

Title: *Side-By-Side Evaluation of Preservation Alternatives for Alfalfa Hays*

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Abstract: Objectives for this study were to assess the storage characteristics of relatively dry mixed-species forage preserved with a propionic-acid-based preservative, or by wrapping (individually) with 7 layers of plastic film as baled silage. Thirty-three bales were produced for the experiment at $25.8 \pm 2.20\%$ moisture, and a 2×2 factorial arrangement of preservative (yes or no) and wrapping (yes or no) treatments were evaluated. For this study, the application of plastic film onto relatively dry alfalfa-grass forages using field procedures identical to those used commonly for wetter baled silages proved extremely effective in reducing spontaneous heating during storage, as well as minimizing nutrient losses during this time interval. This management approach shows promise as an alternative to various preservatives for conserving forages in humid environments, or when unstable weather prohibits desiccation of forages to acceptable moisture targets for safe storage as dry hay. Potentially, this is particularly relevant in circumstances where wilting forages approach suitability for safe storage as dry hay, but weather conditions will not allow the remaining drying necessary for storage in this manner. The production of fermentation acids and associated pH depression were greatly restricted in these dry silages, suggesting preservation was accomplished primarily by exclusion of oxygen, and that maintaining anaerobic conditions within the bale is critical for long-term storage. Furthermore, application of plastic wrap under these conditions should effectively eliminate the effects of weathering that are observed commonly with outdoor storage of round-baled hay.

Introduction: Alfalfa forages are important components of diets for lactating dairy cows and other livestock; however, climatic conditions in the eastern United States often are unsuitable for drying alfalfa or alfalfa-grass mixtures adequately for storage as dry hay. Inadequate desiccation prior to baling dry hays results in respiration of sugars into CO₂, water, and heat in a process referred to commonly as spontaneous heating. In severe cases, this process can further lead to spontaneous combustion causing losses of barns and hay inventories. A generation ago, the general rule-of-thumb for satisfactory storage of small, < 45-kg (100-lb) bales handled manually was a moisture threshold of about 20%. Gradual improvements in baler design have emphasized larger (and frequently denser) bale packages, sometimes weighing as much as 2000 lbs (907 kg). While larger bale packages have greatly improved labor efficiency, they also carry the unintended consequence of increased sensitivity to spontaneous heating, which further complicates the complexity of harvest management. This occurs because larger bale packages have much less surface area per unit of dry matter (**DM**), and therefore can't dissipate heat as easily as smaller bales. Currently, moisture recommendations for safe storage of dry hays packaged in large bales vary, but generally they are about

15%, which is often unattainable in the cooler and/or humid environments in many parts of the eastern United States. These factors place hay producers in a frequent position of choosing between baling hay that is nearing, but has not reached, suitability for safe storage as dry hay, or subjecting their valuable hay crops to rain damage. Both choices have very negative consequences with respect to forage quality, as well as potential value for cash sale.

Materials and Methods: The experimental design for this trial was a randomized complete block with a 2 × 2 factorial arrangement of treatments, which included application of a propionic-acid-based preservative at $0.27 \pm 0.025\%$ of wet bale weight, or wrapping (individually) in 7 layers of stretch film. A total of 33 round bales (1.2×1.5 meters; 4×5 feet) containing 66% legumes (alfalfa) and 31% grasses (orchardgrass) were produced at $25.8 \pm 2.20\%$ moisture. There were 8 field blocks, each containing the full complement of (4) interactive treatments. Blocks were based on field topography (slope), and also coincided with increasing contributions of grass to the total forage pool as field elevation declined. One bale also was produced from an incomplete ninth field block. All bales were measured, weighed, and core sampled immediately after baling to establish pre-storage measurements of bale diameter, volume, moisture concentration, and nutritional indices of interest, which allowed for subsequent calculation of energy density, expressed as total digestible nutrients (TDN) and net energy of lactation (NE_L). Bales were positioned on wooden pallets for 84 days before final sampling. Thermocouples were placed in the geometric center of each bale, and internal bale temperatures were monitored daily during the 84-day storage period. Heating degree days > 30°C were calculated for each bale as an integration of the magnitude and duration of heating above the 30°C (86°F) threshold, thereby providing a more descriptive measure of heating than a single-point-in-time measure, such as maximum temperature.

After the 84-day storage period, all plastic film was removed from the 16 bales wrapped in plastic. All bales were then re-weighed and core-sampled; portions of the post-storage core samples were used to determine final moisture concentrations, pH, and nutritional measures by standard wet chemistry methods. A 125-gram subsample also was sent to a commercial laboratory for quantification of fermentation products within the 16 bales that were wrapped in plastic film. At this point, the experiment was terminated for the 17 bales that were not wrapped in plastic, which had been treated as dry hay.

For bales that had been wrapped in plastic film, a further evaluation of aerobic stability was conducted by inserting a thermocouple approximately 0.15 meters (6 inches) under the bale surface and then monitoring surface and core bale temperatures for 33 days. After 33 days of exposure (without plastic film), additional surface and core samples were obtained for assessment of pH, as well as yeast and mold counts by a commercial laboratory.

Project Objectives and Corresponding Results

Project Objective. Objectives for this study were to assess the storage characteristics of relatively dry (25%), mixed-species forage preserved with a propionic-acid-based preservative, by wrapping with 7 layers of plastic film as baled silage, or with a combination of both approaches.

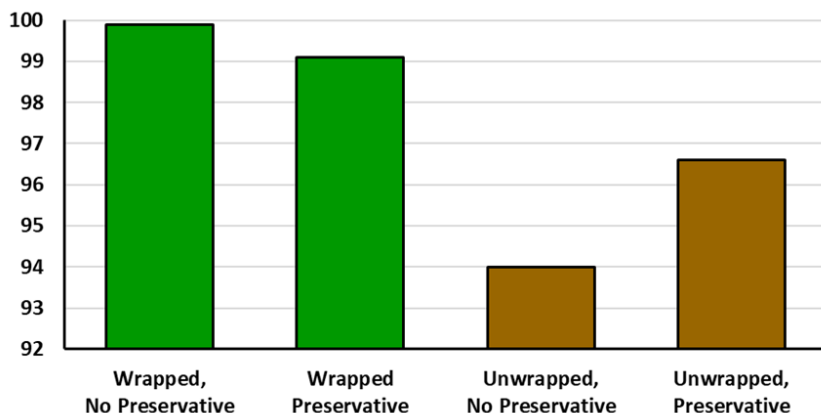
Project Results. The application of plastic film onto relatively dry, mixed-species forages proved extremely effective in reducing spontaneous heating during storage, as well as minimizing nutrient losses. This approach offers considerable promise as an alternative management option for preserving forages when uncooperative weather prevents baling at a moisture level suitable for safe storage as dry hay.

Results and Discussion: The weather conditions under which the trial was conducted closely depicted a typical frustrating scenario encountered by hay producers. Forage for the trial was mowed on 11 August 2020. As forages approached suitability for baling as dry hay, baling operations were delayed by a day due to an unexpected 3.3-millimeter (0.13-inch) shower that fell on 13 August. Trial bales were then generated the next day (14 August) during the late-afternoon at $25.8 \pm 2.20\%$ moisture. However, another 10-

millimeter (0.39-inch) shower occurred during the evening of the same day; therefore, any further attempt at additional field drying would have resulted in significant rain damage, and additional harvest delays.

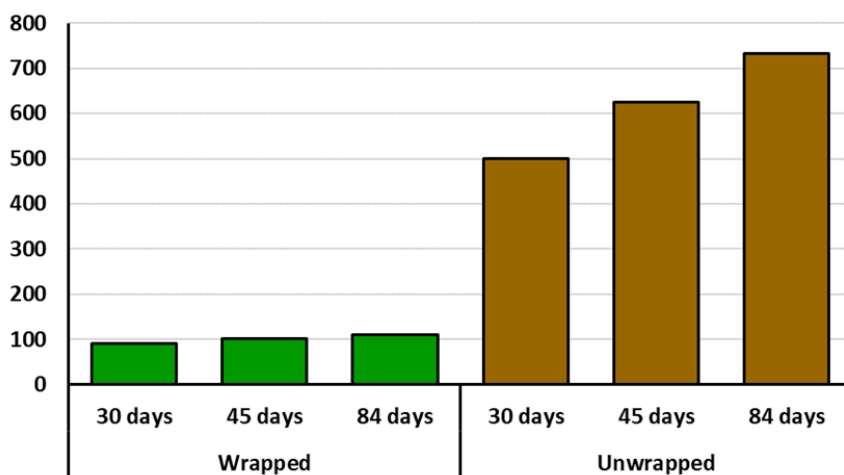
Dry Matter Recovery. An interaction of main effects ($P = 0.018$) was observed for recovery of DM after 84 days of storage, where preservative application did not affect DM recovery from wrapped bales (mean = 99.5%; $P = 0.601$), but improved DM recovery from unwrapped bales (96.6 vs. 94.0%; $P = 0.007$; Figure 1). Recovery of DM was one of very few response variables for which an interaction of preservative and wrapping treatments was detected at a $P < 0.05$ level of confidence.

Figure 1. DM Recovery, %



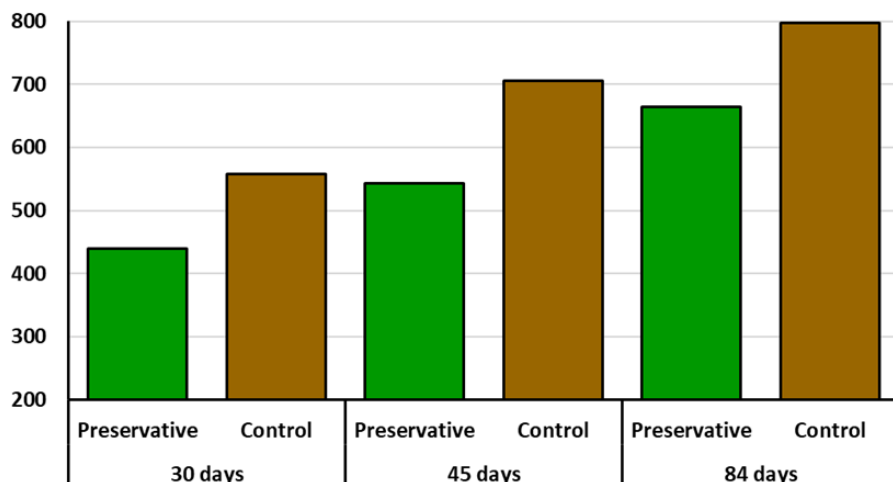
Internal Bale Temperatures. There was no interaction of main effects for maximum internal bale temperature ($P = 0.518$). Unwrapped bales exhibited greater maximum internal bale temperatures than wrapped bales by a margin of $>20^{\circ}\text{C}$ (61.6 vs. 41.5°C ; $P < 0.001$), but preservative application resulted in only a numerically lower temperature compared to bales receiving no preservative (50.4 vs. 52.7°C ; $P = 0.362$). Wrapping bales in plastic film greatly reduced heating degree days $> 30^{\circ}\text{C}$ calculated after 30, 45, and 84 days in storage compared to unwrapped bales ($P < 0.001$). For wrapped bales, heating units generally were accumulated early in the storage period; these relatively small accumulations of heating units were primarily associated with elevated forage temperature at the time of baling ($35.4 \pm 1.59^{\circ}\text{C}$), as well as small amounts of respiration that occurred before anaerobic conditions were established within wrapped bales. In contrast, heating units continued to accumulate throughout storage in unwrapped bales, regardless of whether they received a preservative, or not (Figure 2).

Figure 2. Heating Degree Days $> 30^{\circ}\text{C}$



The sharp differences in heating between wrapped and unwrapped bales (Figure 2) were responsible for a complication within the statistical analysis; specifically, there was not a normal distribution of heating degree day responses, with wrapped and unwrapped bales exhibiting essentially independent populations. To evaluate this further, heating degree days were evaluated for the subset ($N = 17$) of unwrapped bales only. Within this subset of bales, application of a preservative reduced the accumulated heating units significantly after 30 and 45 days in storage ($P \leq 0.027$), but only numerically over the entire storage period ($P = 0.154$) (Figure 3).

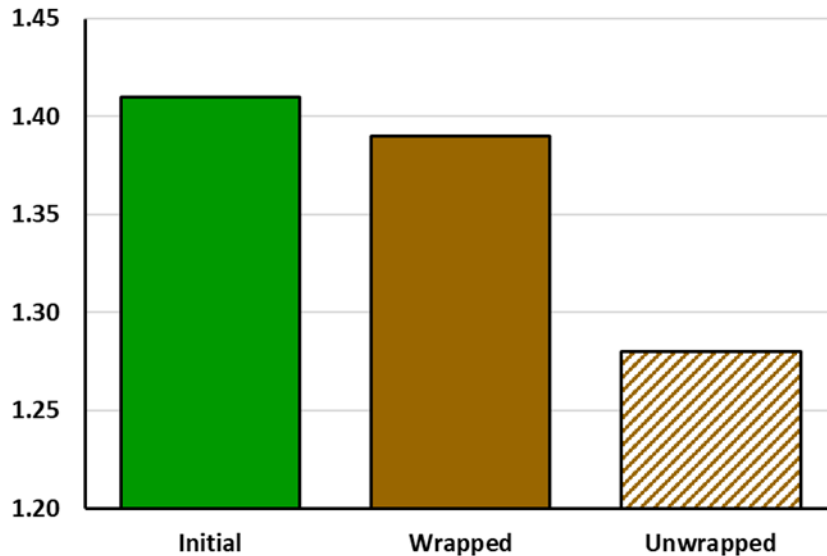
Figure 3. Heating Degree Days > 30°C



It should be noted that a unique observation occurred in this study with respect to preservative application. The preservative applicator system used in this study measures the moisture concentration of the forage every 3 seconds during bale formation. The mean moisture concentration of bales as measured by the product-applicator system differed between treated and untreated hays (21.6 vs. 19.3%; $P = 0.005$), but no difference was detected between wrapped and unwrapped bales ($P = 0.123$). Unlike past experiments in which there was close agreement between baler and laboratory assessments of bale moisture (Coblentz et al., 2020), these baler-moisture determinations varied by >5 percentage units from laboratory determinations. As such, the product application rate ($0.27 \pm 0.025\%$ of wet bale weight) exceeded product recommendations for the moisture range as determined by the baler, but was less than that recommended based on laboratory moisture concentrations (0.4% of wet bale weight). Reasons for this discrepancy are unclear, and it is equally unclear whether the preliminary rain damage that occurred before baling may have been a factor. However, under production situations, producers would not have access to laboratory measurements of bale moisture, and would likely rely heavily on in-situ baler moisture estimates for determining/adjusting appropriate application rates under manual control options.

Nutritive Value. On a post-storage basis, the main effect of preservative application was not significant ($P \geq 0.145$) for any nutritive measure evaluated, nor was the interaction of main effects ($P \geq 0.169$). For all measures of nutritive value, wrapped bales differed ($P \leq 0.004$) from unwrapped bales following storage. Generally, nutritive measures were more desirable for wrapped bales. Most notably, these include differences in water-soluble carbohydrates (7.61 vs. 5.04%), NDF (47.4 vs. 52.6%), lignin (3.89 vs. 5.30%), heat-damaged protein (7.94 vs. 13.85% of CP), and TDN (61.5 vs. 56.9%). Taken in total the combined effects on individual nutritive measures can be summarized by effects on NE_L (Figure 4), where a 9.2% reduction ($P < 0.001$) during storage was observed in unwrapped bales, but only a 1.4% reduction in wrapped bales. The small calculated reduction in energy for wrapped bales did not differ statistically ($P > 0.05$) from nil (no change).

Figure 4. NEL, Mcal/kg DM



Fermentation of Wrapped Bales. Because moisture was limited (25.8%) within wrapped bales, there was little fermentation, regardless of preservative application strategy. Final pH was more acidic following preservative application (5.84 vs. 5.95; $P = 0.007$), but concentrations of lactic, acetic, and total fermentation acids were not affected ($P \geq 0.124$). Final overall mean concentrations of lactic, acetic, and total fermentation acids were 0.32, 0.31, and 0.98%, respectively, indicating minimal fermentation under the conditions of the experiment. As such, preservation of these forages was largely accomplished by exclusion of air, without any of the normal benefits of pH depression.

Aerobic Stability. After an 84-day storage period, plastic was removed from ($N = 16$) wrapped bales, and these bales were exposed to air for 33 days from mid-November through early December. Although the mean ambient temperature during this time period was cool ($1.5 \pm 6.10^{\circ}\text{C}$), the surface pH of preservative-treated silages was 5.95 compared to 6.13 for untreated controls ($P = 0.014$); in addition, detectable yeast counts generally were greater for bales receiving no preservative (5.59 ± 1.107 vs. $4.90 \pm 1.250 \log_{10}$ cfu/g). These responses suggest aerobic stability was improved by preservative application, but obvious indicators of aerobic deterioration, such as differences in surface temperature, were masked by cool ambient temperatures.

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Coblentz, W.K., M.S. Akins, and B.A Kieke. 2020. Storage characteristics and nutritive value of moist large-round bales of alfalfa or alfalfa-grass hay treated with a propionic-acid-based preservative. *Appl. Anim. Sci.* 36:455-470. <https://doi.org/10.15232/aas.2020-02024>

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