animals that are on potential bloat-producing pastures
  - Bloat risk diminishes in the dry, legume hay !!!!
- Poloxalene (‘Bloat-Gard’) with grain or in lick blocks
- Seed non-bloating legumes (Birdsfoot Trefoil)
- Sell ‘chronic bloaters’!

Bloat-free Alfalfa?

For many years, creeping-rooted, pasture-type alfalfa varieties have been marketed as ‘low bloat’ or ‘bloat free’. There is no sound basis for these claims.

An Ag Canada research group has selected alfalfa plants with ‘slow initial cell wall/membrane rupture’, intercrossed these and developed a variety with ‘lower incidence of bloat’. The variety is called ‘AC-Grazeland’ now marketed by Pickseed.

‘Storage-related’ anti-quality concerns

Sweetclover poisoning

- Associated with moldy sweetclover hay or silage!
- A metabolite in moldy sweetclover, dicoumarol inhibits Vitamin K needed for blood clotting - blood clotting time
Sweetclover poisoning –cont.

Coumarin glycosides, present in sweetclover (have vanilla (?) odor)

Treatment
– Vitamin K
– Prevent mold in hay
– Feed or dilute ration with non-toxic hay

Mycotoxins in moldy hay and silage -- may also be a concern

Improper fermentation products

Clostridial botulism
- soil borne, occurs in ‘too wet’ and ‘high pH’ silage
- hay or silage containing dead animals

Listeriosis
-- attributed to soil / manure contamination of forage being ensiled

Anti-quality topics to study

Physical structures can reduce animal grazing
Nitrate toxicity  cause and management
Grass Tetany
Milk Fever
Prussic acid (HCN) ; cause and management
Phytoestrogens – general
Alkaloids – general class of compounds in some grasses
(be able to give examples)
Fescue/Ryegrass endophytes
‘life cycle& plant relationship
alkaloid associated conditions
management approaches & issues
Tannins – ‘pros’ and ‘cons’
Bloat
Sweetclover poisoning

Quiz Tuesday, Sept 24
Forage Species – Group 2
Temperate perennial legumes
(plus … the relative compatibilities with the grasses in Group 1 !)

1st 50-pt ‘Midterm’ / Hour Exam
Thursday, Sept 26

Multiple Choice
Fill-in-the-blanks
Several Essay
Will include questions that relate topic material and forage species implications

Examples of past exams:
Will post PDF example on Class www page