Changes in Nutritive Value of Tall Fescue Hay as Affected by Natural Rainfall and Moisture Concentration at Baling

J.E. Turner[1], *W.K. Coblentz*[1], *D.A. Scarbrough*[1], *R.T. Rhein*[1], *K.P. Coffey*[1],
C.F. Rosenkrans, Jr.[1], *D.W. Kellogg*[1], *and J.V. Skinner, Jr.*[2]

Story in Brief

Relatively little is known about the combined effects of rain damage and spontaneous heating on the storage characteristics and nutritive value of tall fescue (*Festuca arundinacea Schreb*) hay. Our objectives were to assess the effects of these variables in five management situations. Endophyte-infested 'Kentucky 31' tall fescue was packaged in conventional rectangular bales at 9.9 (low, L), 16.4 (ideal, I), and 22.5% (high, H) moisture prior to rainfall, and at 24.6% moisture after a 0.9-in rainfall event (H-R), and at 9.3% moisture after an accumulation of 2.8 in of rain (L-R). Concentrations of fiber components immediately after baling were increased by rain damage, but crude protein (CP) was not affected. In situ dry matter disappearance was lower for the L-R hay immediately after baling than for those hays baled without rainfall. After a 40-d storage period, L and I hays exhibited a 3.1 to 3.5 percentage unit advantage for in situ dry matter disappearance over hays damaged by spontaneous heating (H), rainfall (L-R), or both (H-R). Generally, the effects of a single (0.9-in) rainfall event on the nutritive value of hay appeared to be relatively small compared to the changes that occur naturally as tall fescue matures. This suggests that producers could be more aggressive toward harvesting at an earlier date instead of waiting for better haying conditions when the crop is too mature.

Introduction

Tall fescue is the primary cool season grass forage species in the eastern half of the United States. The recommended growth stage for hay harvest (boot stage to early heading) often coincides with a high probability of rainfall. This can delay harvest, thereby decreasing nutritive value and subsequent animal performance. The alternative to delaying harvest is to subject tall fescue hay crops to a higher probability of rain damage. Most investigations of rainfall effects on wilting forages have been conducted with legumes, and relatively little work has focused on the examination of these effects in grasses. High probabilities of rainfall also may persuade producers to package and store hay at concentrations of moisture that are greater than the 20% moisture threshold level that is generally recommended to limit spontaneous heating and provide for acceptable storage characteristics in small rectangular bale packages. The objective of this research was to assess the influence of natural rainfall, baling moisture, and spontaneous heating on the nutritive value of tall fescue hay.

Experimental Procedures

Sample Generation. A well-established stand of endophyte-infected 'Kentucky-31' tall fescue was harvested when fully headed with a disc mower on May 23, 2000 at the University of Arkansas Forage Research Area in Fayetteville. This mower did not include a conditioning device. The forage used in this study was the initial spring growth. Fertilization consisted of 50 lb N/acre applied as ammonium nitrate on February 25. Forage was mowed in three blocks of 10 swaths each and allowed to dry until May 24, when the highest desired concentration of moisture was reached. The timeline for all raking and baling procedures, as well as daily and cumulative rainfall totals are summarized in Table 1.

Baling, Stacking, and Sampling. For each combination of moisture and field block, 12 conventional rectangular bales were made with a New Holland Model 320 baler (Ford New Holland, Inc., New Holland, PA). The method of stacking the baling treatments was similar to that previously reported (Coblentz et al. 2000; Turner et al., 2002). Core samples were taken from two bales within each replicate of 12 bales prior to stacking and at 4, 8, 12, 24, and 40 d post baling. The d 0 sampling date served as a pre-storage estimate of forage nutritive value. All forage samples were dried under forced air at 131°F for 72 h; for bales sampled on d 0, this technique was used to estimate the initial concentration of moisture for each baling treatment. Recoveries of DM were determined from calculated DM weight of each bale before and after storage. Bales sampled on d 40 of storage were visually appraised for mold growth by the method of Roberts et al. (1987).

Temperature Analysis. Prior to stacking, bales assigned to the 24 and 40-d sampling dates were fitted with single thermocouple wires inserted into the center of each bale. Bale temperatures were recorded twice daily (at 0630 and 1500 h) until all treatments had been in storage for 14 d and once daily (1500 h) during the remainder of the storage period. The temperature data were collected with an Omega 450 AKT Type K thermocouple thermometer (Omega Engineering, Stamford, CT). For each day of storage, heating degree days >86°F (HDD) were calculated by subtracting 86°F from the mean internal bale temperature. These differences were then summed over the 40-d storage period; therefore, HDD is a single number that represents both the magnitude and duration of heating in each bale.

Chemical Analysis of Forage. Dry forage samples were ground through a Wiley mill fitted with a 1-mm screen (Arthur H. Thomas, Philadelphia, PA) and subsequently analyzed for CP, neutral-detergent fiber (NDF), acid-detergent fiber (ADF), and lignin. The NDF, ADF, and lignin analyses were conducted using batch procedures outlined by ANKOM Technology Corp. (Fairport, NY). Sulfite and heat-stable α-amylase were omitted from the NDF procedure.

[1] Department of Animal Science, Fayetteville.
[2] Resident Director, Arkansas Agricultural Experiment Station

Nitrogen was quantified by a modified Kjeldahl procedure (Kjeltech Auto 1030 Analyzer, Tecator, Inc. Herndon, VA); CP was calculated as %N x 6.25. A ruminally cannulated crossbred steer weighing 1060 lb was used to determine the disappearance of DM after a 48-h ruminal in situ incubation (by standard techniques) for bale samples obtained prior to and after the 40-d storage period. Duplicate dacron bags were used to evaluate each forage. The University of Arkansas Institutional Animal Care and Use Committee approved surgical procedures and anesthesia for the cannulation and care of the steer.

Statistical Analysis. Initial bale characteristics were analyzed by SAS PROC MIXED (SAS Inst., Inc., Cary, NC) as a randomized incomplete block design. Four treatments (H, I, L, and L-R) contained three field replications while treatment H-R had two. A similar model was used to test DM recovery, visual mold score, and indices of spontaneous heating for significant treatment effects.

Since the effects of rainfall should be evident prior to storage, the nutritive value of our treatment forages was evaluated by two separate analyses of variance. Rainfall effects were assessed on a pre-storage basis (d 0) using the model described previously. This model was also used to evaluate ruminal in situ DM disappearance for bales sampled prior to storage (d 0) and after the 40-d storage period was completed. Storage effects were evaluated as a split-plot design with baling treatments as whole plots and sampling dates (4, 8, 12, 24, or 40 d) as the subplot effect.

Results and Discussion

Bale Characteristics. Bale weights and densities (DM basis) generally decreased ($P < 0.05$) as the bales became drier at baling (Table 2). The H bales were heavier and more dense ($P < 0.05$) than the other treatments baled without rain (I and L), and H-R bales were 15.4 lb heavier and 2.9 lb/ft^3 more dense ($P < 0.05$) than L-R bales.

Temperature Responses. During the storage period, there was a sharp decline in bale temperatures between 12 and 15 d of storage. This was the result of cool overnight ambient temperatures that approached 50°F. The HDD accumulated during the storage period for hays baled without rain were greater ($P < 0.05$) for H bales than for I or L bales, which did not differ ($P > 0.05$; Table 3). Despite its higher ($P < 0.05$) moisture concentration at baling, the H-R bales accumulated fewer ($P < 0.05$) HDD than H bales. This could have occurred because nonstructural carbohydrates were leached from the H-R hay, thereby reducing the pool of available sugars that could potentially support spontaneous heating. However, a simpler explanation may be that the H-R treatment had a shorter interval of time in storage (by 2 d) prior to the onset of unseasonably cool weather. In a pattern similar to that observed for HDD, the average, minimum, and maximum internal bale temperatures generally decreased as the bales became drier at packaging. However, there was little practical difference in the heating characteristics of L and I bales. This suggests that any extra wilting time used by producers to attain excessively low moisture levels serves little practical purpose in small rectangular bales, but the effects in large round packages remain unclear.

Visible mold score was numerically greatest for H (Table 3), but this estimate differed ($P < 0.05$) only from that of L bales. The low visible mold scores can be explained on the basis of the low overnight temperatures that occurred between 12 and 15 d of storage and the comparatively low initial concentrations of moisture in these baling treatments. Recoveries of DM (Table 3) did not differ ($P > 0.05$) among treatments. However, the poorest recovery was observed in H bales that exhibited measurable heating characteristics. It should be noted that these estimates did not include field losses associated with rainfall events because DM recovery was determined from the DM weight of each bale immediately prior to storage and at 40 d after baling.

Changes in Nutritive Value Prior to Storage. The effects of rainfall on the concentrations of CP and fiber components for the five baling treatments sampled at baling (d 0) are shown in Table 4. Concentrations of total CP were not affected by treatment ($P > 0.05$). On a practical basis, there was little difference in concentrations of fiber components among treatments that did not incur rainfall during the wilting period. Concentrations of NDF, ADF, and lignin were confined to very narrow ranges across H, I, and L treatments on d 0, thereby suggesting there was little evidence of leaf shatter in the driest (L) forage. Concentrations of NDF, ADF, and lignin increased ($P < 0.05$) as the forage was exposed to increased rainfall. The L-R bales exhibited the greatest increases in NDF and ADF concentrations. Respective increases of these fiber components were 10.1 and 5.0 percentage units, relative to those measured for H bales. For H-R bales, increases in NDF and ADF were approximately half (5.6 and 2.8 percentage units, respectively) of those observed for L-R bales. Clearly, these responses reflect the differences in cumulative rainfall prior to baling for the H-R and L-R treatments. The greater concentrations of fiber in the H-R and L-R hays are likely an indirect result of leaching and prolonged respiration of nonstructural carbohydrates, but not an actual accumulation of additional fiber. Pre-storage in situ DM disappearance after a 48-h ruminal incubation (Table 4) was greater ($P < 0.05$) for baling treatments that had not been exposed to rainfall than for the L-R baling treatment. The H-R baling treatment exhibited a numerical decrease in response to rainfall, but did not differ ($P > 0.05$) from any other treatment.

Changes in Nutritive Value During Storage. Since baling treatment x sampling date interactions were found ($P < 0.05$) for concentrations of most fibrous components, only interaction means are presented and discussed (Table 5). Generally, concentrations of fiber components (NDF, ADF, and lignin) increased ($P < 0.05$) throughout the 40-d storage period. The H and H-R treatments exhibited the greatest ($P < 0.05$) change in concentrations of NDF and ADF during storage, as expected based on the larger heating increment in these bales. The maximum change in NDF during storage was 5.4 percentage units for the H-R treatment. Concentrations of CP were relatively stable across sampling dates in all treatments; differences ($P < 0.05$) over sampling dates were only observed for H and L-R treatments, and the magnitude of these differences was generally small with no apparent pattern.

Comparisons of Hays after Storage. Comparisons of nutritive value for treatment hays sampled on d 40 (Table 5; mean comparisons for baling treatments within the 40-d sampling date are not shown for CP, NDF, ADF, and lignin) are probably the most meaningful data for livestock and hay producers. Concentrations of NDF after 40 d in storage were greatest ($P < 0.05$) for the H-R bales. The H and L-R bales had lower ($P < 0.05$) concentrations of NDF, but the magnitude of these differences was small (4.3 and 2.8 percentage units, respectively), relative to H-R bales. The L bales had the lowest ($P < 0.05$) concentration of NDF after storage, and the difference in NDF between H-R and L bales was 10.7 percentage units. Concentrations of ADF were greatest ($P < 0.05$) in bales that were either baled at a higher than ideal concentration of moisture, received rainfall, or both (H, L-R, and H-R, respectively). The L and I baling treatments had greater ($P < 0.05$) post-storage in situ DM disappearance after a 48-h ruminal incubation than the other baling treatments. This may be due to enhanced conservation of nonstructural carbohydrates in the absence of rain damage and spontaneous heating. After 40 d of storage, the in situ DM disappearance of H, H-R, and L-R bales were virtually identical, and ranged from 3.1 to 3.5 percentage units less than the I and L treatments.

Implications

Drastic increases in NDF and concurrent decreases in digestibility occur when tall fescue matures past late-boot stage; by comparison, the effects of a single rainfall event appear to be relatively small. Generally, producers may benefit from pursuing harvest more aggressively, even when there is a chance of rain before the crop is dry.

Literature Cited

Coblentz, W. K., et al. 2000. Crop Sci. 40:1375-1383.
Roberts, C. A., et al. 1987. Crop Sci. 27:783-785.
Turner, J. E., et al. 2002. Agron. J. 94:109-117.

Table 1. Timeline for mowing, raking, and baling events as well as cumulative rainfall for each of the five tall fescue baling treatments

Date	Treatments[1] mowed	Treatments baled	Raking time h	Precipitation in	Cumulative precipitation prior to baling[2] in
23 May	H, I, L, H-R, L-R				
24 May		H, I, L	0830[3]	0.9[4]	0
25 May			1500[5]		
26 May		H-R	0800[5]	1.8 [6]	0.9
27 May				0.1	
28 May					
29 May		L-R	1100[7]		2.8

[1] Abbreviations; H, high-moisture bales (22.5% moisture); I, ideal-moisture bales (16.4% moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6% moisture, 0.9 in. total rainfall); and L-R, low-moisture, rained-on bales (9.3% moisture, 2.9 in.total rainfall).
[2] Total precipitation that fell prior to baling the treatments identified on that date.
[3] Treatments H, I, and L were raked at 0830 h.
[4] Precipitation fell after baling of H, I, and L treatments was complete.
[5] Treatments H-R and L-R were raked at these times.
[6] Precipitation fell after baling of H-R treatment was complete.
[7] Only treatment L-R was raked at this time.

Table 2. Bale characteristics of tall fescue hay made at five concentrations of moisture and with or without natural rainfall

Treatment[1]	Moisture content %	Bale length in.	Bale volume m^3	Bale weight (as-is) lbs	Bale density (as-is) lbs/ft^3	Bale weight (dry matter basis) lbs	Bale density (dry matter basis) lbs/ft^3
H	22.5[b]	35.5[b]	6.0[b]	76.6[a]	13.1[a]	59.4[a]	10.2[a]
I	16.4[c]	35.9[b]	6.0[b]	58.5[b]	9.9[b]	49.1[bc]	8.3[bc]
L	9.9[d]	37.0[a]	6.2[ab]	49.7[bc]	8.1[c]	44.9[cd]	7.3[cd]
H-R	24.6[a]	35.9[b]	6.1[ab]	68.6[a]	11.5[ab]	55.9[ab]	9.4[ab]
L-R	9.3[d]	37.8[a]	6.3[a]	44.2[c]	7.1[c]	40.5[d]	6.5[d]
SE[2]	0.5	0.4	0.1	3.3	0.6	2.6	0.4

[a, b, c, d] Means in the same column with different superscripts differ ($P < 0.05$).
[1] Abbreviations; H, high-moisture bales (22.5% moisture); I, ideal-moisture bales (16.4% moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6% moisture, 0.9 in. total rainfall); and L-R, low-moisture, rained-on bales (9.3% moisture, 2.8 in. total rainfall).
[2] SE = Standard error of the mean for the H-R treatment with n=2 replications. Other treatments had n=3 replications.

Table 3. Heating and storage characteristics of tall fescue hay bales made at five concentrations of moisture and with or without natural rainfall

Bale moisture[3]	HDD[1]	MIN °F	MAX °F	AVG °F	Visible mold[2]	DM recovery %
H	293[a]	72.1[a]	121.6[a]	88.2[a]	1.75[a]	93.4
I	58[c]	68.5[ab]	104.0[b]	81.9[c]	1.08[ab]	96.5
L	25[cd]	64.8b[c]	109.0[b]	76.6[d]	1.00[b]	98.1
H-R	232[b]	67.8[ab]	123.4[a]	85.6[b]	1.71[ab]	95.9
L-R	9[d]	62.6[c]	88.5[c]	76.6[d]	1.04[ab]	94.7
SE[4]	20	1.4	2.3	0.5	0.30	2.1

[a, b, c, d] Means in the same column with different superscripts differ ($P < 0.05$).

[1] Abbreviations: HDD, heating degree days > 86°F; MIN, minimum internal bale temperature; MAX, maximum internal bale temperature; and 40-d AVG, average internal bale temperature over the entire 40-d storage period.

[2] Visible mold assessment score 1 = no visible mold; 2 = presence of spores between flakes; 3 = presence of spores throughout the bale; 4 = mycelial mat between flakes; and 5 = mycelial mat throughout the bale (Roberts et al., 1987).

[3] Abbreviations; H, high-moisture bales (22.5% moisture); I, ideal-moisture bales (16.4% moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6% moisture, 0.9 in. total rainfall); and L-R, low-moisture, rained-on bales (9.3% moisture, 2.8 in. total rainfall).

[4] SE = Standard error of the mean for the H-R treatment with n=2 replications. Other treatments had n=3 replications.

Table 4. Concentrations of fiber components in five baling treatments of tall fescue hay sampled immediately after baling (d 0) that illustrate the effects of natural rainfall during the wilting period

Baling treatment[2]	CP[1]	NDF	ADF	Lignin	In situ disappearance
	% of DM				
H	7.8	66.3[d]	37.6[d]	4.81[c]	64.2[a]
I	8.2	67.7[c]	38.3[c]	5.12[bc]	62.9[a]
L	7.9	67.3[c]	38.1[cd]	4.98[c]	63.9[a]
H-R	8.4	71.9[b]	40.4[b]	5.44[ab]	61.7[ab]
L-R	8.6	76.4[a]	42.6[a]	5.52[a]	59.7[b]
SE[3]	0.3	0.3	0.2	0.1	1.4

[a, b, c, d] Means in the same column with different superscripts differ ($P < 0.05$).

[1] Abbreviations: CP, crude protein; NDF, neutral-detergent fiber; ADF, acid detergent fiber.

[2] Abbreviations; H, high-moisture bales (22.5% moisture); I, ideal-moisture bales (16.4% moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6%, 0.9 in. total rainfall); and L-R, low-moisture, rained-on bales (9.3% moisture, 2.8 in. total rainfall).

[3] SE = Standard error of the mean for the H-R treatment with n=2 replications. Other treatments had n=3 replications.

Table 5. Concentrations of fiber components in five baling treatments of tall fescue hay on five sampling dates and the 48-h in situ DM disappearance of bales sampled at the end of a 40-d storage period

Treatment[3]	Sampling date	CP[1]	NDF	ADF	Lignin	In situ disappearance[2]
	d	----------	----------	% of DM	----------	----------
H	4	8.6[ab]	69.5[c]	38.7[c]	5.11[b]	-
	8	8.4[ab]	71.6[b]	40.2[b]	6.01[a]	-
	12	8.1[b]	72.0[b]	40.8[b]	5.43[ab]	-
	24	8.6[ab]	73.4[a]	39.7[bc]	5.79[a]	-
	40	8.9[a]	74.5[a]	43.4[a]	5.89[a]	59.8[e]
I	4	8.3	66.7[c]	39.1[b]	5.10[c]	-
	8	8.1	67.7[bc]	38.7[b]	5.39[bc]	-
	12	8.2	68.8[b]	38.4[b]	5.13[bc]	-
	24	8.3	69.3[a]	38.8[b]	5.78[ab]	-
	40	8.2	70.5[a]	41.1[a]	6.20[a]	62.9[d]
L	4	7.9	66.9	38.7[ab]	5.18[bc]	-
	8	8.2	67.3	38.3[b]	5.45[abc]	-
	12	8.3	67.0	38.4[b]	5.10[c]	-
	24	8.6	67.3	38.3[b]	5.96[a]	-
	40	7.9	68.1	39.7[a]	5.82[ab]	63.1[d]
H-R	4	8.4	73.4[c]	40.5[c]	5.80[ab]	-
	8	8.1	76.2[b]	43.1[b]	6.35[ab]	-
	12	8.6	75.8[b]	42.8[b]	6.15[ab]	-
	24	8.4	77.0[ab]	43.8[ab]	5.61[b]	-
	40	8.5	78.8[a]	44.6[a]	6.46[a]	59.6[e]
L-R	4	8.4[a]	74.6[b]	42.4[b]	5.96[b]	-
	8	8.4[a]	74.6[b]	44.0[a]	5.74[b]	-
	12	8.4[a]	75.6[ab]	43.5[a]	6.01[b]	-
	24	8.7[a]	76.6[a]	43.9[a]	6.03[b]	-
	40	7.7[b]	76.0[ab]	44.0[a]	6.83[a]	59.7[e]
S.E		0.4[4]	0.7[4]	0.5[4]	0.28[4]	1.6[5]

[a, b, c] Means in the same column and baling treatment with different superscripts differ ($P < 0.05$).

[d, e] Means in the same column with different superscripts differ ($P < 0.05$).

[1]Abbreviations: CP, crude protein; NDF, neutral-detergent fiber; ADF, acid-detergent fiber.

[2]Ruminal DM disappearance during a 48-h incubation in situ. Analysis of variance and mean separation were conducted for the 40-d sampling date only.

[3]Abbreviations; H, high-moisture bales (22.5% moisture); I, ideal-moisture bales (16.4% moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6% moisture, 0.9 in. total rainfall); and L-R, low-moisture, rained-on bales (9.3% moisture, 2.8 in. total rainfall).

[4]SE = Standard error of the baling treatment x sampling date interaction mean for H-R bales with n=2 replications. Other treatments had n=3 replications.

[5]SE = Standard error of the baling treatment mean for H-R bales with n=2 replications. Other treatments had n=3 replications.