Controlling field and storage mycotoxin problems

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Outline

• The current challenge
• Predisposing factors
• Sources, types and effects
• Challenges with diagnosing mycotoxin problems
• Prevention of field mycotoxin problems
• Prevention of storage mycotoxin problems
• Controlling mycotoxin problems
Introduction

• Mycotoxins are secondary compounds that have a defensive role in plants

• Over 400 are known but thousands exist

• Produced by molds (fungi) under stressful conditions

• Molds cause diseases directly (mycoses) or via mycotoxin production (mycotoxicoses)
Current Challenge

• Greater-than-normal mycotoxin load in current feeds

• Wet, late spring delayed planting and cool damp conditions during flowering of corn/ small grains in the North/corn belt increased growth of Fusarium molds and mycotoxin production

• Hence high load of mycotoxins in grains, milling byproducts and some wet feeds (DDGS)
Mycotoxin impacts on cattle

- Irregular heats
- Low conception rates
- Ovarian cysts
- Embryonic loss

- Gastroenteritis
- Intestinal hemorrhages
- Impaired rumen function
- Diarrhea
- Ketosis

- Milk contamination
- Decreased milk production
- Mastitis

- Decreased feed intake
- Lower milk production
- Decreased feed efficiency

(Rodrigues, 2008)
Predisposing factors

• Field factors
  – Adverse weather (temperature & rainfall)
  – Disease, insect or pest damage
  – Excess fungicide spray / weed pressure
  – Late harvest, hail, lodging

• Storage factors
  – Inadequate drying (>12-15% moisture) in grains, hay, byproducts
  – Silages: Oxygen, late harvest, poor packing, late or poor sealing

http://www.ent.iastate.edu/pest/cornborer/
Common spoilage molds

- Fusarium (field mold)
- Aspergillus (storage mold)
- Penicillium (storage mold)

Most common causes of nutrient loss and mycotoxins

- Monascus
- Rhizopus
- Geotrichum
# Toxic molds and mycotoxins in cattle feeds

<table>
<thead>
<tr>
<th>Fusarium</th>
<th>Aspergillus</th>
<th>Penicillium</th>
<th>Claviceps/Neotyphodium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fumonisin</td>
<td>Aflatoxin</td>
<td>Ochratoxin</td>
<td>Ergot alkaloids</td>
</tr>
<tr>
<td>DON</td>
<td>Sterigmatocystin</td>
<td>PR Toxin</td>
<td>Ergotamine (rye)</td>
</tr>
<tr>
<td>Zearalenone</td>
<td>Ochratoxin</td>
<td>Patulin</td>
<td>Ergovaline (fescue)</td>
</tr>
<tr>
<td>T-2 toxin</td>
<td>Fumitremorgens</td>
<td>Roquefortin C</td>
<td>Lolitrem B (ryegrass)</td>
</tr>
<tr>
<td>Diacetoxyscirpenol</td>
<td>Fumitoxins</td>
<td>Mycophenolic acid</td>
<td></td>
</tr>
<tr>
<td>Nivalenol</td>
<td>Cyclopiazonoic acid</td>
<td>Citrinin</td>
<td></td>
</tr>
<tr>
<td>Moniliformin</td>
<td>Gliotoxin</td>
<td>Penetrem</td>
<td></td>
</tr>
<tr>
<td>Fusaric acid</td>
<td></td>
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</tbody>
</table>

(Asher and Whitlow)
Fusarium molds

- Examples F. verticilliodes, F. roseum, and F. proliferatum
- Common in corn, wheat, barley, sorghum,
- Favored by cool damp conditions during growth
- Cause ear and stalk rots, leaf blight etc

Fusarium ear and stalk rot

(Photos by Gary Munkvold)
Fusarium mycotoxins

Fumonisin
- Common in corn, wheat, barley, sorghum
- Forms: $B_1$ (most common and toxic), $B_2$ and $B_3$
- Symptoms: anorexia, weight loss, reduced milk production, and liver damage, death
- FDA guidance: Corn should have < 30 ppm and be < 50% of diet

Zearalenone
- Common in grains, rarely found in forage
- Mimics estrogen function; binds to receptors
- Symptoms: infertility, prolonged oestrous, reduced conception, decreased litter size, rectal or vaginal prolapse and malformed fetus and abortions
- Limit to < 300 ppb
Fumonisin and zearalenone problems

Fusarium verticillioides;  
Photos by Whitlow 2006 and Asher 2010

Diaz et al., 2000

Enlarged vulvas

Rectal prolapse

Scab on Wheat  
USDA
Fusarium mycotoxins - Deoxynivalenol

- DON/Vomitoxin; a trichothecene
- Marker for other mycotoxins
- Symptoms: Reduced milk yield & rumen function, diarrhea, emaciation
- FDA advisory: Feeds should have < 5 ppm of DON and be limited to < 40% of diet. (>500 ppb may reduce milk yield)

Gibberella spp. causes Giberella ear rot and produces DON

(Acosta et al., 2005)
Aspergillus Molds

- Most common in peanuts, corn, sorghum & cottonseed, DGGS
- Produced by A. flavus and A. fumigatus
- Favored by hot, humid conditions or drought stress
- Causes:
  1. Aspergillosis (coughing blood, pneumonia, bloody urine)
  2. Farmers lung (hypersensitivity pneumonia, inflamed alveoli)
  3. Hemorrhagic bowel (bloody gut)
Aspergillus toxins

Aflatoxin

Very toxic and carcinogenic

- Forms: $B_1$, $B_2$, $M_1$, $G_1$, $G_2$
- About 1.7% of $B_1$ in feeds can end up as $M_1$ in milk
- Symptoms: Reduced gain, rumen motility and milk production, immunosuppression, liver damage or cancer, abortions
- FDA Action levels: 20 ppb in dairy feed; 0.5 ppb in milk (100 ppb for breeding beef cattle; 300 ppb for feeder cattle)
Penicillium molds & mycotoxins

- Mold: Penicillium roquefortii
- Acid tolerant therefore common in silages
- Prefers cool wet conditions

Ochratoxin A

- Also produced by Aspergillus ochraceus
- Rapidly ruminally degraded except on a high grain diet
- Symptoms: reduced protein synthesis, abortions, cancer, and immunosuppression, impairs enzyme and kidney function and cellular respiration
Penicillium mycotoxins

Patulin
- Also produced by Aspergillus and Byssochlamys spp
- Reduced digestibility and rumen fermentation, Carcinogenic, mutagenic, gastric paralysis and death

PR Toxin
- Reduced intake, rumen stasis, intestinal irritation, abortion and retained placenta (Whitlow, ...)

![Graph showing digestibility vs patulin concentration]

(Tapia et al., 2004)
Ergot toxin

- Ergot in small grains (rye, sorghum, wheat)
  - Also in argentine bahiagrass
  - Caused by Claviceps purpurea
  - Symptoms: Lameness, reduced fertility, vasoconstriction, gangrene of extremities

- Fescue toxicosis
  - Caused by Neotyphodium coenophialum fungus
  - Symptoms: Vasoconstriction, foot problems, retained winter coat, high body temp, & respiration, reduced fertility, calving difficulties

Images from Roberts & Andrae (2004)
Challenges of dealing with mycotoxins

- Representative sampling is a huge challenge
- Mycotoxins may be present without obvious molds
- Tests for detection of toxin in tissues are uncommon
- Contaminated feed may have been eaten
- Cost of mycotoxin analysis
- Mycotoxins occur together and act in synergy
- Effective antidotes/therapies to mycotoxins are unavailable
Preventing field mycotoxin problems

85% of feed mycotoxins are from the field

• Plant adapted, disease and insect -resistant hybrids e.g. bt-corn
• Apply pesticides/fungicides
• Irrigate/ fertilize / use herbicides to mitigate plant stress
• Maintain harvesting equipment – reduce kernel damage
• Avoid harvesting lodged forage at harvest
• Seeding of non-toxic strains
Preventing mycotoxin problems in stored dry feeds

• Feeds
  – Store grains, hay, by products at <12% moisture
  – Inspect feeds often
  – Avoid condensation, seepage, rainfall on stored feed
  – Clean storage facilities between loads

• Hay
  – Ensure hay is dried to <12% moisture
  – Ensure stacks have adequate aeration and are covered
  – Use additives (mold inhibitors)

• Ensure commodity contracts include mycotoxin clause
Preventing mycotoxin problems in silage

- Use locally adapted, disease/pest resistant hybrids
- Harvest at the right moisture
- Chop properly, fill silo promptly, pack well
- Seal immediately and maintain seal
- Feedout at 12 inches/day (match to herd size)
- Maintain a clean silo face
- Discard spoiled silage
- Use an antifungal inoculant / mold inhibitor
- Greater risk with tropical / later hybrids
Detecting mycotoxin problems

- Monitor performance, review records
- Rule out other causes & identify source
- Representatively sample suspect feeds
  - Take several samples (>10/load), composite and mix well
  - Send to lab (freeze silage/wet samples)
  - Ask for HPLC or Mass spec analysis
  - Test for (AF, DON, ZEN, FB and T2) or base test on symptoms

*Note: Negative test does not imply mycotoxin absence*
Controlling mycotoxin problems

• Dilute contaminated feed in ration
• Offer contaminated feed to less sensitive animals
• Feed well balanced diets
• Ensure fiber adequacy / add buffers to limit acidosis
• Add antioxidants Vit A and E, Se, Cu, Mn, Zn to feeds
• Use a binding or deactivating agent
Strategies to protect against mycotoxins

- Microbial inactivation
- Cleaning/separating fines
- Thermal inactivation
- Irradiation
- Ammoniation
- Ozonation
- Mold inhibitors (Propionic acid)
- Bunk life inoculants (Buchneri)
- Adsorbents

Impractical for forage mycotoxins

Best for forage mycotoxins
Does rust affect forage quality and mycotoxin load? Can inoculants help? (Queiroz et al. 2009)

- 130 acre - field
- Pioneer 33V16
- Infested after tasseling
- 100 kg of – control-no rust, medium rust- high rust

No rust (clean)
Medium rust
High rust
Mycotoxin adsorbents (binders)

• None are approved by FDA as binders
• Added as flow agents to diets
• Many are effective on specific mycotoxins
• In vitro binding data does not always predict in vivo result
• Types:
  1. Activated Carbon or charcoal
  2. Silicates (clays) e.g. bentonite, montmorillonite, HSCAS etc
  3. Cell wall carbohydrates (glycans e.g. glucomannans, peptidoglycans)
  4. Synthetic polymers – polyvinylpyrrolidone and cholestryamine
Effect of adding clay binders at 1% to diets containing 55% AFB on milk AFM1 concentration

Diaz et al. 2004

AFM1, ppb

Days

AFB1 removed  AFB1 added  AFB1 removed

FDA action level

AFB  AFB+clay
Effect of adding a clay binder (Calibrin A) to diets with 75 ppb of AFB1 on milk AFM1

Queiroz et al., 2009
Effect of rate of adding a clay binder (Calibrin A) to diets with 75 ppb of AFB1 on milk

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>AFB1</th>
<th>AFB1+ 0.2% clay</th>
<th>AFB1+ 1% clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, kg/d</td>
<td>20.8</td>
<td>18.0</td>
<td>18.1</td>
<td>20.4</td>
</tr>
<tr>
<td>3.5% FCM yield, kg/d</td>
<td>20.8&lt;sup&gt;x&lt;/sup&gt;</td>
<td>19.0&lt;sup&gt;y&lt;/sup&gt;</td>
<td>20.5&lt;sup&gt;x&lt;/sup&gt;</td>
<td>19.4&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td>Milk Protein %</td>
<td>3.36&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.28&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.35&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.41&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Milk Fat Yield, kg/d</td>
<td>0.74&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.67&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.73&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.69&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Haptoglobin</td>
<td>14.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>16.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>x,y</sup> means in the same row differed, P < 0.1
a, b, means in the same row differed, P < 0.05

Queiroz et al. 2009
Effect of adding binders to diets with 55 ppb of AFB1 on milk AFM1
Effect of adding binders at 0.5% to diets with 112 ppb of AFB1 on milk AFM1

(Kutz, 2009)
Effect of adding binders at 0.5% to diets with 170 ppb of AFB1 on milk AFM1

Adapted from Whiltolw, (2007)
Effect of adsorbents on mycotoxins across species: Summary (Whitlow, 2008)

(Positive Responses/Trial Observations)

<table>
<thead>
<tr>
<th>Mycotoxin</th>
<th>Carbon</th>
<th>Glucan</th>
<th>Clay</th>
<th>PVP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aflatoxin</td>
<td>6/8</td>
<td>7/9</td>
<td>35/35</td>
<td>1/2</td>
</tr>
<tr>
<td>DON</td>
<td></td>
<td>0/1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZEN</td>
<td>1/1</td>
<td>0/1</td>
<td>1/2</td>
<td></td>
</tr>
<tr>
<td>T-2</td>
<td>3/3</td>
<td>1/1</td>
<td>0/5</td>
<td></td>
</tr>
<tr>
<td>DAS</td>
<td></td>
<td></td>
<td>01</td>
<td></td>
</tr>
<tr>
<td>FB</td>
<td>0/1</td>
<td>0/1</td>
<td>0/1</td>
<td></td>
</tr>
<tr>
<td>Ergot</td>
<td></td>
<td>2/2</td>
<td>2/2</td>
<td></td>
</tr>
<tr>
<td>OA</td>
<td>1/2</td>
<td>0/3</td>
<td>0/5</td>
<td>0/1</td>
</tr>
</tbody>
</table>

*Clays are most effective on aflatoxin, less effective on others*
*Carbon & glucans have wider scope but have been less consistent on aflatoxin*
*Research needed on effects of mycotoxin biotransforming agents in cattle feeds*
Take home messages

• Mycotoxin contamination occurs in the field /storage
• Stress/damage to plants, excess moisture in dry feeds, oxygen in silages can increase mycotoxin load
• Mycotoxins reduce performance and welfare or cause severe diseases and death
• Prevention is the best solution
• Effective strategies exist e.g. mold inhibitors, adsorbents
• Adsorbent efficacy varies with the mycotoxin