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COMPARISON OF CONVENTIONAL AND LABORATORY-SCALE ALFALFA HAY BALES IN SMALL HAYSTACKS[1]

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Summary

A system for making laboratory-scale alfalfa hay bales was evaluated in two trials. In the first, conventional rectangular and laboratory-scale bales were made at each of seven different combinations of moisture and density. Laboratory bales were incubated between two parent conventional bales of identical moisture content and bale density. Laboratory bales remained different ($P < .05$) from parent conventional bales for most temperature-related storage traits. Agreement between bale types was better for most quality traits.

To achieve closer agreement between bale types, a second experiment was conducted in which the laboratory bales were made at 1.0, 1.3, 1.6, and 2.0 times the density of the conventional bales. Agreement improved between laboratory bales of higher densities and conventional bales for most temperature traits. High-density laboratory bales had significantly greater acid detergent insoluble nitrogen values than conventional bales, particularly at the highest moisture level. These results implicate bale density as an important factor in heat damage to proteins in alfalfa hay.

(Key Words: Hay, Alfalfa, Bale, Protein, Density.)

Introduction

Baling higher moisture alfalfa hay has been a topic of considerable interest for several years. However, the unpredictability of moisture content within and across alfalfa swaths, variability in ambient storage temperatures during different seasons of the year, and difficulty in controlling bale densities all contribute to the frustrating nature of alfalfa hay research. To help address these concerns, a simple system for making wire-tied, laboratory-scale hay bales was developed and is described on page -- of this report. Two experiments were conducted in 1991 to validate the system as a legitimate tool for hay research. The first experiment compared the performance of laboratory-scale and rectangular alfalfa hay bales in a haystack environment over a wide range of bale moistures and densities. The second experiment determined 1) if increasing laboratory bale densities could equalize heating characteristics between bale types and 2) what effect bale density has on alfalfa hay quality.

Experimental Procedures

Experiment 1. A 2-year-old stand of Germaine WL-3201 alfalfa near Keats, KS was harvested (third cutting) at one-third bloom with a mower-conditioner on July 25, 1991. The forage was mowed in three blocks of eight windrows each and allowed to dry undisturbed until the desired level of moisture was reached.

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One randomly assigned windrow within each block was allocated to one of eight whole plots, which included high- and low-density baling treatments at four different moisture levels. When averaged across both bale density and type, these moisture levels were 30.6, 24.8, 20.3, and 14.3 percent. The low-density treatment at 14.3% moisture was omitted from the experiment.

Three conventional 15 × 18 × 37 in. rectangular bales were made from each whole-plot windrow. One of three conventional bales was weighed, measured for length, and core sampled, then opened to make the laboratory bales. Nontreatment bales were weighed and measured to compute average conventional bale densities.

Treatment bales were opened and flakes were randomly chosen (omitting end flakes) for making the laboratory bales. Bale flakes were placed on a 24-inch paper cutter, where forage was cut to approximately 4 inches to ensure uniform distribution of plant material throughout the laboratory bales. Preweighed amounts of that alfalfa were then used to make 4 × 4 1/4 × 5 1/4 in. laboratory bales of the same density as the field-baled conventional bales.

Two conventional and two laboratory bales from the same whole-plot windrow were then incubated in a single small haystack. Haystacks were stored in an open air building with a concrete floor for 35 days or until internal bale temperatures returned to ambient.

Thermocouples were inserted into the center of conventional bales in the field (one per bale), and initial temperatures recorded. Laboratory bales were fitted with identical thermocouples approximately 1 h after bale formation. Temperatures were recorded at 8 am and 3 pm for the first 15 days of storage and once daily thereafter. Temperature data for laboratory and conventional bales were compared for maximum temperature, 30-day avg temperature, and degree days > 30°C.

After the storage period, conventional bales were weighed and core sampled. Laboratory bales were weighed only. All bales were opened and visually appraised for mold (1 = good, 5 = poor). Core samples from conventional bales and whole laboratory bales were then dried at 50°C; ground; and analyzed for total N, NDF, ADF, and ADIN. Results were analyzed as a split-plot design with the seven combinations of moisture and density as whole plots and bale type (conventional or laboratory) as subplots.

Experiment 2. A 2-year-old stand of Germaine WL-3171 alfalfa near Keats, KS was harvested (fourth cutting) with a mower-conditioner on October 1, 1991. The stand, cut at bud stage, was approximately 15 inches tall. Rainfall during the regrowth period had been limited. The crop was mowed in nine adjacent windrows. Each of three whole-plot treatments, based on moisture content at the time of baling, was replicated three times. Moisture levels for the three whole-plot treatments (high, medium, and low) were 35.3, 25.4, and 18.2%, respectively, when averaged across bale type. The alfalfa was allowed to dry undisturbed until the desired moisture levels were reached the next day, and three conventional bales were made from each whole-plot windrow. Unlike Experiment 1, there was no attempt to control density, except that the baler was adjusted to produce a solid bale. Because of the drought-stressed, immature nature of the alfalfa, bale densities were somewhat higher than normal. Laboratory bales were made as in Experiment 1, with densities 1.0, 1.3, 1.6, and 2.0 times the avg density of the three parent conventional bales. All bales were incubated in haystacks similar to those in Experiment 1. A split-plot design was used with moisture levels as whole plots and bale type-density combinations as subplots. Because of the onset of freezing storage temperatures in late October, heating and deterioration stopped after about 30 days.

Results and Discussion

Experiment 1. Regardless of treatment, conventional bales consistently maintained higher internal temperatures than laboratory bales. However, temperatures of laboratory bales were much more variable. This was particularly true during the first 25 days of storage, when the laboratory bales were most

likely to be actively generating heat. After approximately 25 days of storage, laboratory bales followed essentially the same temperature pattern as the conventional bales, indicating that heat generation after that time was probably minimal.

Temperature traits are compared in Table 1. The best agreement ($P > .05$) between bale types occurred for maximum temperature, indicating that laboratory bales were capable of generating temperatures similar to those of conventional bales when incubated in a small haystack environment. Comparisons of 30-day avg temperature and degree days $> 30°C$ showed that laboratory bales probably lost heat faster than conventional bales. There was better agreement (data not shown) between bale types for other quality traits.

Experiment 2. The physical bale characteristics are shown in Table 2, and statistical comparisons of treatments for storage temperature traits, in Table 3. Although conventional bales generally maintained higher internal temperatures and probably dominated the stack environment, laboratory bales (as in Experiment 1) maintained comparable internal temperatures and exhibited an independent response with respect to temperature.

The most dense laboratory bales maintained the highest internal temperatures. This was expected, because they contained the most plant material and, thus, the most heat-generating substrate. However, even the most dense laboratory bales within a given moisture level did not reach the temperatures of conventional bales for any of the temperature indices measured ($P < .05$).

With few exceptions, ADF and ADIN fractions and visual mold in laboratory bales increased with bale density, regardless of moisture content (Figure 1), and DM recovery decreased as bale density increased. Significant differences in response to sequentially elevated laboratory bale density were observed in: 1) the low-moisture level with respect to ADF, ADIN, visual mold, and DM recovery; 2) the medium-moisture level with respect to ADF and visual mold; and 3) the high-moisture level with respect to ADF, ADIN, visual mold, and DM recovery. Frequently, high-density laboratory bales had significantly higher NDF and ADIN contents than conventional bales. This occurred specifically for NDF content at the high- and low-moisture levels (data not shown) and ADIN content at the high-moisture level. Visual mold responses followed a similar pattern; the 2.0 density factor laboratory bales had higher visual mold scores than conventional bales in the high- and medium-moisture treatments.

The response of ADIN content in laboratory bales to increasing density was unexpected based on the temperature data. Effective heating period, temperature, and moisture content have been implicated as factors influencing heat damage in alfalfa hay. ADIN is expected to increase with heating. However, in laboratory bales, ADIN increased despite essentially steady temperatures, especially in the high-moisture treatment. The temperatures we measured were the net result of heat production from metabolic activity in plant material, heat moving to the laboratory bales from the conventional bales, and heat dissipation to the bale surface and the environment. Differentiation between these heat sources and transfers might be necessary to adequately explain our results.

Our results suggest several possible mechanisms acting independently or in concert; 1) ADIN values might have increased in response to laboratory bale density because of increases in self-generated heat; 2) self-generated heat and heat imposed from adjacent conventional bales might have impacted ADIN values differently during the storage period; and 3) sequential increases in laboratory bale density at a given moisture level might have rendered alfalfa proteins more susceptible to the Maillard reaction (non-enzymatic browning), even though temperatures in these bales were not significantly different. The last explanation, to our knowledge, has not been previously suggested.

Table 1. Temperature Traits for Conventional and Laboratory Hay Bales Made at Seven Combinations of Moisture and Density in Experiment 1

Moisture, %	Density, lb/ft³	Bale type[1]	Temperature, °C: Maximum	Temperature, °C: 30-day avg	Degree days, > 30°C
30.6	High, 21.4	C	54.9	44.3	525
		L	53.1	41.4	408
30.6	Low, 16.8	C	53.7	41.9	439
		L	51.2	38.2	293
24.8	High, 17.6	C	49.9	41.2	383
		L	49.0	40.3	344
24.8	Low, 13.5	C	50.6	38.7	279
		L	46.7	36.2	204
20.3	High, 11.9	C	45.0	32.7	115
		L	41.3	31.3	82
20.3	Low, 8.9	C	39.8	28.5	33
		L	34.8	26.9	11
14.3	High, 10.5	C	32.4	25.8	3
		L	31.7	25.3	2
LSD (P < .05)[2]			3.3	1.1	29

[1]C = conventional and L = laboratory.
[2]LSD values are for comparison of subplot (bale type) means within whole plots (moisture/density level combinations).

Table 2. Description of Treatments and Physical Characteristics of Alfalfa Bales Used in Experiment 2 (Bale wire weights are excluded from all calculations of weight and density involving laboratory bales)

Bale type	Density factor[1]	Moisture, %	Fresh bale wt, lb	Volume[2], ft³	Estimated density, lb/ft³
			High moisture		
Conventional	---	35.3	142	5.79	24.6
Laboratory	1.00		1.29	.0526	24.5
Laboratory	1.33		1.72		32.8
Laboratory	1.67		2.15		40.9
Laboratory	2.00		2.60		49.4
			Medium moisture		
Conventional	---	25.4	122	5.55	22.1
Laboratory	1.00		1.15	.0526	21.8
Laboratory	1.33		1.54		29.3
Laboratory	1.67		1.97		37.5
Laboratory	2.00		2.35		44.8
			Low moisture		
Conventional	---	18.2	88	5.40	16.3
Laboratory	1.00		.84	.0526	16.0
Laboratory	1.33		1.13		21.6
Laboratory	1.67		1.41		26.8
Laboratory	2.00		1.75		33.2

[1]Theoretical quotient of laboratory bale density divided by conventional bale density.
[2]Based on a predetermined avg laboratory bale volume of .0526 ft³.

Table 3. Temperature Traits for Conventional and Laboratory Alfalfa Bales Made at Three Moisture Levels in Experiment 2

Moisture level[1]	Bale type	Density factor[2]	Temperature, °C Maximum	30-day avg	Degree days > 30°C
High	Conventional	---	57.1	51.0	643
	Laboratory	1.00	54.7	48.1	546
	Laboratory	1.33	55.4	48.7	564
	Laboratory	1.67	55.5	48.8	569
	Laboratory	2.00	55.8	49.2	580
Medium	Conventional		51.0	36.4	263
	Laboratory	1.00	48.5	36.2	258
	Laboratory	1.33	47.8	36.1	253
	Laboratory	1.67	49.7	36.9	278
	Laboratory	2.00	48.6	36.9	273
LOW	Conventional	---	46.2	25.8	101
	Laboratory	1.00	42.6	23.6	61
	Laboratory	1.33	42.6	24.1	63
	Laboratory	1.67	43.6	24.6	75
	Laboratory	2.00	44.6	25.8	93
LSD (P < .05)[3]			1.4	1.6	44

[1]Moisture level designations of high, medium, and low correspond to moisture contents of 35.3, 25.4, and 18.2%, respectively, when averaged across bale type.
[2]Theoretical quotient of laboratory bale density divided by conventional bale density.
[3]LSD values are for comparisons of subplot means within whole plots (moisture levels).

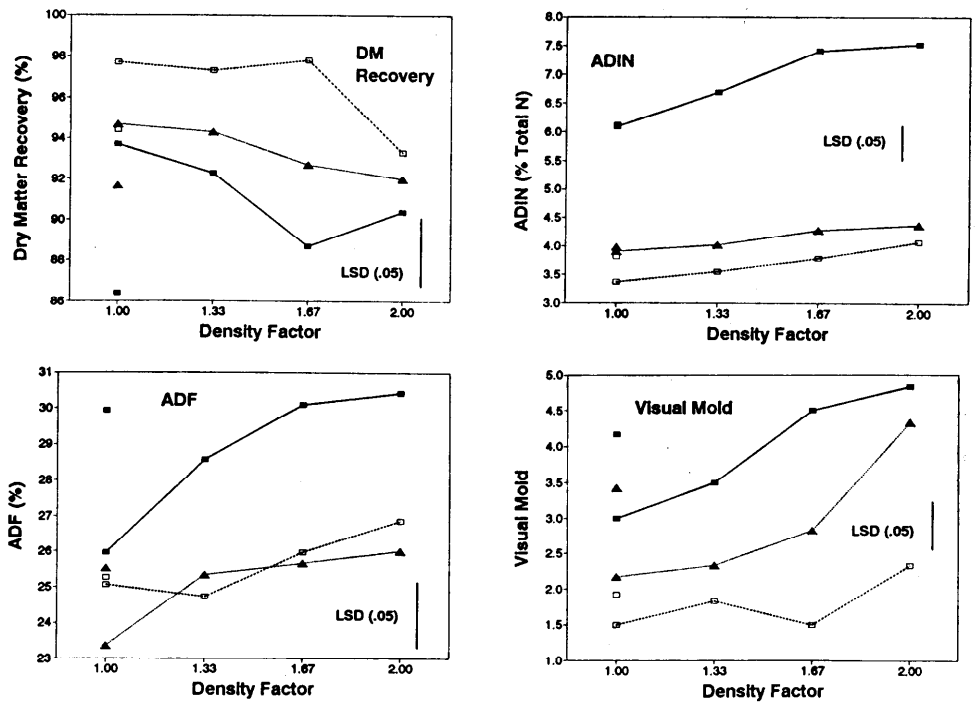

Figure 1. Quality Traits for Conventional and Laboratory Alfalfa Hay Bales in Experiment 2; where □ = Low Moisture, ▲ = Medium Moisture, and ■ = High Moisture; Markers Alone = Conventional Bales, Markers Connected by Lines = Laboratory Bales; and Visual Mold Score 1.0 = Good, 5.0 = Poor