PROTECTING HAY QUALITY DURING STORAGE

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ABSTRACT

When hay is first baled stored, it may go through a "sweat", an increase in bale temperature. This increase in bale temperature is a combination of plant, bacteria, yeast, and fungi respiration. Plant soluble carbohydrates, principally sugars, are the source of energy for this respiration and increase in heat. As hay storage time increases, the hay loses Dry Matter (DM), and increases in Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF). If forages are stored at temperatures > 95° for extended periods, indigestible Maillard products may be formed. Round bales that are stored unprotected may weather on the outer edges; six inches of weathered hay may represent as much as 31% of the total bale. The weathered hay at the bale exterior has less digestible Crude Protein (CP), and has a higher NDF and ADF concentration than at the bale interior. Hay that is stored unprotected in the irrigated Sonoran Desert during the summer may become heat damaged. During extended storage periods, hay may be protected by placing the hay under a roof or by covering the hay with plastic tarp and thereby reduce losses in DM and reduce the increases in NDF, ADF, heat-damage.

Key words: hay storage, Maillard products, tarp, alfalfa

INTRODUCTION

Dry matter loss. Hay baled at 15 to 20% moisture, for the first two or three weeks of storage may go through a "sweat", an increase in temperature caused by both plant and microbial respiration. If the temperatures increase no greater than 130°F, the hay should suffer no great reductions in hay dry matter and quality. However, during the sweat, measurable losses, 4 to 5%, in hay DM may be recorded. As a general rule-of-thumb, after hay has reached its equilibrium moisture in storage, for every 1% loss from its original field baling moisture, there will be a corresponding 1% loss in DM (Collins et al., 1997). For example, if hay was originally baled at 18% moisture and after three weeks in storage has stabilized at 12% moisture, there should be a corresponding 6% DM loss.

Even at <15% moisture, microbial respiration may significantly reduce stored hay bale DM. Bacteria on hay, yeasts, and fungi use water soluble carbohydrates as a source of energy (Collins, 1995). It is precisely these water soluble carbohydrates, however, that impart high quality to hay. During extended storage periods, microbial and fungal respiration depletes the soluble carbohydrates and produce CO_2 and water; causing the reduction in DM. Sugars are the primary plant carbohydrates lost during storage respiration. As water soluble carbohydrates are reduced during

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storage, correspondingly the NDF and ADF fractions increase; thereby reducing hay consumption, digestibility, and quality. As the storage time increases, the DM loss increases (Rotz and Muck, 1994).

Heat damaged hay. Microbial, yeast, and fungal respiration causes an increase in heat, which may have deleterious effects. Depending upon the magnitude of heat production, the color of hay may change from green to varying shades of brown. Brown colored hay is indicative of heat damage. Hays stored at temperatures > 100° over extended periods may form Maillard products (Pitt, 1990). Maillard products are non-enzymatic polymers of hemicellulose and soluble sugars with the amino groups of proteins. Maillard products have the chemical properties of lignin and may be recovered in the lignin fraction of ADF. The nitrogen in Maillard products is generally unavailable for digestion. Maillard products in heat damaged hay may be quantified by measuring Kjeldahl N in ADF; acid detergent insoluble nitrogen (ADIN; Goering et al., 1972). Either ADIN (Van Soest and Mason, 1991) formation or ADIN/N% increase (Thomas et al., 1982) may be used as measures of reduced CP digestibility and decreased livestock performance.

EFFECTS OF LONG-TERM HAY STORAGE

Round bales. Much hay in the US is stored as large round bales, often >500 lb. Often this hay is stored outside unprotected from the environment and much of the hay decreases in quality over time. As the outer edge of the bale weathers, it decreases in digestibility and increases in fiber levels (Collins et al., 1997). Round bales that are protected in a barn or under plastic weather little, however unprotected bales over long storage periods may have as much as 8 inches of the outer edge affected by weathering. One may think that only several inches of the outer edge of the bale is only a small percentage of the whole bale, but in reality if only 6 inches of the outer edge of a bale 6 ft in diameter weathers; 31% of the entire bale (Table 1) has been affected by weathering (Huhnke, 2003). This outside weathered portion of the bale decreases in digestibility by 36 to 48% (Figure 1) in comparison to the un-weathered center of the bale. The protein in the weathered portion of the bale is less efficiently used than the protein in the center of the bale. Even if the CP analyses of the bale’s center and weathered exterior are similar, the nitrogen in the bale exterior is less available for digestion (Collins et al., 1997).

In September 1996, Wilcke et al. (1998) baled alfalfa (initial bale moisture 18%) as 5 ft diameter by 6 ft long round bales and as 3 x 4 x 8 ft rectangular bales. For 8 mo in Minnesota, the bales were stored uncovered on sod, uncovered on gravel, on gravel covered with a tarp, and in a shed. At the end of the trial, bales stored unprotected on sod had absorbed ground moisture and had bale moistures of 32%, causing significant mold damage. Bales stored on gravel and covered with a tarp lost 4.8% in DM compared to the 10.9% in lost DM for uncovered bales on gravel. Bale interiors stored in sheds had a Relative Feed Value (RFV) of 133, lower six inches of bottom bales had an RFV of 106. For bales stored uncovered on sod, bale interiors had an RFV of 114, while bale exteriors had RFV’s of 55-107 (Wilcke et al., 1999). At the end of the study, the hay was sold. Covered bales sold for $75/ton while bales on sod and uncovered sold for $45/ton.

Desert alfalfa. During the summer of 1993, we baled alfalfa hay at three locations in the irrigated Sonoran Desert; in Arizona on the CRIT reservation along the Colorado River, in the Imperial Valley, and in the Mexicali Valley; and stored the hay for 20 weeks (Guerrero and Winans; 1997). The baled hay was stored in an air-conditioned room, outside unprotected, outside under a roof, and protected with grey plastic. From June through October 1993, mean maximum daily temperatures were 114°, 113°, 118°, 112°, and 105°; respectively, at the three sites. At the end of the storage period, all hay increased in DM (Figure 2), NDF (Figure 3), ADF (Figure 4), and ADIN/N% (Figure 5). Regression analyses demonstrated that cumulative degree·hour >95° was the environmental variable that was most associated with the increase (r^2 >0.88) in ADIN, NDF, and ADF. We concluded, "Storing alfalfa hay outdoors for extended periods during the extreme summer heat of the Sonoran Desert has detrimental effects on hay quality." Turner et al. (2002) also noted increases in DM, NDF, ADF, and ADIN/N% of bermudagrass hay stored for 65 d in Arkansas.

In early June of 1998, we baled alfalfa at the UC Desert Research and Extension Center in Holtville and subjected the hay to three storage methods for 21 weeks ; unprotected (T1), under a shade structure (T2), and under a plastic (T3) tarp (Guerrero et al., 2005). During the summer of 1998, mean monthly maximum temperatures were 95°, 108°, 107°, 97°, and 85°; respectively; for June, July, August, September, and October; cooler than long term monthly maximum mean temperatures. After the storage period, we fed the treated hays to Holstein steers during three rotational 14-d digestion trials. Digestibility coefficients were greater ($P < 0.05$) for T2 and T3 than for T1 for total DM%, ADF%, and for CP% (Table 2). We concluded, "… we recommend that hay bales be protected from excessive heat during summer in the irrigated Sonoran Desert, because unprotected alfalfa hay bales become heat-damaged and thereby decreased in overall digestibility."

HAY STORAGE OPTIONS

Once hay is baled, there are several methods to store the hay for extended periods of time. One option is to do nothing and leave the hay road-side unprotected. If the climate is dry, if it doesn't rain or snow, if the hay is not on wet soil, if diurnal temperatures are not > 95°, and if the hay is not stored for too long (> 90 d), doing nothing may be a viable option. To reduce ground moisture absorption, hay should be placed on elevated gravel or on pallets. Hay may be stored under a roof or may be tarped. These options increase costs, but also decrease hay quality reductions and reduce DM losses over extended storage periods. If the protected hay has less shrink than unprotected hay (it does), and if the difference in hay price is greater for the protected hays than for the unprotected hays, then protecting hay during storage may be economically advantageous. Since hay quality determinations are primarily dependent on NDF and ADF levels, and since fiber levels increase over prolonged storage periods, protecting hay quality would seem to be advantageous. Wilcke et al. (1998) concluded, "… it is worth investigating the cost of buying tarps and gravel, or even erecting a storage building for hay storage." I would agree.

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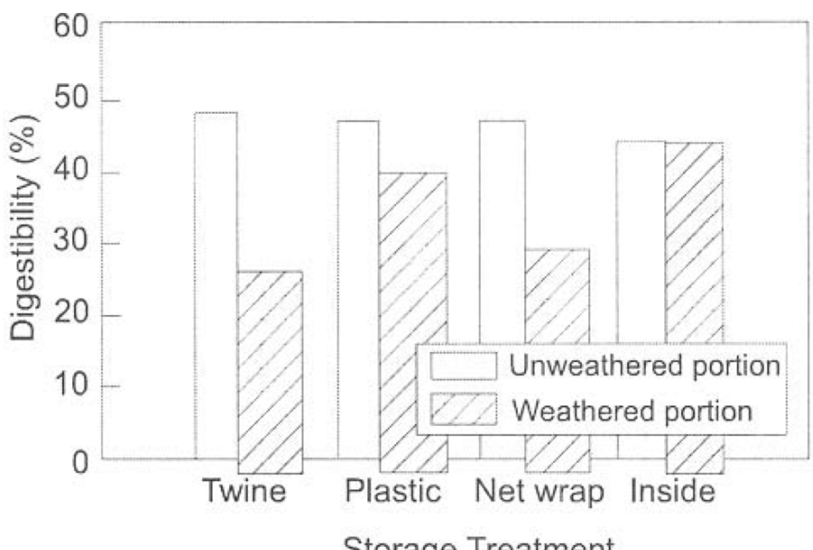

Figure 1. Digestibility of round bale hay stored with different binding materials.
Source: Collins et al. (1997)

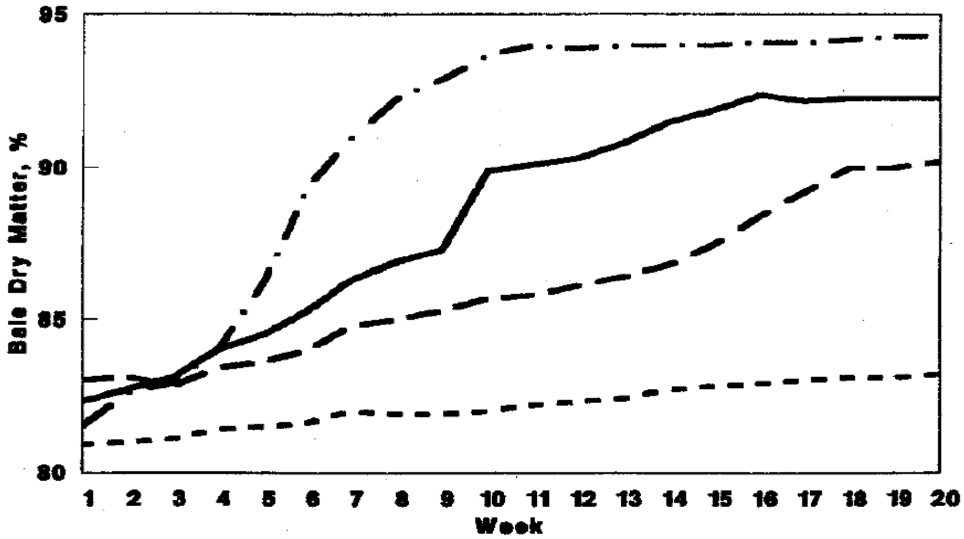

Figure 2. Bale Dry Matter of alfalfa hay stored from May to October 1993 in the Sonoran Desert under four treatments: air conditioned room -----; under a roof ——; covered with plastic tarp – – –; and unprotected – · –.
Source: Guerrero and Winans (1997).

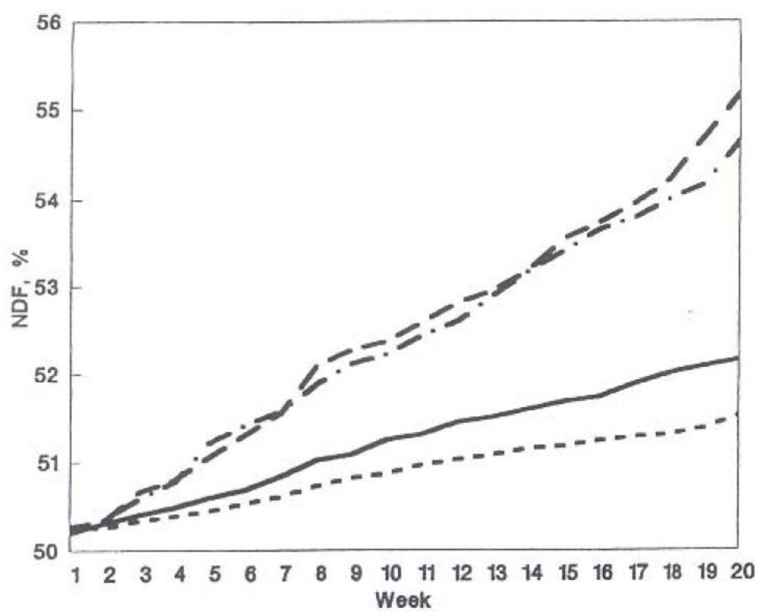

Figure 3. Bale NDF % of alfalfa hay stored from May to October 1993 in the Sonoran Desert under four treatments: air conditioned room -----; under a roof ——; covered with plastic tarp – – –; and unprotected – · –.
Source: Guerrero and Winans (1997).

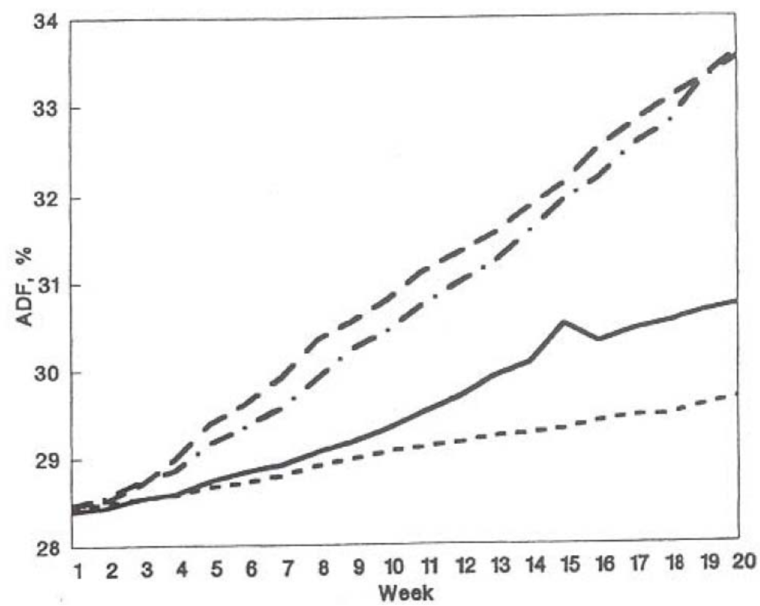

Figure 4. Bale ADF % of alfalfa hay stored from May to October 1993 in the Sonoran Desert under four treatments: air conditioned room -----; under a roof ——; covered with plastic tarp – – –; and unprotected – · –.
Source: Guerrero and Winans (1997).

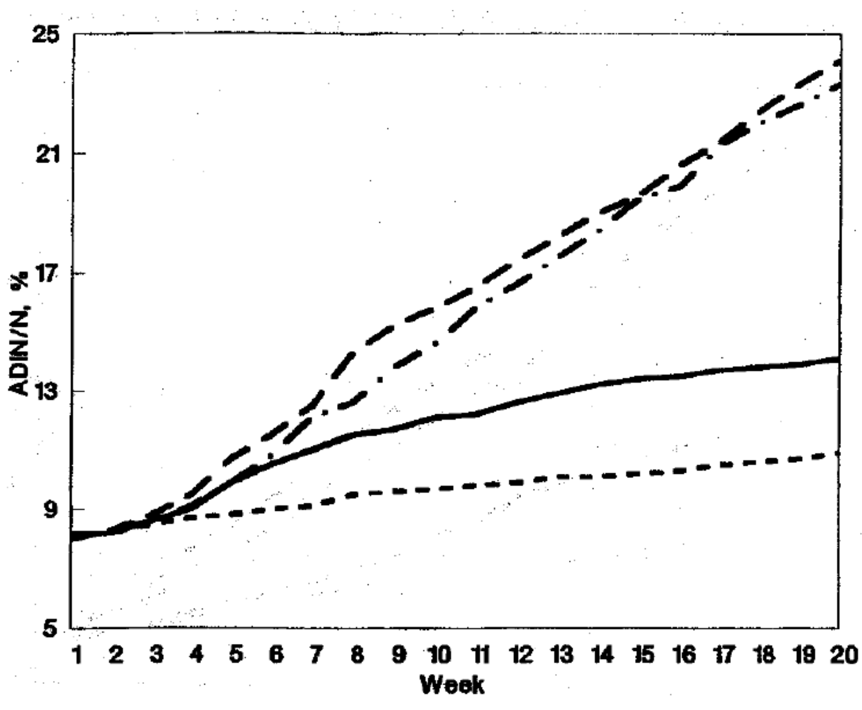

Figure 5. Bale ADIN/N % of alfalfa hay stored from May to October 1993 in the Sonoran Desert under four treatments: air conditioned room -----; under a roof ——; covered with plastic tarp – – –; and unprotected – · –.
Source: Guerrero and Winans (1997).

Table 1. Amounts of round bale dry matter affected by weathering of bale outer edge.

Bale Dia., ft.	Outer Layer Depth 2"	4"	6"	8"
	% dry matter loss			
4	16	31	44	56
5	13	25	36	46
6	11	21	31	40
7	9	18	27	34
8	8	16	23	31

Source: Huhnke, 2003.

Table 2. Mean digestibility of nutrients of 330 lb Holstein steers consuming alfalfa hay stored from June to November, 1998, in the irrigated Sonoran Desert.

	Treatment[*] 1	2	3	SE
Consumption, kg/d				
DM	4.07	4.11	3.60	0.14
NDF	1.30	1.42	1.25	0.08
ADF	0.92[b]	1.08[ab]	0.88[b]	0.11
CP	0.89[a]	0.81[b]	0.84[ab]	0.03
Ruminal digestion, % DM consumption				
DM	49.5[b]	59.2[a]	53.4[ab]	2.1
NDF	40.7[ab]	48.0[a]	32.4[b]	6.0
ADF	35.7[ab]	45.8[a]	25.5[b]	7.0
CP	46.9[b]	58.0[a]	55.0[a]	2.6
Total digestion, % of consumption				
DM	59.5[c]	66.2[a]	64.7[b]	0.7
NDF	39.2[b]	53.2[a]	47.2[ab]	4.2
ADF	33.0[c]	47.5[a]	37.9[b]	2.0
CP	76.7[b]	81.2[a]	80.6[a]	0.3

[*] 1 = stored outside uncovered, 2 = stored outside under a roof and protected from sunlight; and 3 = stored outside covered with plastic tarp.

[a] means within row with different superscripts differ, ($P < 0.05$) paired t-test.

Source: Guerrero et al. (2005).