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Billy D. Nelson

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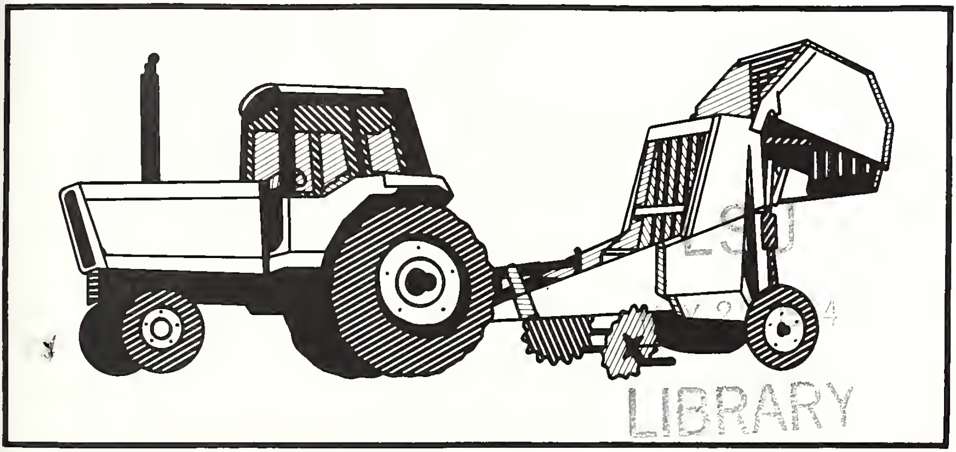
Billy D. Nelson, Lalit R. Verma,
and C. R. Montgomery



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Effects of Storage Method on Losses and Quality Changes in Round Bales of Ryegrass and Alfalfa Hay

BILLY D. NELSON,[1] LALIT R. VERMA[2] AND C. R. MONTGOMERY[1]

According to a recent (1980) USDA report, hay ranked third nationally in dollar value of estimated total agricultural production as follows: corn—$14.9 billion, soybeans—$12.2 billion, and hay—$6.6 billion. The value of hay is often overlooked because most hay is used on farms where it is produced. In 1980, approximately 355,000 acres of hay was harvested in Louisiana.

Every year livestock producers in Louisiana and the humid south need stored feeds during periods when low temperature and/or limited soil moisture restrict plant growth for grazing. Hay, a major stored feed, is an expensive and labor demanding enterprise. Recently, producers have, for the most part, reduced labor requirements by baling hay in large packages rather than conventional square bales. Research has shown that hay stored outside in large bales may undergo substantial physical changes and quality deterioration. Method of storage has been identified as the most important factor affecting these changes. The problem can be most critical in Louisiana because hay quality is often reduced by high humidity and frequent rains prior to baling. To maintain quality, harvested forage should be cured without rainfall and baled at a maximum of 15 percent moisture. Otherwise, hay losses from molding and rotting are intensified in bales stored on the ground, a common practice with large round bales, compared with hay stored in a barn.

Large round hay bales, generally stored outside until fed to cattle, are subjected to weather-induced spoilage. Crop species of hay and size, shape, and density of bales affect storage losses.

This study was conducted to evaluate the effects of six storage methods on quantitative and qualitative changes in ryegrass and alfalfa hays stored as large round bales. Included among qualitative parameters was available protein, that useable by ruminant animals, as affected by heat generated within the bale core during storage.

[1]Associate Professor and Assistant Professor respectively, Southeast Research Station Franklinton, La. 70438

[2]Associate Professor, Department of Agricultural Engineering, LSU, Baton Rouge, La. 70803

Review of Literature

Several studies have been conducted to evaluate storage changes in large round bales of hay. Rider and McMurphy (*9*)[3] reported that round bales of alfalfa, bermudagrass, and forage sorghum should be stored on a well-drained site near the feeding area to minimize quantitative losses due to hay rotting when in contact with the ground. Some of the losses result from hay falling off the bales when moved, with distance of the move being a factor of consideration. Similar losses were found with ryegrass stored on the ground by Louisiana workers (*11*).

Compositional changes and hay losses in large bales stored outside were evaluated by Lectenberg et al. (*5*). Deterioration around the top and sides and at the bottom of bales, where hay was in contact with moist soil, reduced dry weight of alfalfa bales 10 percent and changed hay composition. Nutritive value of hay, measured by *in vitro* digestible dry matter (IVDDM), disappearance decreased, but crude protein percentage increased. Storing bales on crushed rock to prevent soil contact reduced dry matter losses 57 percent compared with hay stored on the ground. Total elimination of weathering losses occurred when hay bales were stored without weathering.

The need for protecting large round bales of alfalfa hay from weathering was demonstrated by Bledsoe et al. (*2*) and Verma (*14*). Hay in bales protected from weather were higher in quality than that left unprotected. Moisture penetrated large round bales of alfalfa 2 to 4 inches in depth when stored outside, and surface hay was 5.5 percent lower in protein and 16 percent less digestible than interior hay of the bale (*14*). Bledsoe et al. (*2*) further showed that hay baled with an initial moisture above 30 percent resulted in poorer quality after storage than that baled below 30 percent.

Storage losses of alfalfa, bermudagrass, and sorghum-sundangrass in large round bales were determined by Rider et al. (*8*). Inside storage or protection by black polyethylene circumferential wrapping of bales minimized both dry matter and digestible dry matter losses for all hays. Circumferential wrapping most effectively maintained total physical mass of bales. Bermudagrass bales, as a result of forming an excellent thatch on the outer surface, were most resistant to weathering of all forages investigated. Shrinkage was reported to be about 15 percent on the average for an 8-month outside storage period of large round alfalfa bales (*13*). A positive relationship was found between bale volume and its overall measurement.

Hay storage studies (*6*) conducted at Auburn University resulted in the following recommendations: 1—if barn space is available, hay should be stored inside, 2—when storing outside, the storage site should be well drained and located as close to the hay field and feeding area as possible,

[3]Italic numbers in parentheses refer to Literature Cited, page 19.

3—if available, store bales on old tires, timber, or other material that will reduce moisture around bottom of bales, and 4—do not store bales under trees.

Procedure

This study was conducted at the Southeast Research Station, Franklinton. Gulf ryegrass and Apollo alfalfa were test crops in 1980, and Gulf ryegrass alone was used in 1981. In 1980, ryegrass was field cured to approximately 20 percent moisture content and alfalfa to approximately 10 percent; in 1981 ryegrass was field cured to approximately 12 percent moisture. The bales were formed by a chain-driven, round-bale machine and stored as follows: (1) on 8-inch gravel bed, (2) directly on the ground, (3) on elevated wooden racks with plastic covering the hay, (4) on elevated wooden racks with hay uncovered, (5) on automobile tires, and (6) inside a barn. The wooden racks consisted of four treated posts driven into the ground in an 18-inch by 36-inch rectangle, with 1-inch by 6-inch treated boards 18 inches long nailed to two posts on each side to form a support for the bales 16 inches above the ground. In 1981 the wooden racks were modified as shown in Figure 1.

Alfalfa bales were placed on one of the following three treatment systems for storage: (1) elevated wooden racks with hay uncovered; (2) elevated wooden racks with plastic covering the hay; and (3) inside a barn.

Ryegrass was cut May 5, 1980, baled May 10, and four bales of each of the six storage treatments were placed in an experimental storage area May 12.

Four alfalfa bales per storage mode were placed in storage June 5, 1980, after forage cut June 2 was baled June 4. Before storing, all bales were weighed and measured and forage samples obtained with a power-driven core sampler (*4*).

Two of the four ryegrass bales from each mode of storage were processed in December 1980 to determine handling, storage, and animal refusal losses; the remaining two bales of each treatment were left in storage through the 1980-81 summer-winter season before obtaining hay loss data.

Alfalfa bales were kept in storage from June 5, 1980 to May 12, 1981, at which time they and the remaining two bales per storage mode of ryegrass were sampled, weighed, and measured to terminate the first year of the study.

All ryegrass and alfalfa bales were core-sampled for laboratory analyses initially and at 30-day intervals during the remainder of the storage period. Quality measurements of ryegrass hay were made from chemical analyses, *in vitro* digestible dry matter (IVDDM), and *in vivo* digestible dry matter (DDM) determinations. Quality measurements of alfalfa were based on chemical analyses and IVDDM.

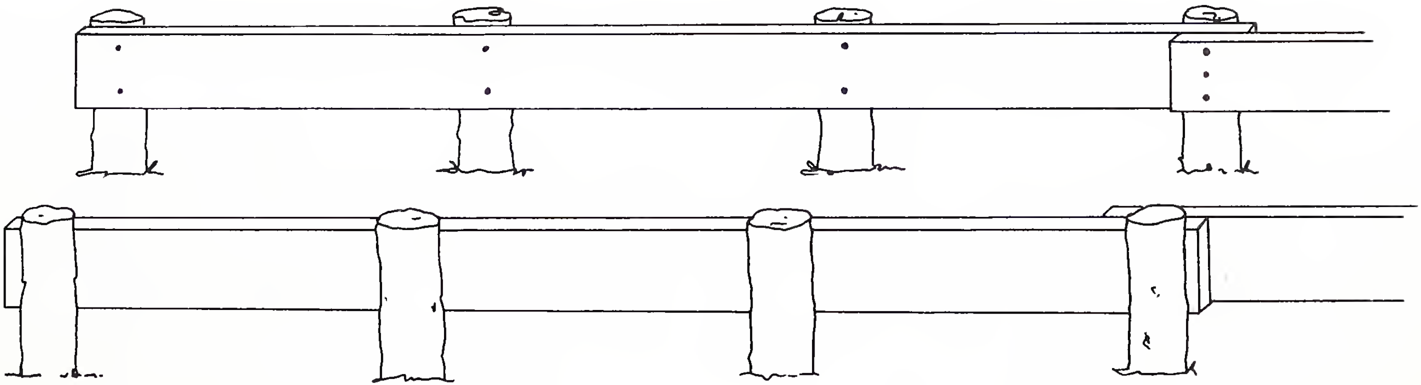

Figure 1. Schematic and specifications of a round hay-bale storage rack, as modified in width, and used during 1981.
Treated post: 3' long, 1½' in ground.
Siderails: 1'' x 6'' treated lumber.
Post spacing: 7' lengthwise, allowing boards to overlap 6'', and 24'' in width.
The posts were driven into the ground for stability.
Nail: 16-penny common.

Rainfall accumulation of 20 inches was recorded in 1980 during the 7-month storage period, after which the first determination of quantitative losses was made. During the last 5 months, December 1980 through April 1981, of the 12-month total storage of the 1980-harvested hays, 23.3 inches of rain fell. Total rainfall for the 12-month period, May 1980 through April 1981, was approximately 25 percent less than that of the same period during 1979-80. Storage losses probably vary among storage periods, depending on rainfall level.

In the second year of the study, ryegrass forage was cut April 23, 1981 and baled and stored April 30. Four storage methods were employed: on the ground, uncovered hay on elevated racks, covered hay on elevated racks, and in the barn. Four ryegrass bales were included in each storage mode. All bales were weighed, measured, and core-sampled April 30, May 12, June 11, August 7, and October 13. Rainfall of 20.02 inches was recorded during the 6-month storage period, averaging 3 to 5 inches per month, except for October when only 1.05 inches fell.

Following 7-month and 12-month storage periods in 1980 and the 6-month storage in 1981, one bale from each storage mode was sliced (*12*), to assess interior damage, chopped in a hammer mill, and fed to sheep in a digestion trial. Another bale from each of the storage systems was fed to adult Holstein cows *ad libitum* to measure animal refusal after 7-month storage in 1980 and after 6-month storage in 1981.

Core samples of all stored hays, collected at various intervals, were analyzed in the laboratory to determine dry matter, structural carbohydrates [neutral-detergent fiber (NDF), acid-detergent fiber (ADF), cellulose, and acid-insoluble lignin (AIL)] as outlined by Goering and Van Soest (*3*). *In vitro* digestible dry matter (IVDDM) was determined by the modified Van Soest procedure (*7*). Hemicellulose was calculated as the difference between NDF and ADF. Crude protein (CP) was determined as outlined by AOAC (*1*), and available protein (AP) was calculated by subtracting the fiber-bound protein from total crude protein. Fiber-bound, or ADF protein, was determined by extracting ADF from forage and determining Kjeldahl nitrogen of the ADF fraction. Duncan's New Multiple-Range Test, as described by Steel and Torrie (*10*), was used to determine differences in treatment means.

Results and Discussion

1980 Harvest of Ryegrass

The decrease in volume of each large round bale is defined as shrinkage. Bales of both ryegrass and alfalfa stored in the barn had minimum shrinkage, as well as shape deformation, when compared to bales in outside storage (Table 1). Ryegrass bales stored on the ground exhibited maximum

Table 1.—Initial bale weight, density, and shrinkage of large round bales after 7 and 12 months in six storage systems, 1980-81

Storoge system	Initial[1] wt, lbs	Initial[1,3] density	Shrinkoge[2], 7 mo, %	Shrinkoge[2], 12 mo, %
		Ryegrass		
Gravel	879	6.85	30.3	36.9
Ground	927	6.84	37.7	51.0
Rack	824	5.74	26.7	29.8
Rack w/cover	950	6.25	17.4	18.3
Tires	856	6.09	29.5	32.1
Barn	892	7.02	5.7	14.2
		Alfalfa		
Rack	1095	7.96	6.69	7.89
Rack w/covers	1125	7.95	5.92	6.22
Barn	1075	10.21	6.16	6.16

[1]Each value is a mean of four bales.
[2]Each value is a mean of two bales.
[3]Pounds per cubic foot.

shrinkage, over 50 percent after 12 months of storage. Alfalfa bales, being more densely packed, showed much less shrinkage than ryegrass bales at comparable periods and methods of storage. Alfalfa bales were heavier and drier initially than the ryegrass bales.

Handling loss is defined as hay left at the storage site following bale removal. Losses for ryegrass bales stored in the barn and on racks with cover after 7 months were not measurable (Table 2). Even after 12 months in storage, ryegrass bales in the barn showed no handling loss. Ryegrass bales stored on tires and on the ground showed highest handling losses of all systems. Those bales were wet at the bottom and the rotted portion of hay was left at the storage site when the bales were removed. Rainwater was trapped in tires of that storage mode and proved to be detrimental to hay preservation. The condition was observed when bales were sectioned.

Dry matter loss was high for all ryegrass bales, except those stored in the barn and on racks with cover (Table 2). Losses in dry matter approached 40 percent for ryegrass hay stored for 12 months on the ground. Storage on tires, on gravel, and on racks without cover resulted in dry matter loss of 30 percent or more.

Animal refusal losses during feeding of large round bales were determined only for ryegrass hay after seven months of storage. Bales stored on the ground were highest in refusal (Table 2). Animal refusal also was high for hay stored on gravel, while bales protected from weather showed the least animal refusal.

Total hay loss, a combination of handling, dry matter, and animal refusal, was 65 percent for ryegrass bales following 7 months of storage outside on the ground (Table 2). Bale storage on gravel and on tires resulted

Table 2.—Percentage losses after 7 and 12 months, from handling, storage, and animal refusal in feeding large round bales of ryegrass hay in six systems, 1980-81

Storage system	Losses[1] Handling		Dry Matter		Animal refusal[2]		Total[2]
	7 mo	12 mo	7 mo	12 mo	7 mo	12 mo	7 mo
	%						
Gravel	1.2	4.0	31.2	31.9	16.8	—	49.2
Ground	15.0	12.4	27.6	39.8	22.0	—	65.2
Rack	5.2	5.0	26.0	31.8	6.3	—	37.5
Rack w/cover	0.0	1.7	12.3	11.1	1.5	—	13.8
Tires	2.0	17.8	35.4	33.0	6.3	—	43.7
Barn	0.0	0.0	2.3	8.8	1.2	—	3.5

[1]Each value is a mean of two bales.
[2]Animal refusal values were not obtained for hay stored 12 months.

in losses exceeding 40 percent, and that hay stored on exposed racks approached 40 percent in total loss. Covered hay bales stored on racks had a total loss of 14 percent. In comparison, bales stored in the barn showed only 4 percent total loss.

1980 Quality Parameters in Ryegrass Hay

The effects of storage conditions on quality parameters of ryegrass hays after 7 and 12 months are shown in Tables 3 and 4. To relate changes in quality parameters during storage, values of each were expressed as a percentage of initial.

The initial dry matter (DM) content of ryegrass hay across all storage systems was 81.7 percent, with values ranging from 79.3 percent for bales stored on racks with cover to 85.4 percent for those stored on tires. Moisture content increased in all bales not protected from rain, with the greatest increase ($P<.05$) being exhibited by that stored on tires (Table 3). Bales stored on covered racks and in the barn decreased ($P<.05$) in moisture content.

Structural carbohydrates content (NDF, hemicellulose, ADF, and cellulose) of ryegrass hay was not affected after 7 months by storage method when expressed as a percentage of initial value. Only hemicellulose and AIL, of the structural carbohydrates, were affected ($P<.05$) by storage system after 12 months.

Initial crude protein (CP) content of ryegrass hay across all storage systems was 9.7 percent. After 7 months of storage, CP content tended to increase in all storage systems, but the increases were not significant. The additional 5 months of storage did not affect CP content of the hay.

Not all of the CP content of forages is available for animal utilization. Some of it is incorporated into the fiber tissue during growth of the plant. In addition, heat generated inside the haybale during storage causes a portion of the CP fraction to be bound to the fiber fraction, making the bound CP unavailable for animal utilization (*3*). The difference between CP and fiber-bound protein is called available protein (AP).

Initial AP content of ryegrass hay averaged 7.7 percent (Table 3). The AP content of ryegrass among storage modes changed considerably ($P<.05$) during storage, ranging from 93.7 percent of initial in hay stored on uncovered racks to 119.5 percent in hay covered on racks. Following 12 months of storage AP values ranged from 88.0 percent of initial for

Table 3.—Effects of storage conditions over time on chemical composition of ryegrass hay in large round bales, 1980-81

Storage system	Storage period			Relation to initial	
	Initial[1] 5-12-80	7 mo[2]	12 mo[3]	7 mo[2]	12 mo[3]
			Dry Matter, %		
Gravel	80.2	76.5b	74.8bc	94.7b	88.7cd
Ground	84.7	78.7bc	77.5a-c	91.9b	92.3c
Rack	79.6	72.0	71.4c	89.3b	95.1bc
Rack w/cover	79.3	87.5a	86.0a	112.1a	107.4ab
Tires	85.4	71.7c	67.4c	81.2b	76.8d
Barn	80.7	89.6a	88.8a	112.9a	114.8a
			Neutral-detergent fiber, %		
Gravel	66.6	69.9b	69.4c	105.9^{ns}	103.5^{ns}
Ground	68.6	70.9ab	71.6ab	103.9	105.2
Rack	67.9	70.3b	70.6bc	104.1	104.7
Rack w/cover	68.4	71.5ab	70.7bc	105.4	102.6
Tires	68.4	71.0ab	70.5bc	104.4	104.8
Barn	68.5	72.0a	73.0a	106.1	109.2
			Hemicellulose, %		
Gravel	25.7	25.1bc	24.1b	97.4^{ns}	90.6b
Ground	26.0	25.0c	25.2b	95.3	95.1b
Rack	26.8	26.3b	26.2b	97.7	97.2b
Rack w/cover	25.8	26.7a	25.9b	104.6	101.3ab
Tires	25.4	25.8bc	25.4b	101.9	100.1b
Barn	26.5	27.7a	29.0a	106.3	119.4a
			Acid-detergent fiber, %		
Gravel	40.9	44.8bc	45.2^{ns}	111.2^{ns}	111.7^{ns}
Ground	42.6	45.9a	46.4	109.3	111.6
Rack	41.1	44.0c	44.4	108.3	109.8
Rack w/cover	42.6	44.8bc	44.8	105.9	103.4
Tires	43.1	45.2ab	45.1	105.9	107.7
Barn	42.0	44.3bc	44.0	106.8	103.4
			Cellulose, %		
Gravel	35.0	35.2ab	34.1c	100.6^{ns}	97.6^{ns}
Ground	34.8	35.7a	36.4a	103.8	107.5
Rack	34.5	34.2b	34.4bc	99.1	99.9
Rack w/cover	35.9	36.0a	35.8ab	100.6	97.2
Tires	36.7	35.2ab	33.6c	95.3	93.8
Barn	35.0	36.0a	35.9a	103.7	100.0

Continued

Table 3.—Effects of storage conditions over time on chemical composition of ryegrass hay in large round bales, 1980-81 (cont'd)

Storage system	Storage period			Relation to initial	
	Initial[1] 5-12-80	7 mo[2]	12 mo[3]	7 mo[2]	12 mo[3]
	Acid-insoluble lignin, %				
Gravel	5.32	8.20a	8.30ab	163.1a	166.5a
Ground	5.37	8.27a	8.60a	163.7a	172.6a
Rack	5.65	7.73ab	8.22ab	142.9ab	148.8b
Rack w/cover	5.87	7.14b	7.37bc	125.0b	126.0c
Tires	5.04	7.74ab	8.64a	163.0a	180.5a
Barn	5.20	6.53c	6.54c	130.8b	116.6c
	Crude protein, %				
Gravel	9.2	11.6[ns]	12.3[ns]	132.7[ns]	128.8[ns]
Ground	8.9	11.4	11.5	133.7	139.4
Rack	10.9	13.2	13.6	124.7	125.7
Rack w/cover	9.0	11.4	11.2	131.7	130.7
Tires	9.9	12.4	12.8	129.6	124.2
Barn	10.1	11.5	11.8	117.9	109.4
	Available protein, %				
Gravel	6.9	7.4cd	7.5ab	110.2a	99.5c
Ground	6.7	6.5d	6.2b	97.5b	99.8c
Rack	8.5	8.0bc	7.4ab	93.7b	88.0c
Rack w/cover	7.5	8.6ab	8.1ab	119.5a	118.2a
Tires	8.1	7.9bc	8.1ab	97.8b	95.1c
Barn	8.4	9.1a	9.1a	111.6a	104.3b
	In vitro digestible dry matter, %				
Gravel	55.2	53.0b	52.3a	95.3b	92.6b
Ground	55.1	52.3b	52.4b	94.1b	94.7b
Rack	55.0	52.9b	52.5b	95.5b	95.6b
Rack w/cover	54.5	55.6a	56.0a	102.3a	103.7a
Tires	56.4	53.5b	52.9a	93.8b	92.3b
Barn	55.4	55.4a	56.5b	100.1a	102.5a

[1] Mean value of four bales when put in storage.
[2] Mean value of four bales and six sampling dates.
[3] Mean value of two bales and three sampling dates.
[a] Values within component columns with different letters differ significantly ($P < .05$).
[ns] Denotes non-significance at ($P < .05$).

ryegrass hay stored uncovered on racks to 118.2 percent for that covered on racks.

Storage of ryegrass hay in a barn and covered on racks had no effect on IVDDM after 7 and 12 months compared to initial values. All other storage systems decreased in IVDDM, but these decreases were very slight after 7 months. The decreases ranged from 7.7 percent for ryegrass hay stored on tires to 4.4 percent for hay stored on uncovered racks after 12 months of storage. *In vivo* digestibility of the quality parameters (NDF, HC, ADF, cellulose, CP, and DDM) of ryegrass hay stored on gravel, on the ground,

Table 4.—Effects of storage conditions over time on *in vivo* digestibility coefficients of nutrients and dry matter of ryegrass hay in large round bales, 1980-81

Storage period	NDF[1]	HC[2]	ADF[3]	Cell[4]	CP[5]	DDM[6]
			Bales stored on gravel			
7 months	54.3[ns]	62.9[ns]	48.8[ns]	62.3[ns]	32.5[ns]	44.2[ns]
12 months	54.1	62.8	49.9	54.6	30.5	47.4
			Bales stored on ground			
7 months	54.7[ns]	60.5[ns]	51.5[ns]	62.0[ns]	35.0[ns]	47.3[ns]
12 months	53.8	64.3	48.2	62.7	34.2	44.8
			Bales stored on racks without cover			
7 months	56.2[ns]	65.6[ns]	49.9[ns]	67.3[ns]	41.2[ns]	46.3[ns]
12 months	56.0	59.5	50.3	62.7	40.2	48.9
			Bales stored on racks with cover			
7 months	61.1a	71.3a	56.1[ns]	75.5a	49.6[ns]	51.4[ns]
12 months	57.3b	64.9b	53.3	62.8b	47.2	51.9
			Bales stored on tires			
7 months	57.0[ns]	66.8a	51.0[ns]	70.6a	40.5[ns]	46.6[ns]
12 months	55.4	60.5b	52.4	63.1b	40.8	48.7
			Bales stored in barn			
7 months	56.4b	62.1b	52.3[ns]	65.4[ns]	48.2[ns]	51.4[ns]
12 months	60.2a	68.1a	52.7	65.4	48.4	53.9

[1] Neutral-detergent fiber.
[2] Hemicellulose.
[3] Acid-detergent fiber.
[4] Cellulose.
[5] Crude protein.
[6] *In vivo* digestible dry matter.
[ns] Denotes non-significance at ($P < .05$).
[a] Values within columns and storage periods across systems with different letters differed significantly ($P < .05$).

and on racks without cover changed ($P < .05$) between 5 and 12 months of storage. The same was true for ADF, CP, and DDM in ryegrass hay stored covered on racks, on tires, and in the barn. *In vivo* digestibility decreased over time for HC and cellulose in ryegrass hay stored covered on racks and on tires. NDF and HC *in vivo* digestibility increased over time in ryegrass hay stored in the barn. After 12 months of storage overall DDM was highest in ryegrass hay stored in the barn, followed by that stored covered on racks, 53.9 percent and 51.9 percent, respectively.

1980 Quality Parameters in Alfalfa Hay

Initial DM content of alfalfa hay was 90.4 percent across all storage systems (Table 5). Hay stored on uncovered racks significantly increased in moisture during storage. Moisture content tended to decline during storage in alfalfa hay bales protected from the rain.

Content of structural carbohydrates (NDF, hemicellulose, ADF, and AIL) in alfalfa hay changed in storage, but the effects of storage methods were insignificant ($P<.05$), when measured as a percentage of initial values. Cellulose content was not affected by either storage method or time.

Initial average CP content of alfalfa hay was 16 percent, which tended to increase during storage. The increase was greater in hay uncovered on racks than in that covered on racks. Available protein in alfalfa hay did not differ significantly among systems after 12 months storage.

Percentage changes in IVDDM of alfalfa hay among the storage methods at 7 and 12 months were significant. Alfalfa hay stored in a barn was 5

Table 5.—Effects of storage conditions over time on chemical composition of alfalfa hay in large round bales, 1980-81

Storage system	Storage period			Relation to initial	
	Initial[1] 6-5-80	6 mo[2]	12 mo[3]	6 mo[2]	12 mo[3]
			Dry matter, %		
Rack	90.3	88.7b	85.9b	97.9b	94.8b
Rack w/cover	90.1	92.6a	91.6a	103.3a	102.0a
Barn	90.8	92.0a	91.2a	101.5a	100.7a
			Neutral-detergent fiber, %		
Rack	48.7	51.7a	53.4a	107.3^{ns}	109.0^{ns}
Rack w/cover	47.7	48.8b	49.9b	102.7	104.3
Barn	48.6	50.2ab	50.5b	104.2	104.2
			Hemicellulose, %		
Rack	9.2	11.9a	12.7a	133.6^{ns}	139.0^{ns}
Rack w/cover	9.4	10.7b	11.5b	126.8	128.7
Barn	9.2	11.3ab	11.5b	127.5	123.8
			Acid-detergent fiber, %		
Rack	39.6	39.9^{ns}	40.7a	100.9	101.7^{ns}
Rack w/cover	38.3	38.0	38.3b	99.3	99.6
Barn	39.4	39.0	39.0b	98.9	98.7
			Cellulose, %		
Rack	30.1	30.6^{ns}	31.0^{ns}	102.3^{ns}	102.7^{ns}
Rack w/cover	29.4	29.9	30.0	102.2	102.1
Barn	29.8	30.3	30.8	102.0	102.3
			Acid-insoluble lignin, %		
Rack	8.35	8.42a	8.75a	101.1^{ns}	104.2^{ns}
Rack w/cover	7.84	7.62b	7.87b	97.1	99.9
Barn	8.35	7.97b	7.89b	96.0	94.7
			Crude protein, %		
Rack	16.3	17.5a	17.6a	108.3^{ns}	109.0a
Rack w/cover	16.6	16.9b	16.7b	102.2	101.4b
Barn	15.2	15.9c	16.1c	105.6	106.5ab

Continued

Table 5.—Effects of storage conditions over time on chemical composition of alfalfa hay in large round bales, 1980-81 (cont'd)

Storage system	Storage period			Relation to initial	
	Initial[1] 6-5-80	6 mo[2]	12 mo[3]	6 mo[2]	12 mo[3]
	Available protein, %				
Rack	12.6	12.7ab	12.4[ns]	101.6[ns]	100.5[ns]
Rack w/cover	13.0	13.3a	12.9	102.6	100.2
Barn	11.6	12.1	12.3	106.1	106.9
	In vitro digestible dry matter, %				
Rack	58.5	59.1[ns]	58.5[ns]	101.3b	100.9b
Rack w/cover	58.4	59.5	59.6	102.3ab	102.5ab
Barn	57.1	59.5	59.7	105.0a	104.9a

[1] Mean value of four bales when put in storage.
[2] Mean value of four bales and six sampling dates.
[3] Mean value of four bales and three sampling dates.
[a] Values within component columns with different letters differ significantly ($P<.05$).
[ns] Denotes non-significance at ($P<.05$).

percent higher in IVDDM ($P<.05$) than that stored uncovered on racks. Irrespective of storage method, all alfalfa hays were as high or higher in IVDDM than initially.

1981 Harvests of Ryegrass

Losses in ryegrass hay stored during the 1981 season are reported in Table 6. Shrinkage was higher in bales stored on the ground (30.8 percent) and on racks without cover (27 percent) than for other storage systems. Shrinkage results were comparable to those obtained in the 1980 study. Shrinkage of bales stored in the barn, however, was greater than in the previous year. Excessive condensate (water) accumulation on the floor increased dry matter loss of hay stored in the barn during 1981 over that of 1980, when the problem was not evident.

Total hay losses were similar to those obtained in 1980-81, with bales not protected from weathering sustaining the greatest losses. Total loss of ryegrass hay covered on racks in 1981 was 15.1 percent compared to 13.8 percent in 1980. The loss figures for barn storage were 5.1 percent and 3.5 percent in 1981 and 1980, respectively.

Laboratory values, changes in quality components, and digestion coefficients for ryegrass hay after 6 months of storage under four different systems during 1981 are shown in Table 7.

Dry matter increased during storage in all hays protected from weathering, while bales stored on the ground and uncovered on racks decreased in dry matter content. Digestible dry matter values of hay stored in the barn and covered on racks were higher ($P<.01$) than those of hay stored on the ground.

Table 6.—Initial bale weight, density, and total percentage shrinkage and losses of ryegrass in large bale package after six months in four storage systems, 1981

Storage method	Initial[1] wt, lbs	Density[1] lbs/ft (3)	Shrinkage[1] 6 mo, %	Losses, %			
				Handling[1]	Dry matter[1]	Refusal[2]	Total
Ground	769	6.64	30.8	8.8	22.8	19.8	51.4
Rack	829	6.04	27.0	5.9	25.9	12.5	44.3
Rack w/cover	865	6.27	14.0	1.1	12.6	1.4	15.1
Barn	895	7.25	17.0	0.0	4.3	0.8	5.1

[1]Each value is a mean of four bales.
[2]Each value from one bale of hay.
[3]Pounds per cubic foot.

Table 7.—Effects of storage conditions over a 6-month period on chemical composition and digestion coefficients of ryegrass hay in large round bales, 1981

Storage system	Composition: Initial[1] 4-30-81	Composition: Final[1] 10-30-81	Composition: Relation to initial	Digestion coefficient
	Dry matter, %			
Ground	89.5	86.5	96.6	47.9b
Rock	88.1	85.7	97.3	49.6ab
Rock w/cover	87.8	91.7	104.4	51.6a
Barn	89.1	90.5	101.1	51.7a
	Neutral-detergent fiber, %			
Ground	63.3	73.0	115.3	60.5^{ns}
Rock	63.8	68.5	107.4	59.9
Rock w/cover	63.4	70.2	110.7	58.2
Barn	63.4	70.2	110.7	62.0
	Hemicellulose, %			
Ground	24.2	26.0	107.4	67.3^{ns}
Rock	23.2	22.1	95.3	66.8
Rock w/cover	21.4	26.3	122.9	68.6
Barn	22.5	26.9	119.6	71.7
	Acid-detergent fiber, %			
Ground	39.1	47.0	120.2	57.2a
Rock	41.1	46.4	112.9	56.2ab
Rock w/cover	42.0	43.9	104.5	52.3b
Barn	40.9	43.2	105.6	55.0ab
	Cellulose, %			
Ground	33.4	37.0	110.8	69.5^{ns}
Rock	34.3	35.1	102.3	66.7
Rock w/cover	35.6	36.1	101.4	65.2
Barn	34.9	36.5	104.6	66.1
	Acid-insoluble lignin, %			
Ground	4.57	8.22	179.9	—
Rock	5.57	9.42	169.1	—
Rock w/cover	5.56	6.51	117.1	—
Barn	5.21	6.16	118.2	—
	Crude protein, %			
Ground	11.0	11.4	103.6	39.6c
Rock	10.9	12.0	110.1	47.0b
Rock w/cover	11.0	10.6	96.4	50.7a
Barn	10.1	10.5	104.0	50.0a
	Available protein, %			
Ground	8.2	5.7	69.5	—
Rock	8.0	6.6	82.5	—
Rock w/cover	8.0	7.0	87.5	—
Barn	7.5	7.6	101.3	—

Continued

Table 7.—Effects of storage conditions over a 6-month period on chemical composition and digestion coefficients of ryegrass hay in large round bales, 1981 (cont'd)

Storage system	Composition: Initial[1] 4-30-81	Composition: Final[1] 10-30-81	Composition: Relation to initial	Digestion coefficient
	In vitro digestible dry matter, %			
Ground	59.4	55.0	92.6	—
Rack	59.0	57.7	97.8	—
Rack w/cover	59.4	58.9	97.6	—
Barn	59.7	59.0	98.8	—

[1] Each value is a mean of four bales of hay.

[a] Values within component sections of digestion coefficient column with different letters differed significantly ($P<.05$).

[ns] Denotes non-significance at ($P<.05$) level.

Neutral-detergent fiber and cellulose increased during storage in all systems. Hemicellulose content increased during storage in all systems but one, uncovered racks. Digestibility of those parameters was not affected by storage mode.

Acid-detergent fiber of ryegrass hay increased during storage in all four systems. However, digestion of ADF was significantly affected only by storage covered on racks compared to storage on the ground. Acid-insoluble lignin of hay also increased during storage. Hay stored on the ground increased 79.9 percent, that on racks uncovered by 69.1 percent, that covered on racks by 17.1 percent, and that in the barn by 18.2 percent. Lignin, an anti-quality component of forage, is considered to be indigestible.

Slight increases in crude protein (CP) content of hay occurred during storage of bales in all modes except covered on racks. Digestibility of CP was reduced significantly, however, where bales were stored without protection from weathering.

Available protein decreased in all hays stored outside. The decrease in AP was greatest in hay stored on the ground, followed by that uncovered on rack. The reductions in AP value were 30.5 percent, 17.5 percent, and 12.5 percent in hay stored on the ground, on exposed racks, and covered on racks, respectively.

Hay stored in all systems was found to have lower *in vitro* digestion values in comparison to initial digestion percentages. The most appreciable decrease in IVDDM occurred in hay that had been stored on the ground.

Summary

Effects of storage method on quantitative and qualitative losses of large, round bales of ryegrass and alfalfa hays were studied in 1980 and 1981. In

1980, ryegrass bales were stored as follows: (1) on an exposed 8-inch gravel bed, (2) directly on the ground, (3) on elevated wooden racks with plastic covering the hay, (4) on elevated wooden racks with hay uncovered, (5) on automobile tires, and, (6) inside a barn. Additionally, in 1980 alfalfa hay was stored in modes 3, 4, and 6. In 1981, ryegrass bales were stored in four of the same modes, omitting storage of bales on gravel and on automobile tires. Losses were determined after 7 and 12 months of storage for ryegrass hay and after 6 and 12 months for alfalfa hay in 1980. For the 1981 crop of ryegrass hay, the losses were measured following 6 months of storage.

Bales of both ryegrass and alfalfa stored in the barn and covered with plastic on elevated wooden racks had minimum shrinkage as well as shape deformation when compared with other storage methods. Ryegrass bales stored on the ground had over 50 percent shrinkage after 12 months of storage. Alfalfa bales showed much lower shrinkage than ryegrass for comparable periods and storage methods.

Ryegrass stored on tires and on the ground showed higher handling losses than that of other storage modes after 12 months. There was no handling loss of hay stored in a barn. Dry matter loss of ryegrass bales stored on the ground approached 40 percent after 12 months of storage, and all other bales not protected from weathering had dry matter losses exceeding 30 percent. Those bales protected from weathering had least animal refusal losses, and bales stored on the ground had highest animal refusal losses.

Total hay loss, a combination of handling, dry matter, and animal refusal, was greater than 50 percent in each year of the 2-year study for ryegrass bales stored outside on the ground. The least total loss occurred in bales protected from weathering.

Moisture content of both alfalfa and ryegrass hay bales increased significantly when not protected from weathering, but bales covered with plastic and those in a barn decreased in moisture content over the storage period.

Structural carbohydrates (NDF, HC, ADF, cellulose) of ryegrass and alfalfa hays were not significantly affected by storage method when measured as a percentage of initial value. However, there were increases in NDF and ADF after 7 and 12 months, irrespective of storage system.

Crude protein (CP) content increased in all bales of all storage systems after 7 and 12 months of storage, but no difference was found among storage modes in CP content as a percent of initial value. Available protein (AP) decreased in weathered bales of ryegrass hay; those bales protected from weathering increased in AP after 7 and 12 months of storage. No difference was shown among storage modes in AP content of alfalfa bales.

In vitro digestible dry matter (IVDDM) of ryegrass hay in exposed storage modes declined, while that of protected hay tended to increase.

There was a significant effect of storage mode on IVDDM of ryegrass hay. The effect was less pronounced in alfalfa hay.

Data from this study show that quality of ryegrass hay in large round bales cannot be preserved if the hay is stored outside without protection from weathering. Outside storage losses can be minimized by storing the bales off the ground on racks and covered with plastic.

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Louisiana Agricultural Experiment Station, Doyle Chambers, Director
Louisiana State University Agricultural Center, Alvin C. Harper, Chancellor