YIELD, QUALITY AND PRICE BENEFITS OF COVERING ALFALFA HAY WITH PLASTIC

V.L. Marble[1], A. F. Van Maren[2], M. W. Demment[1], and J. Kubler[3]

Abstract: Covering 3-twine, light weight, dry alfalfa hay bales produced for the horse market, from August to January was evaluated in the Imperial Valley of Southern California. Covered bales had less shrink, visible mold, musty odor and greater green color after being stored five months and receiving three rains totaling 1.5 inches. Temperatures increased equally for both covered and uncovered bales, advancing 7.3 F the first 24 hours, and 17.1 F two weeks later following a rain of 0.3 inches. Moisture content decreased from 10.0% after baling to 6.0% 37 days and 7.8% 159 days later. Values were not significantly different for covered vs uncovered for 7 samplings, except uncovered top bales were significantly higher moisture after 5 months, and bottom bales for both covered and uncovered were 2.4 percentage units higher than the protected top bales. A hand-held hay moisture probe gave readings that were 3.6 percentage units higher than an oven-dried sample. Protein content and ash were not affected, but NDF increased by 3.05 percentage units, and digestibility decreased by 3.1 units as measured by ADF to predict TDN, and ADFprotein to estimate bound protein, was reduced significantly by not covering alfalfa for 5 months. Covering resulted in an net advantage after all costs and shrink, of $27.43/ton.

Keywords: Covered Alfalfa; mold, color and odor; moisture; quality; changes in protein acid detergent fiber, neutral detergent fiber.

INTRODUCTION

In California, alfalfa hay can normally be baled and stored without serious risk of reducing its quality because of improper moisture conditions. Our summers are warm and dry, with low humidity, but with cool nights. This combination of climatic conditions favors rapid curing of windrowed alfalfa hay, and the formation of "dew" most nights. The surface dew raises the moisture content enough so that the leaves do not shatter, allowing hay to be baled at 12-17 percent moisture during the night and early morning with a minimum of leaf loss and risk of heating and damage from mold.

Most of the 7,000,000 tons of alfalfa produced in the state, as well as the 800,000 tons imported from Nevada, Utah and Arizona (85-90% of imports) is stored in roadside stacks and removed when sold, or sold and stored by the buyer on the production site. Often hay will remain in these stacks for up to 5-7 months before it is moved to provide hay during the winter. Most of this hay is not covered, and is exposed to the elements. Most producers, who have done an outstanding job of baling to preserve quality, do not consider the potential risk of damage from rain to be great enough to invest the time and money to cover, or to build sheds to store, their hay.

This study was conducted to evaluate, for properly cured and baled, covered and uncovered alfalfa hay:

1) the potential weight loss from mid-summer to winter; and
2) the kind and extent of damage that may occur to baled alfalfa during this storage period

METHODS AND MATERIALS

Six stacks of alfalfa hay for the retail "horse" market (96.9 lbs/3-twine bale), were made with a bale wagon during the middle of the day of Aug. 11, 1988. Each stack consisted of three bale wagon loads (dumps) of 76 bales each, for a total of 228 bales (3.68 tons) per stack, and 1,368 bales (23.4 tons) total. All hay was from a field of CUF 101 near Calexico, CA, in Imperial Valley, harvested Aug. 7, 1988, and owned by John Kubler. It was stacked in a north-south orientation, about 50 yards from the office and certified cattle scale of Kubler Farms. The center dump for each of the six stacks was weighed as the bales were removed from the field Aug. 11, 1988, and again at

[1]University of California, Davis, CA 95616; [2]Retired, Cooperative Extension, El Centro, CA 92243 (deceased); and [3]John Kubler Farms, Calexico, CA 92231

the conclusion of the experiment Jan. 17, 1989. Thus each dump to be evaluated was protected on the north and south by another 76-bale dump.

Three replications of two stacks each were established, with all stacks separated by 30 feet on all sides. The two treatments were assigned at random to either:

1) covered with 4-mil, blue plastic; or
2) uncovered.

The plastic covered about 2.5 feet down the stack sides, and about 7 feet down the ends, and was tied down with plastic baler twine. Wind did not disturb the covers. Before covering on Aug. 11, all stacks were sampled for moisture with a Delmhorst moisture probe, for chemical analyses with a coring device, and for temperature with a 30 inch probe attached to an electronic temperature meter.

Samples for chemical analyses and/or moisture content were taken Aug. 11, 22, 29, Sept 6, 1988, and Jan 17, 1989. Each sample consisted of 20 inch deep horizontal cores from the ends of 20 random bales taken from the center layers of each stack. Cores were taken with a "Utah Hay Sampler" with a 0.5 inch inside diameter shaft, attached to a 1/2 inch reversible drill powered by a portable transformer. The samples of Jan. 17, 1989 were expanded to include a sample taken from the top only, bottom only, and middle only layer of bales of each stack. All samples were placed immediately in a plastic bag and taken the same day to the laboratory at the Imperial Valley Agriculture Center for processing and moisture determination.

Moisture samples were weighed to the nearest gram, and dried at 150 F. in a forced air drying oven. All samples were again weighed at 24 and 48 hours to insure complete drying. The samples taken Aug. 11 and 22, 1988, and Jan. 17, 1989, were sent to the laboratory of M. W. Demment, Dept. of Agronomy and Range Science, The University of California, Davis, for chemical analyses of dry matter (DM), total ash (ASH), neutral detergent fiber (NDF), neutral detergent fiber ash (NDFash), acid detergent fiber (ADF), crude protein (CP), and acid detergent fiber protein (ADFprotein). Normal and/or A.O.A.C. procedures were used for all determinations.

Temperature readings were taken, after 2 minutes to equilibrate, with a 30 inch temperature probe attached to a meter. The probe was inserted about 18 inches into the end of test bales, and readings taken Aug. 11 (PM), 12 (AM and PM), 13, 15, 17, 22, 24, 29, Sept. 6, 9, 19, Oct. 6, 27, 1988, and Jan. 16, 1989.

On Jan. 16 and 17 selected bales from the nine rows high dumps were evaluated for visible mold and color, and musty odor. Bales were selected from the top two rows, the fourth and seventh rows from the top, and the bottom row. Each bale was evaluated at three positions within the bale, 1/3 from each end and the center. These three values were very uniform, and were averaged.

The sale value of the hay was established at the site before loading, by an experienced hay buyer who regularly bids on thousands of tons of hay sold in the area. The cost of labor ($2.50/ton) and materials ($4.50/ton) for covering hay stacks to the bottom bale with a 8-10 mil thick plastic was obtained from the principal contractor in Imperial Valley. He also estimated that a 3-4 mil covering could be done for about $2.00 less for material, or a total of $5.00/ton.

Moderate amounts of rainfall occurred three times during the trial Aug 20 1988--0.3 in.; Aug. 24, 1988--0.5 in.; and Jan. 5, 1989--0.7 in.

RESULTS AND DISCUSSION

Weight and moisture losses, and temperature during storage.

The average weights of covered and uncovered bales at the beginning and end of the test period are given in Table 1. There was no significant difference between the average original or final weights of the 76 bales, either covered or uncovered. However, the uncovered bales lost significantly more weight over the five month storage period, 2.34 lbs/bale for the covered, to 2.64 for the uncovered. The original bales were very dry and uniform in temperature (Table 2) and moisture, which resulted in small but detectable weight losses of 2.42 and 2.73 percent, respectively.

More dry matter was lost in the uncovered than the covered bales, probably due to the combined effect over time of the three moderate rains, but neither the temperature or moisture readings were increased enough to be detected. Both treatments had similar temperature (Table 2) and moisture (Table 3) changes throughout the five months of the experiment. The only significant temperature changes occurred in both treatments between the first and second day with an average increase of 7.2 F. and on Aug. 22, two days after a 0.3 inch rain, when the temperature raised 17.1 F. over 5 days. Temperatures for the rest of the experiment declined slowly, apparently equalizing with ambient air temperatures.

The moisture data indicate a gradual reduction of 0.15 percentage units per day, or about 1 unit per week, from an initial Aug. 11 average of 10.0 percent, to 6.0 on Sept.6. This four percentage unit loss was surprising, since hay at 10 percent moisture is considered to be stable and not likely to decrease very much under California conditions. Apparently in August in Imperial Valley, where temperatures average 10-15 F. higher than in the Central Valley, these less dense bales (9.41 lb/cubic foot), weighing only 97 lbs., but of the same dimension (46" x 23" x 17") as the more dense (13.12 lb/cubic foot) 135 lb. bales, can exchange air and continue to lose moisture. When cooler temperatures and higher humidity occur in the fall and winter, the bales picked up 1.87 percentage units of moisture between Sept. 6 and Jan. 17.

The large difference of 3.6 units in moisture content between the Delmhorst hand probe (13.6%) and the core sample dried in an oven (10.0%) indicates that care must be exercised in interpreting probe values. Table 3 indicates a range of differences from 2.97 to 4.67 percentage units, values that should be within the range of tolerance for a grower who has learned to interpret and correlate them with actual moisture conditions in the field. Mr. Kubler, for example, to prevent mold and off color, prefers to have his Delmhorst meters read 15% or lower, and moves out of the field if they read 20% or above, prefering to wait one more day. This corresponds closely with the accepted safe upper level 16-17 percent real moisture content accepted by many people for large, 3-twine bales.

Moisture readings taken Jan. 17, 1989 are presented for not only the middle of the stack, but for the top and bottom rows as well (Table 4). The values from the top bales reflect a 1.41 percentage unit rise for uncovered bales, over covered, probably from the 0.7 inch rain that fell 12 days earlier on Jan. 5. Values for the middle bales were similar for covered and uncovered treatments, and similar to the top row of covered bales, indicating that the plastic cover was effective in protecting the top layer of bales. Bottom bales were not protected by the short 30" cover, and moisture content rose by 2.1 units compared to the middle bales.

Mold, color, and odor changes.

It must be acknowledged that the collection of moisture and temperature samples only near the center of the stack may have been the reason for the failure to find moisture differences during the 5 month storage, that clearly were evident when the bales were broken and color, mold and odor ratings made on Jan. 17, 1989 (Table 5). The scores for all three ratings indicate that the covered, top two rows of bales were protected throughout the 5-month storage period. Mold was absent, odor was very sweet, and color equal to that at baling in these rows. Covered bales in the fourth to the seventh row from the top had substantially higher scores than when uncovered, but there was some mold, musty odor, and discoloration. Different individuals scored the top two rows and the forth, seventh and bottom rows, possibly accounting for the more severe ratings of the latter three layers.

Changes in chemical components that affect hay quality.

The changes in chemical composition of covered vs uncovered hay from Aug. 11, 1988 to Jan. 17, 1989 are given in Table 6; data for the top, middle and bottom row of bales sampled Jan. 17, 1989 are provided in Table 7. In those instances when there was no significant difference between the covered or uncovered treatments, or no interaction was present between the two treatments and sampling dates or row sampled, only the average value for covered + uncovered has been given.

The major chemical changes in this experiment occurred over the 5 month storage

period, and/or in uncovered bales and the bottom row of bales sampled at the end of the trial. All changes were in:

1. ADF (acid detergent fiber) and ADF-bound protein (ADFprotein), which are related to digestibility; and
2. NDF (neutral detergent fiber), total ash, and NDF-bound ash (NDFash), all related to palatibility. NDF is a measure of the amount of cell walls, some of which are digestible.

Ash and NDFash are measures of the inert portion of the alfalfa, such as silica (dirt), and if elevated, indicated a loss of digestible material or contamination from dust or dirt. No significant changes were found from August to January, but the bottom row did increase, indicating either dirt contamination in sampling or a decrease in digestible components in the lower layers (Table 7). The later seems most likely.

Crude protein did not change in any treatment evaluated, including covered vs uncovered, from Aug. 11 to Jan 17, or in any position sampled in the stacks. The average protein value for all 30 analyses was 15.88%. This lack of change/response to obvious visible changes in the stack confirms that protein, although essential to know for ration balancing, is not as good in predicting the energy content of alfalfa hay as ADF.

ADF values will increase as digestibility decreases in alfalfa hay. ADF has been found to be an equal but simpler test of energy prediction for "total digestible nutrients" (TDN) in alfalfa than the old test we all know as the "California modified crude fiber test" (CMCF) used for the last 33 years to predict TDN. The TDN values have been calculated for easier interpretation of quality changes, using the 100% dry matter basis values now recommended for use in California, and not the 90% values everyone has grown accustomed to using. The equation used is found in University of California Leaflet 21457, March 1989, and is:

$$TDN = 82.38 - (0.7515 \times ADF\%), \quad \text{[at 100\% dry matter]}$$

The average covered + uncovered ADF values increased significantly from 29.60% (60.1% TDN) on Aug. 22, 1988 to 33.79% (57.0% TDN) on Jan. 17. There was no detectable change during the 11 days between the first two sample dates, which was as expected since the hay was very dry when placed in the stacks, 9 days before the first rain. ADFprotein, which measures that part of the protein that is unavailable (usually from heat damage), and NDF, which measures the amount of cell walls, both increased similar to ADF, confirming the loss in protein digestibility from heating. These data confirm the increased amount of mold and decrease in green color observed in the bales inspected (Table 5).

Covered alfalfa was higher in quality than hay in the uncovered stacks, at the Jan. 17 date only (Table 6). This is seen in the increase in average ADF of the Jan. 17 uncovered treatment to 34.93% (56.1% TDN) from 32.65% (57.8% TDN). However, even the covered alfalfa lost some quality during the 5-month storage period, with ADF increasing from 30.78% (59.3% TDN) on Aug. 22, 1988, to 32.65% (57.8% TDN) on Jan. 17, 1989. Covering alfalfa hay, with the minimum 30 inch side and 7 foot end, resulted in less of a loss in digestibility than what occurred in the uncovered stacks after the August and January rains.

There were no significant changes in chemical composition in NDF, crude protein, or ADFprotein for the top, middle, and bottom bales (Table 7). The changes in ADF, total ash, and NDFash tend to confirm that water damage did occur in the bottom layer bales, as would be expected in bottom bales that are not protected from rain with an elevated area for the stacks. Apparently the small amount of water damage to the center and lower parts of the stack, which caused increased mold, odor and less green color from heating damage (Table 5), were not enough, or occurred to late in the season to be detected by chemical analyses for these factors.

Economic analysis.

The superior quality of the covered stacks was clearly and positively shown by the sale price set by the hay buyer who evaluated every bale that was opened. An average price of $125.00 per ton for the covered hay, compared to only $90.00 for the uncovered stacks, was offered. (Table 8).

An analysis of the cost to the producer from this reduction in sale price due to the

visible loss in quality from mold, odor, and green color, as well as moisture losses from shrink are also given in Table 8. The cost of the loss in TDN is not indicated since the dollars lost from appearance of the uncovered stacks was far greater than the calculated nutrient loss. Horse hay buyers must have mold-free alfalfa, and they are willing to pay the needed premium to insure that quality. Dairymen, on the other hand, are also interested in the energy or TDN content. They are willing to pay an additional price of $15-$25 per ton to obtain the nearly "premium grade" originally baled by Mr. Kubler, over the price for mold free, bright green "fair grade" alfalfa hay. The uncovered, low quality "fair grade" alfalfa, would only be purchased for the dry cow or sun cured pellet (grinding) market at a substantial discount of $30-40 per ton.

These data indicate that the cost of covering alfalfa hay with plastic was about $10.00/ton. The total labor and material cost, obtained from the largest custom "stack-coverer" in Imperial Valley, was $7.00/ton. Labor was $2.50/ton and materials an additional $4.50/ton. To these costs must be added an additional $3.00/ton moisture shrink, which only averaged 2.42% of the original weight for these very dry, light weight, less dense, covered bales. It is obvious that the $10.00 per ton costs were recovered by a factor of three ($27.43) in the increased net sale price of the covered hay over the uncovered.

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Table 1. Effect of covering alfalfa hay bales on bale weight changes from August 11, 1988 to January 17, 1989.

	Original weight		Final weight		Weight loss		
	76 bales	1 bale	76 bales	1 bale	76 bales	1 bale	% Loss
Covered	7360	96.8	7182	94.5	78 b	2.34 b	2.42 b
Uncovered	7373	97.0	7172	94.4	201 a	2.64 a	2.73 a
Mean	7367	96.9	7177	94.4	189.5	2.49	2.58

Table 2. Temperature and moisture changes for covered and uncovered baled alfalfa in Imperial Valley. John Kubler Farms, Calexico, California. 1988-89.

Date		Covered		Uncovered	
		°F	% Moisture	°F	% Moisture
Aug. 11	p.m.	74.6	9.75	73.9	10.29
12	a.m.	77.8		78.5	
	p.m.	81.3		81.7	
13		81.8		81.3	
15		79.0		79.3	
17		79.7		78.3	
20	0.3" rain	--		--	
22		95.8	8.02	96.4	7.72
24	0.5" rain	--		--	
24		94.3		96.0	
29		96.3	6.02	95.7	7.42
Sept. 6		91.8	5.38	89.2	6.51
9		87.7		87.2	
9		80.3		80.0	
Oct. 6		83.7		82.3	
27		83.0		81.3	
Jan. 5	0.7" rain	--		--	
16		63.0	7.96	63.0	7.66

Al readings except Aug. 11 and Aug. 12 p.m. were taken in the a.m.

Table 3. Changes in moisture percent of six alfalfa hay stacks (three dumps of 79 bales per stack) over a five month period, August 11, 1988 to January 17, 1989. Readings in percent moisture.

Treatment		August 11, 1988 Delmhorst probe	Oven	Difference	Aug. 22 oven	Aug. 29 oven	Sept. 6 oven	Jan. 17 oven	1/17-9/6 difference
Rep. I	Covered	12.96	9.64	3.32	8.11	6.80	5.15	6.94	1.79
Rep. I	Uncovered	14.45	9.78	4.67	7.27	8.25	6.54	8.57	2.03
Rep. II	Covered	13.59	10.26	3.33	8.33	5.77	5.83	7.41	1.58
Rep. II	Uncovered	13.59	10.62	2.97	8.93	6.06	6.73	7.50	0.77
Rep. III	Covered	13.44	9.37	4.07	7.61	5.49	5.15	9.52	4.37
Rep. III	Uncovered	13.66	10.48	3.18	6.96	7.96	6.25	6.90	0.65
Covered average		13.33	9.75	3.57	8.02	6.02	5.38	7.96	2.58
Uncovered average		13.90	10.29	3.61	7.72	7.42	6.51	7.66	1.58
Grand Mean		13.62	10.03	3.59	7.87	6.72	6.00	7.81	1.87

Samples used for these data were taken from the center rows of each stack, and do not contain the values obtained from the top and bottom rows on January 17, 1989.

Table 4. Variation in moisture content of bales covered versus uncovered, sampled from the top, middle and bottom tier of bales on January 17, 1989, 12 days after a 0.7 inch rainfall. Kubler Farms, Calexico California.

Treatment		Top	Middle	Bottom	Average
Rep.	Covered	6.98	6.94	9.23	7.72
Rep.	Uncovered	8.57	8.57	10.17	9.10
Rep. II	Covered	7.94	7.41	9.52	8.29
Rep. II	Uncovered	9.52	7.50	10.53	9.18
Rep. III	Covered	7.41	9.52	1.11	9.34
Rep. III	Uncovered	8.45	6.90	8.70	8.02
Average covered		7.44	7.96	9.95	8.45
Average uncovered		8.85	7.66	9.80	8.77
Grand Mean		8.15	7.81	9.88	8.61

Table 5. Visible mold, odor and color scores foir plastic covered and noncovered stacks of baled alfalfa. John Kubler Farms, Calexico, California. January 16, 1989.

Observation	Top row			2nd row			4th row			7th row			Bottom row - 9th		
	Covered	Uncovered	Ave.	Covered	Uncovered	Ave.	Covered	Uncovered	Ave.	Covered	Uncovered	Ave.	Covered	Uncovered	Ave.
Visible mold	9.9	5.6	7.7	10.0	5.0	7.5	5.8	4.0	4.9	6.3	5.0	5.6	5.0	2.5	3.7
Odor	9.7	6.0	7.8	10.0	4.8	7.4	6.8	4.0	5.4	6.8	5.5	6.1	5.0	3.5	4.2
Color	7.3*	5.5	6.4	7.3	4.7	6.0	6.0	4.0	5.0	7.0	5.0	6.0	5.0	3.0	4.0

Baled and stacked August 11, 1988. Three replications, each with three bale wagon dumps of 76 bales each; 228 bales per treatment. All evaluations were from center dump.

Rainfall: August 20 = 0.3 inches; August 24 = 0.5 inches; January 5 = 0.7 inches.

Plastic: 4 mil, covered top two bales on each side and five of nine bales on each end.

Scores: 1 = very heavy mold, musty odor, and black color; 5 = moderate mold and odor, and brown-yellow color; 10 = no mold, excellent odor, and very bright green color.

* Equal to the color when baled, which had some sun bleach.

Table 6. Effect of covering alfalfa hay on its chemical composition for three sampling dates over five months. All samples from the middle rows only. John Kubler Farms, Calexico, California. August 11, 1988 to January 17, 1989. 100% dry basis.

Date	Total ash average*	NDF average*	NDF-ash average*	ADF			C. Protein average*	ADF-protein average*	TDN**		
				Covered	Uncovered	Average			Covered	Uncovered	Average
Aug. 11	9.97	42.96 b	0.73	30.77	28.44	29.60 b	16.09	0.94 b	59.3	61.0	60.1
Aug. 22	8.85	43.19 b	0.61	30.78	29.67	30.23 b	16.73	0.93 b	59.2	60.1	59.7
Jan. 17	10.02	46.01 a	1.20	32.65 b	34.93 a	33.79 a	16.11	1.07 a	57.8	56.1	57.0
Average	9.61	44.05	0.84	31.40	31.04	31.21	16.32	0.98	58.8	59.1	58.9
LSD .05	ns	.48	ns			.90	ns	0.02			
% C.V.	11.4	2.1	78.6			4.3	5.1	8.9			

* Covered and uncovered were not significantly different. Only the average value is shown.
** Estimated from ADF, using the equation: TDN = 82.38 - (0.7515 x ADF).

Table 7. Effect of covering alfalfa hay on its chemical composition. Sampled five months after baling, by rows. John Kubler Farm, Calexico, California. January 17, 1989. 100% dry basis.

Position	Total ash Covered	Total ash Uncovered	Total ash Average	NDF average*	NDF-ash average*	ADF average*	C. Protein average*	ADF-protein average*	TDN average**
Top row	9.14	9.26	9.20 b	47.12	0.86 b	35.27 a	15.09	1.07	55.9
Middle row	9.58	10.45	10.02 a	46.01	1.20 b	33.79 b	10.11	1.07	57.0
Bottom row	10.45	10.44	10.45 a	47.52	1.73 a	35.66 a	16.44	1.11	55.6
Average	9.72 b	10.05 a	9.89	46.88	1.26	34.91	15.88	1.09	56.1
LSD .05			0.92	ns	0.38	1.33	ns		
% CV			6.6	2.73	21.62	2.7	7.8	7.3	

* Covered and uncovered were not significantly different. Only the average value is shown.
** Estimated from ADF, using the equation: TDN = 82.38 - (0.7515 x ADF).

Table 8. Economic benefits of covering alfalfa hay stored in a bale pile in Imperial Valley for five months. Hay baled for sale to horse accounts (final weight = 94.4 lbs per three twine bale). January 17, 1989.

	Covered 10 mil	Covered 3 mil	Uncovered	Cover advantage 10 mil	Cover advantage 3 mil
	---------- $/Ton on January 17, 1989				
Sale price[1]	125.00	125.00	90.00	35.00	35.00
Costs					
1. Labor, custom	-2.50	2.50	-0.00		
2. Materials	-4.50	2.50	-0.00		
	118.00	120.00	90.00	28.00	30.00
3. 5 months shrink	(2.42%)	(2.42%)	(2.73%)		
the $ value of shrink	-3.03	-3.03	-2.46		
Net sale price	114.97	16.97	87.54	27.43	29.43

[1]All bales evaluated and priced by an experienced commercial hay buyer/broker for horse accounts in southern California.