BIG BALES, SMALL BALES AND SAMPLING LOCATION: ARE THERE DIFFERENCES?

Preliminary results of a 1999 study

Steve Orloff, Dan Putnam, Tracy Ackerly, and Shu Geng

ABSTRACT

Little information is known on the effect of different types of balers on forage quality. A trial was conducted during the summer of 1999 to evaluate the forage quality of alfalfa hay baled with five different balers [a one-ton baler, two mid-sized balers, and two 3-tie balers (a side delivery baler and a center delivery baler)]. The alfalfa was baled under two moisture regimes: favorable moisture conditions and dry conditions. With the conditions and methods used in this study there was no difference in forage quality of alfalfa baled with the different balers. A second trial was conducted to document the variability in forage quality that occurs in 1-ton bales to help develop a sampling protocol. Results indicated more variation in forage quality within individual bales than between bales. There was no significant difference whether the front-end, middle, or butt-end was sampled so sampling the bale ends should be sufficient. The interaction between the position on the bale (i.e. the center vs. the edges) and the moisture under which the hay was baled was found to be important. These preliminary results suggest that it may be preferable to sample a few different positions on the end of several bales than to sample just the center of a high number of bales. Because of degree of variability observed in single cores, we recommend a minimum of 20 cores be used until more results are available.

Key Words: Alfalfa, *Medicago sativa*, harvesting, equipment, baling, forage quality, sampling, quality, ADF, TDN, NDF, CP

INTRODUCTION

The importance of producing high-quality alfalfa hay cannot be overstated. Under the alfalfa market conditions of the past two years quality can mean the difference between alfalfa that sells itself and alfalfa that does not sell at all. Producing high-test dairy-quality hay is no easy feat. Alfalfa must be harvested at an immature growth stage. This is not done without a price; early cutting normally means sacrificing yield. However, even when alfalfa is cut at the appropriate growth stage for high quality, the hay may still fall short of dairy quality if it is not 'put up' (raked and baled) properly. 'Put up properly' means using the right equipment, properly adjusted, and under favorable environmental conditions. If the hay is not raked or baled under the right conditions excessive dry matter losses can occur. Greatest losses occur with the leaf

---

[1] S. Orloff, UC Cooperative Extension 1655 S. Main St., Yreka, CA 96097; D. Putnam, T. Ackerly, and Shu Geng, Agronomy and Range Sci. Dept. University of California, Davis, CA 95616; Published **In**: Proceedings, 29th California Alfalfa Symposium, 8-9 December, 1999, Visalia, CA, UC Cooperative Extension, University of California, Davis.

fraction of the hay because the leaves are more brittle and easily lost than the stems. Leaves are far more nutritious than stems so if a disproportionate amount of leaves are lost the overall quality of the hay decreases significantly.

STANDARDIZED RECOMMENDATIONS FOR HAY SAMPLING

The greatest source for error in assessing the forage quality of alfalfa hay is believed to occur from the sampling process. Over the years, a systematic protocol has been developed for sampling stacks of 3-tie square bales to estimate hay quality. Most of these recommendations apply to big bales as well.

Here are some important principles and guidelines for taking samples of alfalfa hay:

Identify a single lot of hay- A lot must be from the same cutting, variety, field, stage of maturity and harvested within 48 hours. Do not mix lots. A lot must not exceed 200 tons.

Choose an appropriate, sharp coring device. The coring device should have an inside diameter of the cutting edge at least 3/8 inch and no more than 5/8 inch. The cutting edge should be at right angles to the shaft, and kept sharp. Dull probes will cause material to be pushed away from the core. Do not use an open auger or corkscrew type device, which selectively samples leaves.

Sample at random. Walk around the entire stack and sample bales at various heights. Do not bias the sample by avoiding some bales or choosing others.

Take enough cores. Per lot, sample a minimum of 20 bales (one core per bale). Take more cores (20-40) in larger lots or if the hay is very heterogeneous.

Use proper technique. Probe the ends of bales near the center, and at least 12-18 inches into the bale. Probe should be at right angles to the bale end. Do not slant the probe.

Handle samples correctly. Combine cored samples into a single sample and store them in a sealed polyethylene freezer bag. Do not expose to heat or direct sun, and send to the lab as soon as possible.

Not too big, not too small. The sample should weigh about ½ lb. If you obtain greater than this amount, your probe may be too large in diameter; many labs will not grind a large sample. Too small a sample will not represent the hay lot. Do not send a flake or a small teaspoon to a lab for analysis.

Split samples correctly. If you want to test the performance of a lab, send a fully ground and mixed sample to another lab, never split an un-ground sample. Most labs will return your ground sample for further testing, if you wish.

Research has shown that if these simple guidelines are followed, representative samples and reliable results can be obtained, even using different probes or people.

BALE PACKAGES HAVE CHANGED DRAMATICALLY

A three-wire bale was once the standard in California. Except for a handful of cubing operations and a rare two-wire baler, nearly all the hay in the state was baled with three-wire (or three string) balers. However, balers have changed dramatically in the past decade and now many different types are available. Large one-ton bales and mid-sized 1,000- and 1500-pound bales are becoming increasingly common because of increased efficiency in the field and because of improved ease-of-feeding at dairy operations.

An additional advantage of the large balers is that they use a center delivery or inline-feed mechanism rather than side-delivery feeder forks used with conventional balers. Therefore, the hay is handled less on its journey to the chamber. Additionally, the plunger on some balers does not continually strike the hay on set time intervals—the plunger strokes only once sufficient hay has accumulated in the chamber or pre-chamber. These two features are believed to be gentler on the hay causing less leaf loss, especially under dry baling conditions.

In theory, these features should result in higher test hay. A center delivery baler was previously only available in large square or round balers. However, over the last five years the center delivery mechanism has become available in the standard 3-tie balers commonly used in the West. Little research has been done comparing the effect of baler type on alfalfa forage quality.

The objective of the research was to quantify what effect, if any, different types of commercial balers had on the forage quality of alfalfa baled under favorable moisture conditions as well as dry conditions.

PROCEDURES

Field trials were established in Bakersfield CA to evaluate forage quality of alfalfa hay baled with five different balers, and to evaluate the sampling methods for big bales. We conducted two Experiments.

Experiment I evaluated the differences between 5 balers under two baling conditions (moist—early morning, and dry—late afternoon) in a randomized block design with a split plot restriction. The balers tested were as follows.

Balers Evaluated:

1) a one-ton Heston baler (2,000 lb bale Model 4900 Heston);
2) a mid-size Heston (1,000 lb bale Model 4755 Heston);
3) a mid-size Freeman (1,400 lb bale Model 1592 Freeman);
4) a small conventional Freeman 3-tie baler (125 lb bale Model 330 Feeman);
5) a small Heston 3-tie center delivery baler (125 lb. Bale in-line Heston).

Two commercial fields were selected for the study, with two replications per field. The alfalfa was baled under two different moisture conditions favorable moisture conditions (at 6:00 a.m.) and dry conditions (at 11:00 a.m.). All five balers were operating simultaneously in different border checks so that all plots were baled under approximately the same environmental conditions. Each plot was one border check in size (approx. 50 ft. x 0.25 miles). After baling was completed, the bales were sampled using a Penn State Forage sampler driven by a power drill to a depth of approximately 18 inches. Ten cores were taken per plot for a total of 40 cores per treatment. Dry matter, crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) and were determined using near-infrared reflectance spectroscopy (NIRS).

Experiment II evaluated the between-bale and within bale variation in forage quality of 1-ton bales. While the sampling procedure for small rectangular bales is well defined, little is known about the best way to sample large bales. The first step toward developing a recommended sampling protocol for large bales is to determine the degree of variation in forage quality that occurs within a large bale. Ten one-ton bales were taken from the baler comparison experiment described above (using the Heston 4900 Baler) and transported to a dairy where they could be broken open and intensively sampled. Five of the bales were baled at 6:00 a.m. under favorable moisture conditions and the other five were baled at 11:00 a.m. under excessively dry conditions (wet vs. dry). Bales were cored using a Penn State Forage Sampler to a depth of 18 inches. Sixteen cores were taken from each end of the bale (Figure 1). A one- by one-foot grid was used to determine the location for each coring. Since the dimensions of the bale were 4 ft. by 4 ft. this resulted in a grid having a total of 16 squares. A single core was taken from the center of each 1- by 1-ft. square. To better sample the interior of the bale, the bale was opened and nearly half of the bale peeled away so the center of the bale could be sampled. Sixteen additional cores were taken in the same grid arrangement. This resulted in a total of 48 cores per bale (32 cores from the ends and 16 from the center). The dry matter, CP, ADF, and NDF were determined for each core using near-infrared reflectance spectroscopy (NIRS).

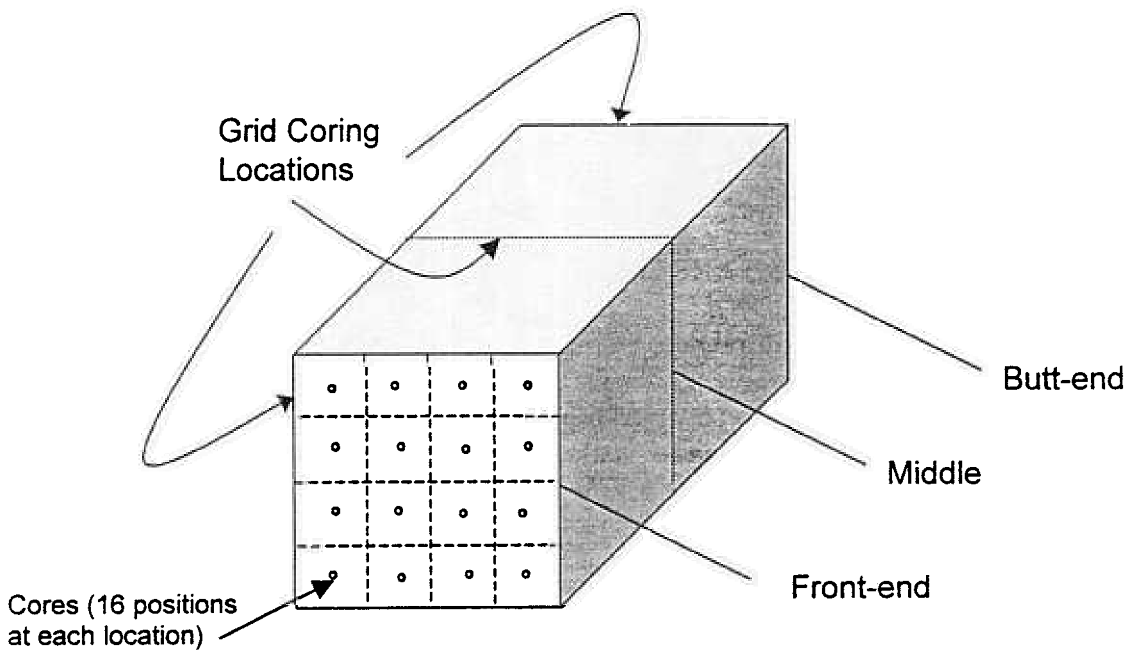

Figure 1. Sampling location of individual cores used in the study to evaluate the variation in forage quality in one-ton bales. Each circle represents an individual core. 48 cores were make per bale.

BALER COMPARISON (Experiment I)

The moisture content of the hay baled under favorable conditions was about 15 percent, while the hay baled under dry conditions averaged about 8 percent. There was no difference in the moisture content of hay baled with the different balers. Similarly, there was no difference in forage quality CP, ADF, or NDF of the alfalfa baled with the different balers (Table 1). The overall forage quality of this hay was poor (approximately 34.4 % ADF), but this probably should not affect the relative differences that there may be between balers. These results should not be construed to mean that baler type has no effect on forage quality or the leaf retention of alfalfa hay. It is widely believed that the center delivery system is less damaging to dry alfalfa than is the side delivery system—many have noted that they can bale drier hay with the in-line delivery system and still maintain good leaf retention. However, differences in forage quality attributable to the baler type are likely so small that they were undetectable under the conditions encountered and the methods employed in this experiment.

Table 1. Effect of five different balers on Dry Matter, Crude Protein, Acid Detergent Fiber, and Neutral Detergent Fiber of alfalfa grown in Bakersfield, CA (1999).

Baler	Dry Matter	CP	ADF	NDF
	-------------------------------%---------------------------			
One-ton Heston	88.7	19.1	34.5	43.1
Mid-size Heston	87.4	19.2	34.4	42.9
Mid-size Freeman	88.5	19.1	34.8	43.5
3-tie Freeman (*conventional)*	89.1	19.3	34.2	43.3
3-tie Heston (*in-line)*	88.9	19.2	34.4	42.7
Significance:	n.s.	n.s.	n.s.	n.s

NO QUALITY DIFFERENCE DUE TO MOISTURE—WHY?

Surprisingly, there was also no difference in forage quality due to the two distinct moisture conditions at the time of baling (the same results were also found in Experiment II). These results astonished us. Everyone has observed the dry matter losses—a cloud of green dust and a trail of powdered alfalfa behind the baler—that occur from baling alfalfa hay too dry. Presumably the majority of the dry matter loss is leaf material so forage quality should be affected.

Why then in this experiment did we observe no difference in forage quality with the two different moisture conditions? Three plausible reasons are proposed. Loose leaves tend to accumulate in one side of the bale. Perhaps we would have found differences due to the moisture conditions at baling had it been possible to grind entire bales and analyze the whole bale for forage quality. However, by taking selected cores in the locations we sampled, we were unable to detect a difference. We also may have found differences had the test been conducted on higher-quality alfalfa. For example, if leaf percentage was 35% of dry matter (a likely scenario in this case), then the potential impact of leaf loss might be less than a field containing 55% leaves. Another possible reason for there being no detectable difference in forage quality is that the amount of leaf material that actually becomes detached and falls to the ground may be minor in comparison to the leaves that remain in the bale (both attached and detached). The actual amount of leaves that was lost (not included in the bale) was apparently small and insufficient to cause a measurable difference in forage quality in this experiment.

Other research supports that, within reason, the effect of moisture content on forage quality may not be that great. Meyer and Jones quantified the effect of moisture conditions at the time of raking and baling on forage quality. They found that dry conditions while the hay is raked had a much more detrimental effect on forage quality than did baling under dry conditions. The greatest negative effect on forage quality occurred when the hay was both raked and baled under dry conditions. Another study reported in *Silage and Hay Preservation* reported dry matter looses of 4 percent (6 percent leaf loss) when hay was baled at 20% moisture and 6 percent (8 percent leaf loss) when baled at 12% moisture. The relatively small increase in leaf loss when baling under dry conditions may not be sufficient to cause a significant reduction in forage quality.

Favorable moisture conditions and an effective baler design may have a greater impact on the "leaf pattern" (the arrangement and attachment of leaves on the stem) than they do on the total amount of leaves in a bale. Depending on how the hay is fed, detached leaves may or may not have a significant effect on the feeding value of the hay. We would clearly not recommend baling hay under dry conditions but the effect on forage quality may not be as great as we had anticipated.

VARIATION IN FORAGE QUALITY IN ONE-TON BALES (Experiment II)

This experiment (Experiment II) was designed to look at the amount of variation between bales and within one-ton bales. There were 480 samples taken over the 10 bales (48 per bale). At this writing, further analysis of the data remains to be completed, although several aspects of the data can be shared as a preliminary report.

Moisture at baling (time of day at baling) had a significant effect on dry matter content (as would be expected- Table 2). However, CP, ADF and NDF were not affected by the moisture content at baling, results similar to Experiment I. In this data, there were small but non-significant trends towards higher quality under wet conditions, but they could not be statistically proven even with the large amount of replication in this trial.

Table 2. Influence of moisture as a main effect on Dry Matter, Crude Protein, Acid Detergent Fiber, and Neutral Detergent Fiber of alfalfa grown in Bakersfield, CA (1999).

Moisture at Baling	N	Dry Matter	CP	ADF	NDF
		------------------------------%------------------------------			
Wet	240	85.4	19.0	35.2	44.1
Dry	240	92.4	18.8	35.5	44.3
Significance:		***	n.s.	n.s.	n.s

N = number of samples

*** Effect is significant at P<0.001

In this experiment, there were no mean differences between sample locations within a bale (front end compared with butt end or middle-Table 3.). This indicates that the average of the 160 front-end samples (16 on each front-end x 10 bales) did not differ from the average of the 160 samples taken from the middle of the bale, as compared with the 160 samples taken from the butt end of the bales.

Table 3. Influence of location within a bale (Front end or butt end compared with the middle) as a main effect on Dry Matter and Crude Protein, Acid Detergent Fiber, and Neutral Detergent Fiber of alfalfa grown in Bakersfield, CA (1999). All samples were taken perpendicular to the ends of the bales, approximately 18" deep.

Location Within a Bale	N*	Dry Matter	CP	ADF	NDF
		----------	%	----------	
Butt end	160	88.7	18.7	35.5	44.5
Middle	160	88.9	19.0	35.4	44.1
Front end	160	89.1	19.0	35.1	43.9
Significance:		n.s.	n.s.	n.s.	n.s

N = number of samples

SOURCES OF VARIATION WITHIN- AND BETWEEN- BALES

A statistical analysis of the data from our 'Big Bale' experiment II provides guidance as to the sources of variation we observed in this experiment (Table 4). Moisture at baling had a significant effect on dry matter content of the hay, but not on forage quality (CP, ADF, and NDF). There were some bale-to-bale differences (Rep within moisture level) in ADF and NDF, but these were not highly significant (Table 5). As discussed previously, the location effect was non-significant for all measured variables, but the interaction between the location (front end, middle, and butt end) and the bale-to-bale variation (rep within moisture) was highly significant for all measured variables. This indicates that the trends across the locations (front end, middle, and butt end) were not the same for each bale that we studied.

The position from which the samples were taken (samples were taken on a 4 x 4, 16 sample grid at each of the 3 bale locations) had an effect on DM and CP, but not ADF and NDF. However, there was a strong interaction between the moisture at baling and the position from which the sample is taken. These interactions appear complex, and further analysis is required to understand these interactions.

Table 4. Analysis of Variance Table for Experiment II. Sources of variation include moisture at bailing (Moisture), bale-to-bale (Rep w/Moist), Location in the bale (Location-Front end, Middle, Butt end), Position (16 positions of samples at each location).

Source	df	DM	CP	ADF	NDF
1. Moisture	1	***	n.s.	n.s.	n.s.
2. Rep (w/Moist)	8	n.s.	n.s.	<0.09	*
3. Location	2	n.s.	n.s.	n.s.	n.s.
4. Moist X Loc	2	n.s.	n.s.	n.s.	n.s.
5. Loc X Rep (w/Moist)	16	***	***	***	***
6. Position	15	**	<0.07	n.s.	n.s.
7. Moist X Position	15	***	***	**	*
8. Loc X Position	30	n.s.	n.s.	n.s.	n.s.
9. Moist X Loc X Position	30	n.s.	n.s.	n.s.	n.s.
10. Error	360				
Total	479				

*,**,*** Effect is significant at P<0.05, P<0.01, or P<0.001, respectively

COMPONENTS OF VARIANCE

Bale-to-Bale Variation. Between-bale variance was estimated by using the replication (within Moisture level) term in Table 4. The average forage quality of individual bales in this experiment is presented in Table 5, indicating a range in ADF from 33.8 to 36.7. Between-bale variance appeared to be far less than the sources of within-bale variation (Table 6). Between-bale variance accounted for about 1 to 16% of the variance, depending upon the variable. The purely within-bale variance, including the position from which the sample was taken, and interactions between the positions and other factors, consisted of greater than 50% of the variance for the forage quality parameters (ADF, CP, and NDF), and 34% for DM (Table 6). This analysis indicates that though both between- and within-bale variance must be accounted for when sampling hay, within-bale variation was likely more important source of variation in this experiment. One ton of hay, after all, encompasses a considerably larger field area than small 125 lb. bales, and considerable variation must be contained in a single bale.

Table 5. Variation in mean Acid Detergent Fiber values of bales of alfalfa hay baled under favorable and dry conditions. Each mean represents an average of 48 samples, the overall mean the average of 240 samples. Bakersfield, CA (1999).

	Bale Number						
Baling Moisture	1	2	3	4	5	Ave.	S.D.
	------------------------------%----------------------------						
Wet	35.9	33.9	36.0	33.8	36.2	35.2	2.1
	35.8	35.9	34.7	34.3	36.7	35.5	2.2

S.D. Standard deviation

Within Bale Variation. The within-bale variance, as a percentage of the total variance, can be seen in Table 6. This variation is illustrated in Figure 2. This figure illustrates the amount of variation in a single bale of hay, baled under favorable moisture conditions in Bakersfield, CA. It is clear from this 'response surface' that ADF values of individual core samples can range at least 6-7 percentage points across the face of each one of our sampling grids. Considerable variation was present in the middle of the bale as well as on the front and butt-ends of the bale. The range of variation within single bales and between whole bales of alfalfa hay should be of considerable practical concern for hay growers and buyers. If nothing else, this is a strong signal to hay samplers that numbers of samples is very important to characterize forage quality of a hay lot. Both between- and within-bale variation must be considered. Thus, our 20-core minimum traditional recommendation will likely still apply to large bales, but further modeling will be required to determine a minimum number more precisely.

Table 6. Relative percentage of Variance Components accounted for by within-bale, and between bale variation, and the variance accounted for by interactions between bale (replication) and Location within the bale.

Source	**DM**	**CP**	**ADF**	**NDF**
	------------------% of Total Variance-----------------			
Between Bale Variance (Rep/Moist)	14.8	0.9	13.9	15.6
Interaction between Location and Bale (Loc*Rep/Moist)	51.3	19.5	31.1	
Within-Bale Variance (including Position, Moist*Position, Location*Position, and Moist*Location*Position)	33.9	79.6	55.0	69.9
Total	100	100	100	100

Interactions. The interactions in this experiment were significant and interesting (see Table 4 and Table 6). A full discussion of these interactions is beyond the scope of this report, but some effort to determine the cause of these interactions, and to further study the nature of these interactions is warranted. The primary interactions were between location of the sampling grid (front-end, middle, butt-end) and the bale-to-bale variation, and between the moisture level and the position of the sample.

One of these interactions is between the Position of the sample on the grid pattern ("Position" in Table 4) and the moisture level during baling (Position X Moisture interactions, Table 4). This interaction indicated a greater frequency of higher-ADF samples in the dry bale than in the wet-baled alfalfa, though it should be remembered that the overall mean was determined to be the same (between wet and dry). The effect of the sampling position (i.e., which of the 16 cores in the grid; toward the top, bottom, center or the edges of the bale) was different for the bales baled under favorable moisture conditions than it was for the dry bales. This suggests that the leaves may have congregated in different portions of the bale in the dry bales compared with the higher moisture bales. Further study, and perhaps greater replications (additional fields and bales sampled) are likely required to determine whether there are consistent patterns within these large bales.

PRELIMINARY SAMPLING RECOMMENDATIONS FOR LARGE BALES

Although further work is required to fully characterize the recommended sampling methods for big bales, some preliminary conclusions can be drawn. First, the within-bale variance appeared to be a higher percentage of the total variance than the bale-to-bale variance. The pattern of the front-end vs. middle vs. butt-end locations for ADF, CP, and NDF appeared different for different bales. It does not appear that there are clear differences between the outer exposed surfaces (front-end and butt end) and the inside of the bale (all "Location" effects were non-significant), when considering the mean of the multiple samples which were taken in this study. This would suggest that sampling the two exposed surfaces of large bales might be adequate to characterize the range of variation within large bales (unless further data is developed that support deeper sampling). Coring to a depth of 18 inches, as is done with small bales, may be sufficient.

The position at which the sample was taken appeared to be important, primarily because there was variation as to the pattern of the ADF, CP, and NDF across the sampling grid at the two different moisture levels. However, the sources of this variation appear complex and worthy of further study. Overall, individual samples from these bales ranged from 29.1 to 41.2 ADF, indicating the wide range of forage quality of samples obtained from these 10 bales. This indicates a need to keep the number of cored samples high (eg. at the recommended level of >20) to adequately characterize the forage quality of the alfalfa in big bales. It appears, at this time, that it is important to sample different positions on the ends of the bale rather than sampling just the center, as is recommended for small bales. For example, it may be best to sample four positions on the end of the bale (not always the center) on at least 5 bales than it is to sample just the center on the end of at least 20 bales. However, further work on the interactions present in this study may be required to confirm this recommendation.

REFERENCES

Meyer, J. H. and L. G. Jones. 1962. Controlling alfalfa quality. California Agricultural Experiment Station Bulletin 784.

Orloff, S. B. 1997. Hay curing, baling, and storage. In S. B. Orloff and H. L. Carlson (eds.), Intermountain alfalfa management. 109–115 Oakland: University of California Division of Agriculture and Natural Resources, Publication 3366.

Pitt, R. E. 1990. Silage and hay preservation. Ithaca, NY: Northeast Regional Agricultural Engineering Service. NRAES-5.

Acknowledgements

The authors would like to thank Truman Brown, Executive Director of Kern County Hay Growers Association for his help arranging for the field location, balers, and baler operators to conduct this research. He also made arrangements with a dairy where the bales could be opened and evaluated. This research would not have been possible without Truman's assistance. Many thanks also go to the San Joaquin Valley Haygrowers Association for their contribution towards the cost of analysis.

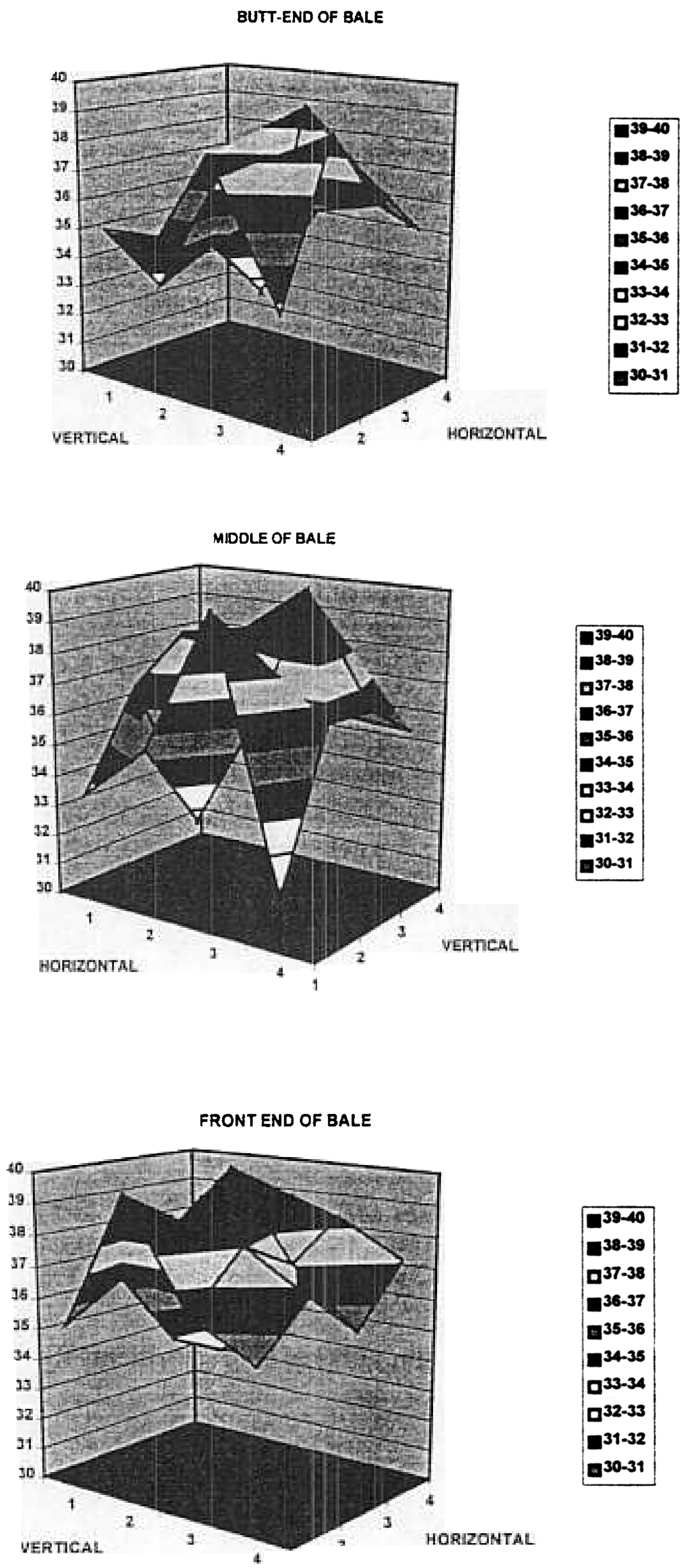

Figure 2. Variation in ADF% in the front-end, middle, and butt-end of a single one-ton bale (favorable moisture).