Final Report

Title: Interaction of Bale Size and Preservative Rate for Large-Round Bales of Alfalfa Hay

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Abstract

Recently, two studies conducted at the US Dairy Forage Research Center have reported inconsistent storage responses following the application of propionic-acid-based preservatives to alfalfa or alfalfa-orchardgrass hays. One of these studies utilized 5-foot-diameter round bales, and produced disappointing results across a wide range of moisture concentrations (10 to 40%) relative to untreated control hays. In contrast, large-rectangular (3 × 3 × 6-ft) bales of alfalfa-orchardgrass hay made at 20, 24, and 27% moisture exhibited clear suppression of spontaneous heating and preservation of nutritive value when preservatives were applied at rates of either 0.6 or 1.0% of wet bale weight. Our objective for this experiment was to assess the potential effects of (round) bale diameter on the effectiveness of acid-based preservatives applied to alfalfa/mixed grass hays (83% alfalfa) with the Harvest Tec 647C application system. A total of 18 bales were made at 21% moisture at 2 bale diameters (4 or 5 feet), and with acid preservative applied using 3 application strategies: i) CON, control (no preservative); ii) FULL, fully automated, with automatic adjustments for bale moisture and baling rate; and iii) CONRATE, constant baling rate, which assumes a constant baling rate, but adjusts for bale moisture. All bales were stored outdoors on wooden pallets for 75 days. Measures of spontaneous heating differed between 4-ft and 5-ft diameter bales for maximum bale temperature (107 vs. 115°F; P = 0.012) and heating degree days (HDD) > 86°F (191 vs. 601 HDD; P = 0.024). Effects of preservative application on bale temperature were not observed (P ≥ 0.181); however, large numerical differences were observed between preservative-treated hays and CON baled at a 5-ft diameter (846 vs. 481 HDD; P = 0.144). Unlike measures of spontaneous heating, concentrations of NDF and TDN exhibited interactions (P ≤ 0.044) of main effects, with little change for 4-ft bales, but increased NDF (P = 0.001) and concomitantly decreased TDN (P = 0.011) in response to the additional heating observed in CON. Based on these preliminary findings, bale size/diameter likely plays an important role in the effectiveness of propionic-acid-based preservatives, but more field replications will be required to fully evaluate these relationships.

Introduction

Recently, two studies conducted at the US Dairy Forage Research Center/University of Wisconsin Marshfield Agricultural Research Station (Coblentz and Bertram, 2012; Coblentz et al., 2013) have reported inconsistent storage responses following the application of propionic-acid-based preservatives to alfalfa or alfalfa-orchardgrass hays. One of these studies (Coblentz and Bertram, 2012) utilized 5-foot-diameter round bales, and produced disappointing results across a wide range of moisture concentrations (10 to 40%) relative to untreated control hays. In that study, there was a clear reduction in heating units (measured as HDD) during the first 28 days of storage for acid-treated hays, but these advantages largely were lost when considered over the entire storage period. In reality, propionic acid is hygroscopic, and treated bales often retain water longer
than control bales; as a result, treated large-round bales may run a ‘low-grade fever’ for months, which can continue longer than active heating persists within untreated control bales. In contrast, large-rectangular (3 × 3 × 6-foot) bales of alfalfa-orchardgrass hay made at 20, 24, and 27% moisture exhibited distinct, and very beneficial, responses to acid treatment relative to untreated controls when acid was applied at rates of either 0.6 or 1.0% of wet bale weight (Coblentz et al., 2013). These large-rectangular bales weighed only about 50% of the large-round bales described previously. While the underlying causes of these contrasting responses are likely quite complex, the objective of this research project was to assess the effects of bale diameter on the effectiveness of propionic-acid-based preservatives applied with the technological advancements provided by the Harvest Tec 647C application system for large-round bales.

Materials and Methods

A mixed stand of alfalfa/grass comprised of 83% alfalfa (dry weight basis) was harvested to a 3-inch stubble height with a Case-International Harvester Model 8830 mower-conditioner (J. I. Case Co., Racine, WI) equipped with a sickle-bar cutting mechanism and metal conditioning rollers on 13 August 2016. Hay was wilted, undisturbed, until it was inverted with a side-delivery rake at 1030 h on 16 August, and baling began at approximately 1330 h on the same day. A total of 18 bales were made at 21% moisture (Table 1) with a New Holland Roll Belt 450 Crop Cutter round baler (CNH America, Racine, WI), and the propionic-acid-based preservative (CropSaver™, New Holland Agriculture, Racine, WI) was applied with a Harvest Tec 647C (Harvest Tec, Inc., Hudson, WI) application system. Experimental design was a randomized complete block with 3 replications (field blocks). A 2 x 3 factorial arrangement of treatments were evaluated that included 2 bale diameters (4 or 5 feet) and 3 preservative-application strategies. These included: i) CON, no preservative applied; ii) FULL, fully automated with automatic adjustments to preservative application rate based on moisture and baling rate; and iii) CONRATE, constant application rate, with preservative application rate based on an estimated, pre-programmed baling rate, and adjusted only for bale moisture. All bales were fitted with thermocouples placed in the geometric center of each bale, and internal bale temperatures were monitored daily with measurements recorded between 1400 and 1600 h. Heating degree days >86°F were calculated by determining the difference by which the internal bale temperature was greater than 86°F, and summing these differences over the entire 75-day storage period. All bales were stored outdoors on wooden pallets and core-sampled immediately after baling, and at the conclusion of the 75-day storage period. Forage samples were analyzed for NDF, ADF, hemicellulose, cellulose, lignin, ash, CP, 48-hour neutral-detergent-fiber digestibility (NDFD), neutral-detergent-insoluble CP, and acid-detergent-insoluble CP; in addition, total digestible nutrients (TDN) were calculated by the summative equation (NRC, 2001) using the acid-detergent lignin option to calculate truly-digestible fiber. All analyses were conducted by the US Dairy Forage Research Center, Marshfield (WI).
Table 1. Field characteristics for 18 bales of alfalfa/mixed grass hay made at Marshfield (WI) during 2016. Mean and high moisture estimates shown below were obtained from the Harvest Tec 647C preservative application system.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Diameter</th>
<th>Lab Baler Mean</th>
<th>High Baler</th>
<th>Acid Rate</th>
<th>Baling Time</th>
<th>Baling Rate</th>
<th>Wet Weight</th>
<th>Dry Weight</th>
<th>DM Density</th>
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</thead>
<tbody>
<tr>
<td>Control</td>
<td>4</td>
<td>21.5</td>
<td>20.0</td>
<td>23.0</td>
<td>0</td>
<td>58</td>
<td>20.6</td>
<td>654</td>
<td>514</td>
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<tr>
<td>Fully Automated Control</td>
<td>4</td>
<td>20.0</td>
<td>23.0</td>
<td>25.7</td>
<td>0.60</td>
<td>61</td>
<td>19.8</td>
<td>666</td>
<td>533</td>
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<tr>
<td>Constant Bale Rate Control</td>
<td>4</td>
<td>18.7</td>
<td>19.3</td>
<td>22.7</td>
<td>0.29</td>
<td>64</td>
<td>18.8</td>
<td>661</td>
<td>538</td>
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<tr>
<td>Control</td>
<td>5</td>
<td>21.4</td>
<td>21.0</td>
<td>29.0</td>
<td>0</td>
<td>117</td>
<td>14.7</td>
<td>926</td>
<td>728</td>
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<tr>
<td>Full Automated Control</td>
<td>5</td>
<td>20.5</td>
<td>22.0</td>
<td>26.0</td>
<td>0.51</td>
<td>87</td>
<td>19.3</td>
<td>923</td>
<td>735</td>
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<tr>
<td>Constant Bale Rate Control</td>
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<td>21.6</td>
<td>24.0</td>
<td>28.7</td>
<td>0.60</td>
<td>91</td>
<td>18.6</td>
<td>932</td>
<td>731</td>
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<td>1.88</td>
<td>1.65</td>
<td>0.058</td>
<td>6.7</td>
<td>1.07</td>
<td>8.3</td>
<td>11.5</td>
<td>0.26</td>
</tr>
</tbody>
</table>

**Results and Discussion**

Maximum internal bale temperature and accumulated HDD measured within experimental hays are summarized in Figures 1 and 2, respectively. Both maximum temperature and HDD differed ($P \leq 0.024$) between 4- and 5-ft diameter bales, but interactions of main effects were not detected ($P \geq 0.332$) for either response variable. However, large numerical differences in HDD were observed among 5-ft diameter bales between preservative-treated (FULL and CONRATE) compared to CON (481 vs. 846 HDD; $P = 0.144$), suggesting spontaneous heating was reduced by application of preservatives. More bale numbers may be required to clearly define these relationships based on statistical significance. Although HDD accumulated were substantially reduced, a similar numerical trend existed for 4-ft diameter bales (135 vs. 304 HDD; $P = 0.480$). A similar response was observed within 5-ft bales for maximum temperature, where CON was numerically greater than preservative-treated hays (121 vs. 112°F; $P = 0.062$). Generally, these experimental means obscured responses for individual field replicates; this is illustrated in Figures 3 to 5 by temperature curves during storage for 5-ft bales. Close inspection of these curves indicate that preservatives worked poorly in Replication 1, with intermediate success in Replication 2, and with great success in Replication 3, suggesting that 21% may be the threshold for successful use of preservatives without any reprogramming of the application system to allow for increased application rates. Furthermore, responses may become erratic as this threshold is approached, largely due to within-field moisture variability.
Figure 1. Maximum internal bale temperature for 18 round bales of alfalfa-mixed grass hay made at Marshfield, WI.

Figure 2. Heating degree days > 86°F accumulated during storage for 18 round bales of alfalfa-mixed grass hay made at Marshfield, WI.
Figures 3-5. Internal bale temperatures of 5-ft bales for field replications 1 (top), 2 (middle), and 3 (bottom), where the red (▬), green (▬), and blue (▬) lines represent CON, FULL, and CONRATE preservative-application treatments, respectively.
Concentrations of NDF and TDN are shown in Figures 6 and 7, respectively. Both NDF and TDN exhibited interactions ($P \leq 0.044$) of main effects, with little change for 4-ft bales, but increased NDF ($P = 0.001$) and concomitantly decreased TDN ($P = 0.011$) in response to the additional heating observed for CON in 5-ft bales. These responses are predictable considering the additional respiration occurring in CON bales that was reflected in numerically greater measures of spontaneous heating (Rotz and Muck, 1994). There were no significant treatment effects observed ($P \geq 0.307$) for NDFD, indicating fiber digestibility was not impaired by spontaneous heating in these hays (overall mean = 40.2% of NDF).

Figure 6. Concentrations of NDF for alfalfa-mixed grass hays made in Marshfield, WI.

Figure 7. Concentrations of TDN for alfalfa-mixed grass hays made in Marshfield, WI.
Moving Forward – Working Hypotheses

● This experiment will need to be repeated several times to establish clear statistical inference.

● The effectiveness of preservatives is likely very dependent on bale size.

● The threshold bale moisture for effective use likely declines in an inverse relationship with bale size.

● As bale moisture approaches the threshold for effectiveness, heating responses will likely become increasingly erratic (field variability).

● Previously observed discrepancies between the effectiveness of propionic-acid-based preservatives with large-round and large-square bales can partially be explained on the basis of differences in bale size.

References


Keywords: alfalfa, hay, preservatives, spontaneous heating

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