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Storage characteristics, nutritive value, and fermentation characteristics of alfalfa packaged in large-round bales and wrapped in stretch film after extended time delays[1]

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ABSTRACT

The production of baled silage is attractive to producers because it offers advantages over dry hay, particularly by limiting risks associated with wet or unstable weather conditions. Our objectives were to test the effects of delayed wrapping on silage fermentation, storage characteristics, and the nutritive value of baled alfalfa silages. To accomplish this, large-round bales of alfalfa were wrapped in plastic film within 4 h of baling (d 0), or after delays of 1, 2, or 3 d. A secondary objective was to evaluate a prototype bale wrap containing an O_2-limiting barrier (OB) against an identical polyethylene wrap without the O_2 barrier (SUN). Sixty-four 1.19 × 1.25-m bales of alfalfa were made from 4 field blocks at a mean moisture concentration of 59.1 ± 4.3% with a mean initial wet bale weight of 473 ± 26.4 kg. Two bales per field block were assigned to each combination of bale wrap (SUN or OB) and wrapping time (0, 1, 2, or 3 d postbaling), and one bale of each pair was fitted with a thermocouple placed in the geometric center of each bale. All bales were sampled after a 97-d storage period. Internal bale temperatures, recorded at the time bales were wrapped, were greater for all bales with wrapping delays compared with bales wrapped on d 0 (54.9 vs. 34.9°C), and increased to a maximum of 63.9°C after a 3-d delay exhibiting a linear effect of time delay. Total silage fermentation acids (lactic, acetic, propionic, butyric, and isobutyric) were greatest when bales were wrapped on d 0 compared with all bales wrapped with time delays (4.64 vs. 2.26% of DM), and declined with linear and quadratic effects of wrapping delay. Total fermentation acids also were related quadratically to internal bale temperature by regression [Y (% of DM) = $0.0042x^2 - 0.50x + 17.1$; $R^2 = 0.725$]. Similar responses were observed for lactic acid, except that trends were linear, both for orthogonal contrasts evaluating length of wrapping delay, and in regressions on internal bale temperature [Y (% of DM) = $-0.046x + 3.5$; $R^2 = 0.663$]. Butyric acid also was detected, regardless of treatment, but was greatest within bales wrapped on d 0 compared with those with wrapping delays (0.99 vs. 0.38% of DM), and a similar response (0.68 vs. 0.52% of DM) was observed for NH_3-N, suggesting that clostridial activity occurred during silage fermentation. Based on these results, silage fermentation characteristics and the nutritive value declined with time delays before wrapping, but responses were exacerbated when delays exceeded 1 d.
Key words: alfalfa, baled silage, oxygen barrier, wrapping delay

INTRODUCTION

The production of baled silage is attractive to many small or mid-sized dairy producers because it offers several advantages over conserving forages as dry hay. Perhaps the most important advantage is the reduced risk of rain damage to forage crops because the time requirement for wilting to a recommended moisture threshold for this silage type (~45 to 55%; Shinners, 2003) is greatly reduced relative to the time required to wilt forages properly for conservation as dry hay. Other advantages over dry hay include (1) better retention of leaves from legume forages, and (2) potential for outside storage because the ensiled forage is wrapped completely in film, and therefore sheds water. However, silage fermentation within wrapped round-bales differs somewhat from precision-chopped silages. Typical moisture recommendations for baled silages range from 45 to 55% (Shinners, 2003), which is considerably drier than recommendations for precision-chopped alfalfa silages (≤70%; Muck et al., 2003). This lower moisture

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may restrict the production of fermentation acids and limit the concomitant pH depression within the silage (Nicholson et al., 1991). Furthermore, the long-stem nature of baled forages restricts the release of sugars required for fermentation by lactic-acid-producing bacteria (Nicholson et al., 1991; Muck et al., 2003; Savoie and Jofriet, 2003), slowing the rate and limiting the extent of silage fermentation. This problem also may be exacerbated by the forage DM densities produced by round balers, which often are less than well-packed, precision-chopped silages.

Other factors also may affect the fermentation characteristics of round-bale silages. One such factor is the potential for delays in wrapping silages after baling is completed, which allows O_2 access to the silage mass, and can cause increased internal bale temperatures, oxidation of water-soluble carbohydrates, a greater final silage pH, and if wrapping delays are extended, formation of N-containing Maillard products that have poorer bioavailability within livestock than native forage N compounds or proteins (McBeth et al., 2001). Moshtaghi Nia and Wittenburg (2000) observed most of these responses following a 19-h wrapping delay when whole-crop barley silage was wrapped within 2, 10, or 19 h of baling; however, differences between 2- and 10-h delays generally were minimal. Borreani and Tabacco (2008) have raised more subtle issues related to O_2 infiltration based on the greater ratio of surface area to total silage DM in silage bales compared with chopped silages stored in bunkers or other large silo structures, as well as the somewhat permeable nature of bale wraps to O_2, particularly when an inadequate number of polyethylene film layers are applied. Hancock and Collins (2006) evaluated the effect of polyethylene layers on preservation of alfalfa baled silage, determining that 2 wrapping layers was inadequate for preservation, but little advantage was gained by using more than 4 film layers within a 5-mo storage period in Kentucky. Permeability of film to O_2 has the potential to stimulate aerobic microorganisms, including yeasts and molds, thereby resulting in DM losses and aerobic deterioration. Recently, Borreani and Tabacco (2008) found that insertion of an O_2-limiting barrier within the polyethylene wrap reduced losses of DM during storage and had the potential to reduce the number of wrapping layers required for good fermentation and storage, which may provide a cost incentive to producers. Our objectives for this project were to test the effects of delayed wrapping on silage fermentation, storage characteristics, and the nutritive value of baled alfalfa silages. To accomplish this, large-round bales of alfalfa were wrapped in plastic film within 4 h of baling (d 0), or after delays of 1, 2, or 3 d. A secondary objective was to evaluate a prototype bale wrap containing an O_2-limiting barrier (**OB**) against the identical polyethylene wrap without the O_2 barrier (**SUN**).

MATERIALS AND METHODS

Field, Storage, and Sampling Procedures

Description of Field Site and Experimental Layout. An 8.0-ha site on the University of Wisconsin Marshfield Agricultural Research Station, located near Stratford, Wisconsin (44°7′N, 90°1′W), was selected for the experiment. The field site was planted to Croplan Rebound 6.0 alfalfa (Winfield Solutions LLC, St. Paul, MN) at a seeding rate of 13.4 kg/ha during 2013. During 2014, the second cutting from this site was mowed at 25% bloom on August 5, 2014, with a 4.9-m-wide Case-International Harvester Model DC163 Hydroswing mower-conditioner (CNH Industrial America LLC, Racine, WI) equipped with metal conditioning rollers. Subsequently, the field was raked at 0930 h on August 7 with a Kuhn Model GA 4220 TH Masterdrive side-delivery rake (Kuhn S.A., Saverne, France). Sixty-four round bales bound with net wrap (2 revolutions) were made between 1400 and 1600 h on the same day with a New Holland BR740A Crop Cutter round baler (CNH Industrial America LLC); the option for cutting alfalfa stems into shorter lengths was not engaged during this study. Prior to initiating the experiment, the field site was subdivided primarily on the basis of topography (slope), into 4 experimental blocks of approximately equal size (2 ha); therefore, a total of 16 bales were made per field block for the study.

Description of Experimental Treatments. Silage bale wraps used in this study included SUNFILM (750 mm × 1,500 m × 25 μm; AEP Industries Inc., Mt. Top, PA), which is a commercially available product commonly used throughout the United States (SUN), and a prototype film produced identically, but with an O_2-limiting barrier (Kuraray America Inc., Pasadena, TX) inserted within the wrap (OB). Oxygen transmission rates for a single layer measured at 1 atm of pressure, 20°C, and 65% relative humidity were 6,931 and 198 $cm^3/m^2 \cdot d$ for SUN (MOCON Testing Service, Minneapolis, MN) and OB (Kuraray America Inc.), respectively. This study was designed as a randomized complete block with a 2 × 4 factorial arrangement of treatments that included 2 wrap types (SUN or OB) and 4 wrapping times (d 0, or after 1-, 2-, or 3-d delays). As described, 8 treatment combinations were represented within each field block, and 2 bales were produced per block for each treatment combination. Treatment assignments within each block were randomized before the trial began, such that successive bales discharged from the baler were not assigned to