Using Propionic Acid to Preserve More Hay

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Unfortunately, harvests of alfalfa or other hays are frequently complicated by poor drying conditions, or unexpected rainfall events.
Therefore, hay producers often must choose between subjecting their valuable hay crops to rain damage, or accepting inadequate desiccation and spontaneous heating.
Spontaneous Heating

- result of plant and microbial respiration
- occurs in consistent patterns across forages
- many contributing factors
  - moisture
  - bale density and/or size
  - environmental factors
  - storage site
  - preservatives
- **good predictor of changes in forage quality!**
Patterns of Spontaneous Heating in Alfalfa Hay (45-kg bales)

Coblentz et al. (1996)

Temperature (°F)

Plant-associated respiration

Microbial respiration

Storage Time (Days)

Coblentz et al. (1996)
Heating Degree Days vs. Initial Bale Moisture
Alfalfa Hay (Small Rectangular Bales) - 1991

Y = 56x - 891
r² = 0.902

Coblentz et al. (1994)
Wisconsin Round-Bale Studies

- alfalfa-orchardgrass hays from 3 harvests
- 3 bales/interactive treatment (3, 4, or 5-ft diameter)
- storage was outdoors on wooden pallets
- bales were monitored daily until internal bale temperatures indicated no further spontaneous heating
- bales were sampled rigorously on a pre- and post-storage basis
Maximum Internal Bale Temperature (Coblentz and Hoffman, 2009)

- 5-ft bales
  \[ Y = 1.9x + 87.1 \]
  \[ r^2 = 0.971 \]
- 4-ft bales
  \[ Y = 1.5x + 91.5 \]
  \[ r^2 = 0.943 \]
- 3-ft bales
  \[ Y = 1.6x + 86.2 \]
  \[ r^2 = 0.955 \]

Coblentz and Hoffman (2009)
Cost and availability of labor has forced the dairy and hay industries towards larger hay packages, and these bales are far more likely to exhibit spontaneous heating.

Coblentz and Hoffman (2009)
NDF

N = 32 baling treatments
Initial = 46.5%, which corresponds generally to \( \Delta \text{NDF} = 0 \) on the y-axis

Wisconsin Round Bale Study (2006-07)

Acid-Detergent Lignin

N = 32 baling treatments
Initial = 5.54%, which corresponds generally to \( \Delta \text{LIG} = 0 \) on the y-axis

Fiber Components

Coblentz and Hoffman, 2009

Heating Degree Days > 86°F
Figure 7.12. The relationship between the hemicellulose content of orchardgrass and the extent of the Maillard reaction. Hemicellulose declines as it is used in the heat damage reaction (Goering et al., 1973). Damaged carbohydrates no longer analyze as such and appear in the lignin fraction.

Van Soest, 1982

Bermudagrass Hay (Coblentz et al., 2000)
Hemicellulose

N = 32 baling treatments

Initial = 15.1%, which corresponds generally to $\Delta$HEMI = 0 on the y-axis

Intersection of regression lines occurred at 347 HDD > 30°C

Acid Detergent Insoluble Crude Protein (ADICP)

N = 32 baling treatments

Initial = 6.3% of CP and 15.1% of DM, which correspond generally to $\Delta$ADICP = 0 and $\Delta$Hemicellulose (gray line) = 0, respectively, on the y-axis
TDN

N = 32 baling treatments

Initial = 57.9%, which corresponds generally to $\Delta\text{TDN} = 0$ on the y-axis

Coblentz and Hoffman, 2010
Use of Propionic Acid-Based Preservatives
Summary of 10 Experiments
Rotz et al. (1991)

- each experiment contained:
  - positive (dry) hay control (10 to 20%)
  - treated hays (20 to 37%)
  - untreated hays (19 to 40%)
- application rates ranged from 1.0 to 2.3% of bale weight (50% dilution)
- some experiments contained more than one treated vs. untreated comparison

Conclusions

- results were inconsistent across studies
- spontaneous heating was reduced, but not eliminated within treated hays
- regardless of treatment, HDD > 86°F were positively related to initial bale moisture
- losses of DM were positively related to HDD > 86°F accumulated during the first 30 to 45 days of storage
### Application of Propionic Acid Preservative\(^1\) to Large Square Bales\(^2\) of Alfalfa-Orchardgrass Hay (Coblentz et al., 2013)

<table>
<thead>
<tr>
<th>Group</th>
<th>Moisture</th>
<th>Volume</th>
<th>Wet Weight</th>
<th>Dry Weight</th>
<th>DM Density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>ft(^3)</td>
<td>lbs</td>
<td>lbs</td>
<td>lbs DM/ft(^3)</td>
</tr>
<tr>
<td>High</td>
<td>27.4</td>
<td>40.7</td>
<td>644</td>
<td>467</td>
<td>11.5</td>
</tr>
<tr>
<td>Medium</td>
<td>23.8</td>
<td>40.7</td>
<td>626</td>
<td>476</td>
<td>11.8</td>
</tr>
<tr>
<td>Low</td>
<td>19.6</td>
<td>42.1</td>
<td>613</td>
<td>494</td>
<td>11.7</td>
</tr>
<tr>
<td>SEM</td>
<td>0.80</td>
<td>0.39</td>
<td>9.3</td>
<td>10.4</td>
<td>0.20</td>
</tr>
</tbody>
</table>

\(^1\) Rates: 0, 0.6, or 1.0% of fresh weight.

\(^2\) Large square bales were 3 x 3 x 6 ft.
Heating Degree Days > 86°F

Coblentz et al. (2013)

Moisture, %

- High (27.4%)
- Medium (23.8%)
- Low (19.6%)

Treated vs. Control, $P < 0.01$
1.0 vs. 0.6% Rate, $P < 0.01$

Treated vs. Control, $P < 0.01$
1.0 vs. 0.6% Rate, $P = 0.81$

Treated vs. Control, $P < 0.01$
1.0 vs. 0.6% Rate, $P = 0.99$

Coblentz et al. (2013)
NDF

Contrasts

<table>
<thead>
<tr>
<th></th>
<th>( P &gt; F )</th>
</tr>
</thead>
<tbody>
<tr>
<td>HM: Acid-Treated vs. Control</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>HM: 1.0 vs. 0.6% Rate</td>
<td>0.14</td>
</tr>
<tr>
<td>MM: Acid-Treated vs. Control</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>MM: 1.0 vs. 0.6% Rate</td>
<td>0.46</td>
</tr>
<tr>
<td>LM: Acid-Treated vs. Control</td>
<td>0.29</td>
</tr>
<tr>
<td>LM: 1.0 vs. 0.6% Rate</td>
<td>0.50</td>
</tr>
</tbody>
</table>

\( N = 9 \) baling treatments

Prestorage NDF = 53.7\%, which corresponds generally to \( \Delta \text{NDF} = 0 \) on the y-axis

\( Coblentz \text{ et al.} (2013) \)
N = 9 baling treatments

Prestorage ADICP = 1.70%, which corresponds generally to $\Delta$ADICP = 0 on the y-axis

Contrasts

<table>
<thead>
<tr>
<th></th>
<th>$P &gt; F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HM: Acid-Treated vs. Control</td>
<td>0.16</td>
</tr>
<tr>
<td>HM: 1.0 vs. 0.6% Rate</td>
<td>0.13</td>
</tr>
<tr>
<td>MM: Acid-Treated vs. Control</td>
<td>0.01</td>
</tr>
<tr>
<td>MM: 1.0 vs. 0.6% Rate</td>
<td>0.39</td>
</tr>
<tr>
<td>LM: Acid-Treated vs. Control</td>
<td>0.72</td>
</tr>
<tr>
<td>LM: 1.0 vs. 0.6% Rate</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Coblentz et al. (2013)
N = 9 baling treatments

Prestorage TDN = 55.3%, which corresponds generally to \( \Delta \)TDN = 0 on the y-axis

Contrasts

<table>
<thead>
<tr>
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<th>( P &gt; F )</th>
</tr>
</thead>
<tbody>
<tr>
<td>HM: Acid-Treated vs. Control</td>
<td>0.01</td>
</tr>
<tr>
<td>HM: 1.0 vs. 0.6% Rate</td>
<td>0.37</td>
</tr>
<tr>
<td>MM: Acid-Treated vs. Control</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>MM: 1.0 vs. 0.6% Rate</td>
<td>0.35</td>
</tr>
<tr>
<td>LM: Acid-Treated vs. Control</td>
<td>0.27</td>
</tr>
<tr>
<td>LM: 1.0 vs. 0.6% Rate</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Coblentz et al. (2013)
In Vivo Digestibility in Growing Lambs

Coblentz et al. (2013)
Propionic Acid Preservative on Round Bales of Alfalfa Hay
Coblentz and Bertram (2012)
Propionic Acid on Round Bales of Alfalfa Hay

Heating Degree Days > 86°F vs. Initial Bale Moisture

- Untreated
- Treated (0.5% of wet weight)

First 28 Days
Entire Storage Period

Coblentz and Bertram (2012)
Control, N = 42 bales

Acid-treated, N = 38 bales

Prestorage NDF = 38.4%, which corresponds generally to $\Delta \text{NDF} = 0$ on the y-axis

NDF

ADICP

Control, N = 42 bales

Acid-treated, N = 38 bales

Prestorage ADICP = 1.57%, which corresponds generally to $\Delta \text{ADICP} = 0$ on the y-axis

Coblentz and Bertram (2012)
Control, \( N = 42 \) bales

Acid-treated, \( N = 38 \) bales

Prestorage TDN = 61.5%, which corresponds generally to \( \Delta \text{TDN} = 0 \) on the y-axis
• Propionic acid-based preservatives will not eliminate spontaneous heating, and effectiveness will decline as bale moisture increases.

• Effectiveness will be greatest when moisture concentrations are < 25%; however, it should not be assumed that these products will be as effective within large stacks of bales.
Summary

• Based on our work, propionic acid-based preservatives are more likely to be effective within rectangular bales in which the preservative is applied in the bale chamber.

• Keep a written log of baling conditions, initial bale moisture, acid-application rates, and stacking/storage management in order to assess effectiveness of these products under routine production management.
Summary

- Hays baled in large hay packages have a much increased likelihood of heating spontaneously, and catching fire.
  - *Be cautious!*

![Graph showing the relationship between heating degree days and moisture at baling for different diameter bales.](source: Oklahoma State University)