Hay Preservation

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Presentation outline

- Role of hay preservatives
- Types of preservatives
- Research on preservatives at LRC
- Conclusions
Role of hay preservatives

- Increase flexibility in haying operations
- Reduce field curing time
- Ability to bale at higher moisture content

→ Reduce dry matter losses during baling and storage
Dry matter losses in haying operations

- Field curing – 6% (10 - 15%)
- Raking and baling – 10% (10 - 25%)
- Storage – 5% (10 – 35%)
Causes of DM loss and heating in stored hay

- **Exothermic chemical reactions**
  - 130°C
  - 110°C
  - 88°C
  - 65°C
  - 45°C
  - 20°C

- **Heat resistant fungi**

- **Fungi & bacteria**

- **Plant cell respiration**
Types of hay preservatives/additives

- Conditioning aids
  - these increase drying rates
  - e.g., alkaline solutions, organic solvents, sodium azide, etc.

- Preservatives
  - these prevent spoilage
  - direct acidifiers, e.g., organic acids
  - antimicrobials, e.g., ammonia products
  - microbial inoculants, e.g., LAB
Acidifiers – organic acids

These act as fungicides and/or fungistats

**Category A (corrosive and volatile):**
- Propionic
- Acetic

**Category B:**
- Dilute acid products
- Buffered acids (NH$_4$, Ca & Na salts of propionic)
Organic acids

- most popular is propionic acid
- application rate is moisture dependent: 1.25 kg per 100 kg water
- generally effective at ~10 kg/1000 kg forage

<table>
<thead>
<tr>
<th>% Prop. Acid (w/w)</th>
<th>Temp. (°C)</th>
<th>DM loss (%)</th>
<th>Digestibility (% DM)</th>
<th>Total CHO (% DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>51</td>
<td>15.1</td>
<td>60.5</td>
<td>3.4</td>
</tr>
<tr>
<td>0.02</td>
<td>53</td>
<td>16.7</td>
<td>61.8</td>
<td>3.1</td>
</tr>
<tr>
<td>0.2</td>
<td>46</td>
<td>13.2</td>
<td>62.2</td>
<td>3.9</td>
</tr>
<tr>
<td>0.5</td>
<td>40</td>
<td>11.7</td>
<td>61.0</td>
<td>4.1</td>
</tr>
<tr>
<td>1.0</td>
<td>29</td>
<td>7.6</td>
<td>65.0</td>
<td>6.5</td>
</tr>
</tbody>
</table>

*Purdue Univ. data (Riddell and Evans)
Antimicrobial hay preservatives

These are fungistats and include:

(a) Anhydrous ammonia
(b) Cold-flow ammonia (liquid & vapour mix)
    - both require plastic cover to be effective
    - both are very caustic and volatile
(c) Urea $\rightarrow \text{NH}_3$

ureases

Effective rate: $\sim$2% (w/w) for hay of 25-30% moisture.

Urea is effective at 4% but could be toxic at that level.
Microbial-based hay preservatives

Generally contain one or more of:

**Lactobacillus**
- e.g., *L. plantarum*, *L. acidophilus*, *L. lactis*

**Pediococcus**
- e.g., *P. acidilactici*, *P. pentosaceus*, *P. cerevisiae*

**Streptococcus**
- e.g., *S. faecium*, *S. diacetylactis*, *S. cremoris*

**Bacillus**
- e.g., *B. subtilis*
Which bacterial species?

**Heterofermentative**
- Glucose → Lactic acid, Acetic acid, Ethanol

**Homofermentative**
- Glucose → 2 Lactic acid
What is a good hay preservative?

1. Ability to prevent/reduce fungal invasion
2. Easy and safe to apply
3. Cost effective
4. Have no adverse effect on animals
5. Leave no residues in animal products
Study 1. Effect of preservative on nutritive value of forages

Preservatives

- Liquid *Lactobacillus buchneri* preparation
  @ 1.2 m cfu per gram of fresh forage

- Granular *L. buchneri* preparation
  @ 1.2 m cfu per gram of fresh forage

- Buffered propionic acid*
  @ 1% per kg of fresh forage

*Composition of buffered propionic acid
  Propionic acid – 56%
  Ammonium hydroxide – 30%
  Acetic acid – 14%
Study 1. Effect of preservative on nutritive value of forages

- **Forages**
  - First cut alfalfa in mid-bloom
  - First cut timothy in mid-bloom

- **Forage moisture levels**
  - Alfalfa: 14–17% and 18–21%
  - Timothy: 15–18% and 19–22%

- **Bales**
  - three 500-kg round bales for each additive and moisture level
Study 1. Effect of preservative on nutritive value of forages

- **Measurements**
  - Chemical composition
  - Temperature
  - Microbiology
    - (yeast, molds, LAB, total bacteria)
  - Feed intake and digestibility by sheep
Effect of preservative on chemical composition of timothy hay baled at 20% moisture and stored for 60 d

<table>
<thead>
<tr>
<th>Component</th>
<th>Control</th>
<th>LLB</th>
<th>GLB</th>
<th>BPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM (g/kg)</td>
<td>901</td>
<td>903</td>
<td>908</td>
<td>885</td>
</tr>
<tr>
<td>CP (g/kg DM)</td>
<td>98</td>
<td>108</td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td>NDF (g/kg DM)</td>
<td>758&lt;sup&gt;a&lt;/sup&gt;</td>
<td>744&lt;sup&gt;a&lt;/sup&gt;</td>
<td>728&lt;sup&gt;a&lt;/sup&gt;</td>
<td>695&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>ADF (g/kg DM)</td>
<td>454&lt;sup&gt;a&lt;/sup&gt;</td>
<td>447&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>426&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>420&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>ADIN (% TN)</td>
<td>14.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.9&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>WSC (mg/g)</td>
<td>38.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>58.9&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>45.5&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>64.2&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

LLB = liquid preparation of *L. buchneri*
GLB = granular preparation of *L. buchneri*
BPA = buffered propionic acid
Effect of preservative on recovery of microorganisms ($\log_{10}$ cfu/g) from timothy hay baled at 20% moisture and stored for 60 d

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>LLB</th>
<th>GLB</th>
<th>BPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactobacilli</td>
<td>0.45(^a)</td>
<td>0.00(^b)</td>
<td>0.54(^a)</td>
<td>0.00(^b)</td>
</tr>
<tr>
<td>Yeasts</td>
<td>3.49(^b)</td>
<td>5.36(^a)</td>
<td>4.97(^a)</td>
<td>3.86(^b)</td>
</tr>
<tr>
<td>Molds</td>
<td>3.51(^a)</td>
<td>0.00(^b)</td>
<td>2.91(^a)</td>
<td>0.78(^b)</td>
</tr>
<tr>
<td>Total bacteria</td>
<td>6.25(^a)</td>
<td>6.09(^a)</td>
<td>6.66(^a)</td>
<td>5.24(^b)</td>
</tr>
</tbody>
</table>

LLB = liquid preparation of *L. buchneri*
GLB = granular preparation of *L. buchneri*
BPA = buffered propionic acid
Effect of preservative on chemical composition of alfalfa hay baled at 19% moisture and stored for 60 d

<table>
<thead>
<tr>
<th>Component</th>
<th>Control</th>
<th>LLB</th>
<th>GLB</th>
<th>BPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM (g/kg)</td>
<td>893</td>
<td>888</td>
<td>870</td>
<td>879</td>
</tr>
<tr>
<td>CP (g/kg DM)</td>
<td>225</td>
<td>226</td>
<td>238</td>
<td>225</td>
</tr>
<tr>
<td>NDF (g/kg DM)</td>
<td>438</td>
<td>419</td>
<td>412</td>
<td>414</td>
</tr>
<tr>
<td>ADF (g/kg DM)</td>
<td>308</td>
<td>319</td>
<td>310</td>
<td>320</td>
</tr>
<tr>
<td>ADIN (% TN)</td>
<td>7.7</td>
<td>7.6</td>
<td>5.8</td>
<td>6.9</td>
</tr>
<tr>
<td>WSC (mg/g)</td>
<td>17.8</td>
<td>20.0</td>
<td>19.1</td>
<td>22.0</td>
</tr>
</tbody>
</table>

LLB = liquid preparation of *L. buchneri*
GLB = granular preparation of *L. buchneri*
BPA = buffered propionic acid
Effect of preservative on recovery of microorganisms (log_{10} cfu/g) from alfalfa hay baled at 19% moisture and stored for 60 d

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>Control</th>
<th>LLB</th>
<th>GLB</th>
<th>BPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactobacilli</td>
<td>1.59</td>
<td>1.54</td>
<td>1.10</td>
<td>1.27</td>
</tr>
<tr>
<td>Yeasts</td>
<td>5.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.04&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>4.70&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Molds</td>
<td>1.57</td>
<td>1.71</td>
<td>2.54</td>
<td>2.07</td>
</tr>
<tr>
<td>Total bacteria</td>
<td>5.67&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.90&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.73&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.39&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

LLB = liquid preparation of *L. buchneri*
GLB = granular preparation of *L. buchneri*
BPA = buffered propionic acid
Effect of preservative on temperature in round bales of alfalfa hay baled at 17% moisture
Effect of preservative on temperature in round bales of timothy hay baled at 17% moisture

Days after baling

Temperature (°C)

- Ambient
- Control
- L. buchneri (liquid)
- L. buchneri (granular)
- Propionic acid
Effect of preservative on temperature in round bales of alfalfa hay baled at 19% moisture
Effect of preservative on temperature in round bales of timothy hay baled at 20% moisture
Effect of preservative on dry matter intake of timothy hay by lambs

Dry matter intake (kg/d)

- Control: 1.06
- L. buchneri: 1.33
- Propionic acid: 1.13
Effect of preservative on apparent dry matter digestibility of timothy hay by lambs

![Bar chart showing dry matter digestibility (%) for control, L. buchneri, and propionic acid with values 47.6, 50.7, and 48.8 respectively.]
Study 2. Preservation of high-moisture alfalfa hay

- **Treatments**
  - Buffered propionic acid preparation*
  - Applied at:
    - 4 kg/tonne on forage at 18% moisture
    - 8 kg/tonne on forage at 23% moisture

- **Bales**
  - three 800-kg square bales (2nd cut) per treatment

- **Measurements**
  - Chemical composition
  - Temperature
  - Microbiology (yeasts, molds, LAB, total bacteria)

*Active ingredients: 68% propionic acid; 22% ammonium hydroxide; 2.5% citric acid.*
Visual changes in alfalfa hay preserved with propionic acid

Control

Propionic acid

13% moisture hay

18% moisture hay

23% moisture hay
Effect of buffered propionic acid on chemical composition of alfalfa hay baled at 18% or 23% moisture and stored for 60 d

<table>
<thead>
<tr>
<th>Component</th>
<th>18% moisture</th>
<th></th>
<th>23% moisture</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>PA</td>
<td>Control</td>
<td>PA</td>
</tr>
<tr>
<td>DM (%)</td>
<td>86.8</td>
<td>86.8</td>
<td>84.9</td>
<td>84.1</td>
</tr>
<tr>
<td>CP (% DM)</td>
<td>18.4</td>
<td>19.5</td>
<td>18.7</td>
<td>18.4</td>
</tr>
<tr>
<td>NDF (% DM)</td>
<td>47.2</td>
<td>46.6</td>
<td>48.8</td>
<td>47.4</td>
</tr>
<tr>
<td>ADF (% DM)</td>
<td>37.9</td>
<td>36.7</td>
<td>37.9</td>
<td>38.1</td>
</tr>
<tr>
<td>ADIP (% DM)</td>
<td>4.1</td>
<td>4.3</td>
<td>4.3</td>
<td>4.0</td>
</tr>
<tr>
<td>WSC (g/kg)</td>
<td>9.6</td>
<td>9.9</td>
<td>13.3</td>
<td>17.5</td>
</tr>
</tbody>
</table>
Effect of propionic acid on temperature in large square bales of alfalfa hay baled at 13%, 18%, or 23% moisture
Effect of moisture and buffered propionic acid on average daily temperature in alfalfa hay during storage for 60 d

<table>
<thead>
<tr>
<th></th>
<th>18% moisture</th>
<th></th>
<th>23% moisture</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>BPA</td>
<td>Control</td>
<td>BPA</td>
</tr>
<tr>
<td>Average (°C)</td>
<td>26.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>29.2</td>
<td>29.4</td>
</tr>
<tr>
<td>Degrees above ambient</td>
<td>13.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>16.5</td>
<td>16.7</td>
</tr>
</tbody>
</table>

Average ambient temperature was 12.8°C.
## Do hay preservatives pay?

<table>
<thead>
<tr>
<th></th>
<th>Baled dry</th>
<th></th>
<th>Baled wet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No rain</td>
<td>1” rain</td>
<td>Untreated</td>
</tr>
<tr>
<td>Yield lb/ac</td>
<td>2,000</td>
<td>2,000</td>
<td>2,000</td>
</tr>
<tr>
<td>TDN before cut, %</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Respiration loss, %</td>
<td>5</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Harvest loss, %</td>
<td>10</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Harvested yield, lb/ac</td>
<td>1,700</td>
<td>1,500</td>
<td>1,800</td>
</tr>
<tr>
<td>Storage loss, %</td>
<td>5</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>Final yield, lb/ac</td>
<td>1,600</td>
<td>1,400</td>
<td>1,400</td>
</tr>
</tbody>
</table>

Adapted from Holt and Lectenberg
Conclusions

- Preservatives are most effective when hay moisture content is 20 to 30%.

- It is critical to follow manufacturer’s recommendations on application rates and storage.

- Preservatives will only increase the chances of maintaining the quality of the forage at harvest.

- Apart from ammonia and urea, preservatives generally do not increase forage quality.
Conclusions

- Microbial-based preservatives do not give consistent results.
- Further research is required to determine the precise conditions when application of a preservative is needed.
- The decision to use hay preservatives must be evaluated from an economic viewpoint.