Aerobic Stability of Wheat and Orchardgrass Round-Bale Silage

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Story in Brief

In Arkansas, silage often is stored in long rows of round bales wrapped in plastic film that is described commonly as balage. It is important to evaluate the aerobic stability of this fermented forage when it is exposed to air, especially during the winter months when the majority of this product is fed to livestock, or sold as a cash crop. Two types of forage, orchardgrass (*Dactylis glomerata* L.) and wheat (*Triticum aestivum* L.), were harvested in May 2002 and stored as balage. Twenty-one bales of each forage type were unwrapped and exposed to air on December 10, 2002 for 0, 2, 4, 8, 16, 24, or 32 d to evaluate the aerobic stability of these silages. For both orchardgrass and wheat balage, final bale wt, dry matter (DM) content, and pH were not affected ($P > 0.05$) by exposure time. Across both balage types, DM recoveries were ≥ 97% for all bales, indicating that both types of balage were very stable when exposed to air. Concentrations of neutral detergent fiber (NDF) and 48-h ruminal in situ digestibility were not affected ($P > 0.05$) by exposure time for either balage type. Concentrations of N were greater ($P = 0.045$) for orchardgrass balage exposed to air for 16 d or longer compared to balage sampled at exposure (d 0), but this response was not observed ($P > 0.05$) for wheat balage. These results suggest that the balage evaluated in this trial was very stable after exposure to air for up to 32 d. This should allow considerable flexibility with respect to feeding, transport, and marketing of balage during winter months without significant aerobic deterioration.

Introduction

Recently, an alternative methodology has been developed that allows small-sized producers to make silage by baling long-stem forages in large round packages and then wrapping them in plastic. This form of storage, often called balage, has become very common in northwest Arkansas. Balage is often stored in long rows of bales that are wrapped with an in-line bale wrapper. This is very convenient and efficient at harvest, but leads to possible problems at feeding, especially when the balage is marketed as a cash crop. Once a long row of balage is opened, oxygen has access to the exposed silage and aerobic deterioration can occur if the balage is not fed or sold quickly. Common indicators of aerobic deterioration in silages include mold development, spontaneous heating, dry matter (DM) loss, elevated pH, and reduced forage quality. Forage producers interested in marketing balage as a cash crop often inquire whether balage will remain stable during loading, transport, and subsequent feeding operations at the buyers' facility. Currently, the aerobic stability of exposed balage, particularly during winter months when most of this product is fed or sold, remains unclear. Our objectives were to evaluate the aerobic stability of orchardgrass and wheat balage exposed to air during December and January.

Experimental Procedures

Forages, Ensiling, and Storage. On May 6 and 7, 2002, "Benchmark" orchardgrass and an unstated variety of soft-red winter wheat were harvested with a mower conditioner (Model 1411; Ford New Holland, Inc., New Holland, Pa.) and allowed to wilt to an appropriate DM concentration for ensiling as balage. The orchardgrass was harvested at the heading stage of growth, while the wheat was harvested when the grain head reached the milk stage of development. When the forages had been wilted to the desired DM concentrations, they were raked into windrows with a New Holland Model 258 side-delivery rake. Immediately after raking, forages were packaged into 4 x 4-ft round bales (Model XL604; Vermeer Manufacturing Co., Pella, Iowa). Bales were hauled out of the field and wrapped with six layers of plastic film (Sunfilm; AEP Industries, Inc., Mt. Top, Pa.) on an in-line bale wrapper (Reeves Manufacturing Ltd., Miscouche, PE, Canada). The bales were stored on a concrete pad in rows that were at least 23 bales long. Each row contained only one forage type. Bales remained there, undisturbed, until December 10, 2002.

Exposure to Air. On December 10, 2002, the plastic wrap covering each row of wheat and orchardgrass balage was cut and removed. The bales at the end of each row were discarded. The 21 internal bales in each row were sampled (Star Quality Samplers, Edmonton, AB, Canada) on one side with an 18-in bale probe to determine the DM content of the bales at the time of exposure. Bales were blocked, based on position in the row, and designated for a second sampling after either 0, 2, 4, 8, 16, 24, or 32 d of exposure. Since these bales were to be evaluated over a 32-d period, holes created by the initial 18-in core sample were filled with spray foam insulation to prevent air from accessing the core of the bale.

Initial Bale Evaluation. At exposure (d 0), bales were removed from the concrete pad, weighed, and placed on individual wooden pallets in an open-air pole barn. This method of stacking provided air space between the bales, and ensured equal air exposure for all bales. Bales were not moved with a hay spike; instead, a hydraulic grasping attachment was used that did not create holes or tunnels that reached into the core of the silage bale. Bale width and diameter were measured, and the volume and DM density of each bale were calculated. Bales that were designated for exposure to air for 32 d were fitted with thermocouple wires that were inserted into the core of each bale in order to monitor changes in internal bale temperature over time. Bale temperatures were taken once daily with an Omega 450 AKT Type K thermocouple thermometer (Omega Engineering, Stamford, Conn.).

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Final Bale Evaluation. Each bale of both forage types was evaluated a second time after 0, 2, 4, 8, 16, 24, or 32 d of exposure to air in order to evaluate aerobic stability over time. On each sampling date, three bales of each forage type were removed from the barn and weighed. The bales were core sampled on the opposite side of the bale from the initial 18-in core sample taken on d 0. A portion of each forage sample was dried under forced air at 122°F to determine the final DM content of each bale; the other portion was used to determine silage pH with a portable pH meter (Model AP5, Denver Instruments, Arvada, Colo., USA) . In addition, the three orchardgrass and wheat bales sampled on each of the seven sampling dates were appraised visually for mold and aerobic deterioration on a scale of 1.0 to 5.0, where 1.0 = ideal and 5.0 = white mold and/or other evidence of aerobic deterioration covering the entire outside surface of the bale. Increments of 0.25 were used during the evaluation process.

Forage Nutritive Value. Dry forage samples were ground through a Wiley mill (Arthur H. Thomas, Philadelphia, Pa.) fitted with a 1-mm screen and subsequently analyzed for N, NDF, and 48-hour ruminal in situ DM disappearance. Analysis of NDF was conducted using batch procedures outlined by ANKOM Technology Corp. (Fairport, N.Y.) for an ANKOM200 Fiber Analyzer. Total N for each silage sample was determined by combustion (Elementar Americas, Inc. Mt. Laurel, N.J., USA). Silage samples also were incubated in the rumen of two fistulated steers for 48 h to provide an estimate of digestibility for each forage (Turner et al., 2003). The University of Arkansas Institutional Animal Care and Use Committee approved surgical procedures for cannulations, and the subsequent care of the fistulated steers.

Statistics. Data were analyzed as a randomized complete block design with three replications. Each balage type was evaluated independently. Single-degree-of-freedom contrasts were used to evaluate the effects of exposure time on each response variable. Contrasts included linear, quadratic, and cubic effects of exposure time; in addition, all exposed bales (2, 4, 8, 16, 24, or 32 d) were compared with bales sampled at exposure (d 0), and bales exposed for 16 d or more (16, 24, or 32 d) also were compared with bales sampled at exposure (d 0).

Results and Discussion

Initial bale characteristics. Within balage type, no contrast was significant ($P > 0.05$) with respect to bale characteristics at the time of exposure to air (Tables 1 and 2). This was expected at the time of exposure because silage generally remains stable during storage unless the anaerobic environment is compromised. Generally, orchardgrass and wheat bales had virtually identical measurements of diameter, width, and volume. This also was expected since the bale size was pre-set electronically, and each bale was processed, wrapped in plastic, and stored in an identical manner. Although balage types were not compared statistically, the orchardgrass bales were substantially heavier (mean bale wt = 1,512 vs. 1,167 lb) when the silage plastic was removed. Part of the advantage in weight observed for the orchardgrass balage was associated with DM content; the mean DM content for orchardgrass at exposure was 8.0 percentage units lower than for wheat (62.4 vs. 54.4%; Tables 1 and 2). However, differences in bale weight between orchardgrass and wheat bales were not explained entirely on the basis of differences in concentrations of DM. The DM density of orchardgrass bales ranged from 12.6 to 14.7 lb/ft^3 compared to only 10.3 to 11.7 lb/ft^3 for wheat; however, the DM density of the wheat bales was still within the acceptable range (9.4 to 11.2 lb/ft^3) for round-bale silage reported by Savoie and Jofriet (2003). High bale or silage density is known to be effective at reducing the permeability of the silage mass to oxygen, thereby reducing subsequent microbial respiration, elevated internal bale temperatures, and DM loss (Pitt, 1990).

Internal bale temperatures. Generally, elevation of bale temperatures would be expected in bales undergoing aerobic deterioration (Pitt, 1990), but there was relatively little temperature response over the 32-d exposure period. One of the wheat bales monitored for 32 d exhibited some increase in internal bale temperature (Fig. 1), but this response was not observed until the bale had been exposed to air for at least 3 weeks. The elevated temperature in this specific wheat bale was an exception to the normal lack of response for other wheat and orchardgrass bales. An example of an individual wheat bale that exhibited little or no temperature response also is shown for comparison purposes in Figure 1. Internal bale temperatures fluctuated somewhat with changes in ambient air temperature; however, this would be expected, especially during a December and January exposure period when the ambient air temperatures can be very low. Monthly normals for maximum, mean, and minimum ambient temperatures at Fayetteville in December are 44.7, 37.9, and 28.1°F; similarly, these respective normal temperatures are 44.3, 34.3, and 24.2°F for January (NOAA, 2002).

It is not surprising that the bale exhibiting elevated internal temperatures was comprised of wheat forage. Orchardgrass bales were packaged at a substantially higher DM density that should theoretically reduce permeability of the air, and limit potential for heating via respiration. Many cereal grains, including wheat, have hollow stems, which results in a bulkier forage that is difficult to pack (Coblentz et al., 2001). This is reflected in the lower DM density of wheat balage (Tables 1 and 2) and the increased likelihood of elevated internal bale temperatures relative to orchardgrass balage.

Final bale characteristics. For both orchardgrass (Table 3) and wheat (Table 4), there were no changes ($P > 0.05$) in bale weight, concentration of DM, or pH over the 32-d exposure period. All recoveries of DM were ≥ 97% (Tables 3 and 4), which is near complete recovery and suggests that both balage types were very stable after exposure to air. The linear ($P = 0.011$) and quadratic ($P = 0.036$) decreases in DM recovery over the 32-d exposure period observed for orchardgrass represented a very small range (97.3 to 100%; Table 3), and were probably not biologically meaningful. Similarly, the cubic ($P = 0.034$; Table 4) response observed over time for wheat balage comprised a similar small range (97.0 to 100%), and also was probably of limited importance. Visual mold scores were very low (≤ 2.17) for all bales of both types, indicating the balage was well preserved at exposure and showed little sign of deterioration thereafter. No contrast was significant for wheat ($P > 0.05$; Table 4), but a cubic ($P = 0.009$; Table 3) response over exposure time was observed for orchardgrass. However, visual mold scores for the orchardgrass balage were extremely low, and the overall range was very narrow (1.08 to 1.42).

Final bale quality. Exposure time had no effect ($P > 0.05$) on concentrations of N, NDF, or digestible DM for wheat balage (Table 5), and no effect on ($P > 0.05$) on concentrations of NDF or digestible DM for orchardgrass. Bales of orchardgrass exposed to air for 16 d or more had greater ($P = 0.045$) concentrations of N than those sampled immediately after exposure. However, the total range of response (1.96 to 2.30%) was relatively narrow. Generally, the very limited responses over the exposure period further indicated that these bales were very stable after exposure to air during December and January.

Implications

Overall, this experiment showed that well-preserved wheat and orchardgrass balages were very stable for more than a month after exposure to air, and this could provide considerable flexibility for feeding, transport, and marketing during winter months without significant aerobic deterioration. It is important to emphasize that the exposure period occurred during the winter months when temperatures were low. It should not be inferred that aerobic stability would be the same during other months when temperatures are substantially warmer.

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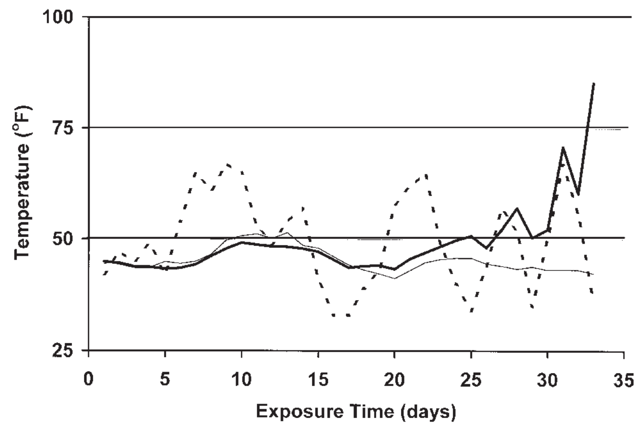

Fig. 1. Relationship between internal bale temperature and exposure time for unstable (bold, solid line) and stable (light, solid line) wheat balage. The maximum daily ambient air temperature (hashed line) also is shown for reference. Orchardgrass balage exhibited very little temperature response over exposure time and was omitted for clarity.

Table 1. Physical characteristics of bales of orchardgrass balage on the date of exposure (December 10, 2002) and allocated to various future sampling dates.

Exposure time	DM[1]	Diameter	Width	Volume	Wt (wet)	DM density
days	%	ft		ft³	lb	lb DM/ft³
0	51.00	4.31	4.08	59.7	1487	12.60
2	53.10	4.32	4.05	59.6	1573	14.00
4	58.20	4.29	4.10	59.2	1493	14.70
8	54.80	4.34	4.03	59.7	1473	13.50
16	51.20	4.34	4.06	60.2	1540	13.10
24	56.40	4.36	4.10	61.2	1540	14.10
32	56.40	4.38	4.14	62.4	1480	13.40
SEM[2]	4.81	0.064	0.049	1.78	38.6	0.90
Contrasts	P > F					
linear[3]	NS[4]	NS	NS	NS	NS	NS
quadratic[3]	NS	NS	NS	NS	NS	NS
cubic[3]	NS	NS	NS	NS	NS	NS
all exposed vs. 0-d[5]	NS	NS	NS	NS	NS	NS
exposed 16 d or more vs. 0-d[6]	NS	NS	NS	NS	NS	NS

[1] DM, dry matter.

[2] SEM, standard error of the mean.

[3] Linear, quadratic, or cubic effects of designated exposure time.

[4] NS, nonsignificant (P > 0.05).

[5] Contrast of bales to be exposed for 2, 4, 8, 16, 24, and 32 d vs. bales designated for immediate sampling (0-d).

[6] Contrast of bales to be exposed for 16, 24, or 32 d vs. bales designated for immediate sampling (0-d).

Table 2. Physical characteristics of bales of wheat balage on the date of exposure (December 10, 2002) and allocated to various future sampling dates.

Exposure time	DM[1]	Diameter	Width	Volume	Wt (wet)	DM density
days	%	ft		ft^3	lb	lb DM/ft^3
0	65.8	4.49	4.08	64.8	1013	10.3
2	60.0	4.57	4.04	66.4	1207	10.7
4	63.5	4.54	4.10	66.6	1187	11.3
8	60.9	4.56	4.06	66.1	1247	11.1
16	62.0	4.48	4.07	64.2	1133	10.9
24	62.8	4.49	4.03	63.8	1193	11.7
32	62.1	4.49	4.08	64.8	1187	11.4
SEM[2]	3.89	0.044	0.050	1.62	137.2	0.74
Contrasts	P > F					
linear[3]	NS[4]	NS	NS	NS	NS	NS
quadratic[3]	NS	NS	NS	NS	NS	NS
cubic[3]	NS	NS	NS	NS	NS	NS
all exposed vs. 0-d[5]	NS	NS	NS	NS	NS	NS
exposed 10 d or more vs. 0-d[6]	NS	NS	NS	NS	NS	NS

[1] DM, dry matter.

[2] SEM, standard error of the mean.

[3] Linear, quadratic, or cubic effects of designated exposure time.

[4] NS, nonsignificant (P > 0.05).

[5] Contrast of bales to be exposed for 2, 4, 8, 16, 24, and 32 d vs. bales designated for immediate sampling (0-d).

[6] Contrast of bales to be exposed for 16, 24, or 32 d vs. bales designated for immediate sampling (0-d).

Table 3. Characteristics of orchardgrass balage after exposure to air for 0, 2, 4, 8, 16, 24, or 32 days.

Exposure time	Bale wt (wet)	Visual score[1]	DM[2]	DM recovery	pH
days	lb		%	%	
0	1487	1.25	52.2	100.0	5.31
2	1567	1.17	54.1	99.7	5.12
4	1493	1.25	59.5	100.0	5.04
8	1460	1.08	56.4	100.0	5.26
16	1527	1.25	52.2	99.7	5.78
24	1513	1.42	58.8	100.0	5.04
32	1427	1.08	56.9	97.3	4.84
SEM[3]	39.5	0.075	4.82	0.57	0.305
Contrasts	P > F				
linear[4]	NS[5]	NS	NS	0.011	NS
quadratic[4]	NS	NS	NS	0.036	NS
cubic[4]	NS	0.009	NS	NS	NS
all exposed vs. 0-d[6]	NS	NS	NS	NS	NS
exposed 16 d or more vs. 0-d[7]	NS	NS	NS	NS	NS

[1] Visual score (scale 1 to 5); 1 = no evidence of aerobic deterioration,
5 = white mold and/or other evidence of aerobic deterioration over the entire bale surface.

[2] DM, dry matter.

[3] SEM, standard error of the mean.

[4] Linear, quadratic, or cubic effects of exposure time.

[5] NS, nonsignificant (P > 0.05).

[6] Contrast of bales exposed for 2, 4, 8, 16, 24, and 32 d vs. bales evaluated immediately (0-d).

[7] Contrast of bales exposed for 16, 24, or 32 d vs. bales evaluated immediately (0-d).

Table 4. Characteristics of wheat balage after exposure to air for 0, 2, 4, 8, 16, 24, or 32 days.

Exposure time	Bale wt (wet)	Visual score[1]	DM[2]	DM recovery	pH
days	lb		%	%	
0	1013	1.17	64.8	99.3	5.37
2	1213	1.33	58.2	98.7	5.39
4	1173	1.42	63.8	98.3	5.41
8	1227	1.08	59.2	97.0	5.15
16	1140	1.33	61.3	99.3	5.35
24	1180	1.33	65.8	100.0	5.52
32	1113	2.17	64.8	98.0	5.6
SEM[3]	129.5	0.375	3.53	0.95	0.239
Contrasts	P > F				
linear[4]	NS[5]	NS	NS	NS	NS
quadratic[4]	NS	NS	NS	NS	NS
cubic[4]	NS	NS	NS	0.034	NS
all exposed vs. 0-d[6]	NS	NS	NS	NS	NS
exposed 16 d or more vs. 0-d[7]	NS	NS	NS	NS	NS

[1] Visual score (scale 1 to 5); 1 = no evidence of aerobic deterioration, 5 = white mold and/or other evidence of aerobic deterioration over the entire bale surface.

[2] DM, dry matter.

[3] SEM, standard error of the mean.

[4] Linear, quadratic, or cubic effects of exposure time.

[5] NS, nonsignificant (P > 0.05).

[6] Contrast of bales exposed for 2, 4, 8, 16, 24, and 32 d vs. bales evaluated immediately (0-d).

[7] Contrast of bales exposed for 16, 24, or 32 d vs. bales evaluated immediately (0-d).

Table 5. Characteristics of nutritive value for orchardgrass and wheat balage exposed to air for 0, 2, 4, 8, 16, 24, or 32 days.

	Orchardgrass			Wheat		
Exposure time	N	NDF	Digestibility	N	NDF	Digestibility
days	% of DM[1]					
0	1.96	65.0	78.2	1.28	66.2	73.6
2	2.16	65.3	78.7	1.25	63.6	76.2
4	2.15	67.3	77.8	1.22	64.2	75.5
8	2.18	67.5	78.4	1.27	62.2	76.0
16	2.24	67.4	77.9	1.20	65.3	74.8
24	2.30	65.3	80.5	1.14	61.4	76.2
32	2.15	66.3	79.6	1.22	64.9	75.5
SEM[2]	0.103	1.24	0.83	0.044	2.49	1.7
Contrasts	P > F					
linear[3]	NS[4]	NS	NS	NS	NS	NS
quadratic[3]	NS	NS	NS	NS	NS	NS
cubic[3]	NS	NS	NS	NS	NS	NS
all exposed vs. 0-d[5]	NS	NS	NS	NS	NS	NS
exposed 16 d or more vs. 0-d[6]	0.045	NS	NS	NS	NS	NS

[1] DM, dry matter.

[2] SEM, standard error of the mean.

[3] Linear, quadratic, or cubic effects of exposure time.

[4] NS, nonsignificant (P > 0.05).

[5] Contrast of bales exposed for 2, 4, 8, 16, 24, and 32 d vs. bales evaluated immediately (0-d).

[6] Contrast of bales exposed for 16, 24, or 32 d vs. bales evaluated immediately (0-d).