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The evaluation of hollow core, sliced, and solid large round hay bales

James William Bedford

To the Graduate Council:

I am submitting herewith a thesis written by James William Bedford entitled "The evaluation of hollow core, sliced, and solid large round hay bales." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Biosystems Engineering Technology.

Bobby Bledsoe, Major Professor

We have read this thesis and recommend its acceptance:

Robert Freeland, William Hart, John Waller

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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William E Hart

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John C Waller

Dr. John Waller

Accepted for the Council:

Associate Vice Chancellor and
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The Evaluation of Hollow Core, Sliced, and Solid Large Round Hay Bales

A Thesis

Presented for the

Master of Science Degree

The University of Tennessee, Knoxville

James William Bedford
August 1999

Dedication

This thesis is dedicated to my parents

William G. and Sandra H. Bedford

for their unconditional love and support

through my college career.

Acknowledgments

I would like to express my deepest gratitude to the people who influenced me to attend The University of Tennessee. Larry Moorehead, the Moore County Leader of the Agricultural Extension Service, was the first person to visit the Agriculture Campus with me. Dr. William E. Hart, also a committee member, was very instrumental in my decision to attend graduate school. Special thanks to Dr. Roland Mote for allowing me to participate in the graduate program in Agricultural and Biosystems Engineering Technology.

I would like to thank the people who assisted me with my research project. Shop personnel Paul Elliott, Walker Garner, and Craig Wagoner need special recognition for assisting me in building apparatuses used in the field. Fellow graduate students Jonathan Adamson and Daniel McKinney were extremely helpful collecting field data. The assistance of Dr. Dennis Onks and personnel at the Middle Tennessee Experiment Station in Springhill was beyond the call of duty. Statistician Dr. Arnold Saxton was instrumental in writing the programs and evaluation of the data collected in the field.

Lastly, I would like to thank my committee members Dr. Bobby Bledsoe, Dr. Robert Freeland, Dr. William E. Hart, and Dr. John Waller. Their guidance and assistance while conducting the research were impeccable.

Abstract

Three bale-package types, hollow core, solid, and sliced large round hay bales, were evaluated. An experiment was conducted to determine differences among package types for temperature buildup during curing and nutritional losses during storage. Also, the amount of energy required to tub grind each bale type was measured. Third-cutting alfalfa hay was baled at two moisture content levels into the three bale types and was left outside for 36 days immediately after baling for curing. After curing, most bales were moved inside for the remaining six months of storage; however, five bales were left outside for comparison of differences in nutrient losses for inside and outside storage.

Temperature buildup during curing was minimal in the 15% moisture treatment. The hollow core bales had significantly lower temperature than other bales ($p<0.05$). In the 20% moisture treatment, no differences were found ($p<0.05$). The bale temperatures of the 20% moisture treatment were significantly higher than the ones of the 15% moisture treatment. Moisture content and density of bales in the 15% moisture treatment were different from that of bales in the 20% moisture treatment. Hollow core bales packaged at 15% moisture content exhibited lower moisture contents and densities than any other bale packages or moisture treatments.

Nutritional losses of the 20% moisture content treatment bales stored inside and of outside stored bales were significantly greater than those of the 15% moisture bales stored inside ($p<0.05$). There were no differences in nutritional losses among bale packages. Bales stored outside lost the greatest amount of nutritional value

($p<0.05$). There were no statistical differences of nutritional losses among bale package types at any moisture level or storage treatment. The number of bales available for grinding was too few to show any significance in the amount of energy required to grind each bale type ($p<0.05$).

Table of Contents

List of Figures

Nomenclature

Term	Abbreviation
Moisture Content Wet Basis	mcwb
Dry Matter	DM
Crude Protein	CP
Acid Detergent Fiber	ADF
Neutral Detergent Fiber	NDF
Non Structural Carbohydrates	NSC
Total Digestible Nutrients	TDN
Net Energy for Gain	NEg
Net Energy for Maintenance	NEm
Net Energy for Lactation	NEl
Relative Food Value	RFV
Total Mixed Rations	TMR
Power Take-Off	PTO
Celsius	°C
Fahrenheit	°F
Inches	in.
Centimeter	cm
Foot	ft
Meter	m
Pounds	lbs
Grams	g
Kilograms	kg
Horse Power	hp
Kilowatts	kW
Hours	hr
Ton	t
Metric Ton	mt

Chapter 1

Introduction and Objectives

Increased efficiency and decreased labor are goals of people engaged in production agriculture. These goals especially apply to production of high quality forages, which, traditionally, is highly labor intensive. However, the invention of the baler for making large round hay bales helped ease some of hay making labor needs. Today, a farmer alone can cut, rake, and bale hay almost from the seat of a tractor; and depending on the scale of operation, that person may need no further labor assistance in harvesting hay.

Presently, alfalfa hay grown on 40,000 acres (16187.5 ha) in Tennessee is worth approximately 14.2 million dollars annually (Danekas, 1997). Yet, the nutritional losses from mechanical harvesting, storing, feeding, and from lack of timeliness of cutting have been estimated nationally at 25% (Rotz and Sprott, 1984). Since Tennessee is located in a humid region of the United States, significant problems occur in field curing hay in a timely manner without losses. Adverse weather conditions, such as rain, can significantly reduce the nutritional value of hay (Koegal *et al.*, 1985). Because of the climate in Tennessee, many farmers use mechanical devices to aid in field drying hay. These machines include mower conditioners, tedders, and rakes, which can damage alfalfa herbage through excessive leaf loss (Hobby, 1995; Miller *et al.*, 1996). If a forage is baled before it has adequately dried to a safe storage level (approximately 15%), then microbial respiration within the packaged hay can alter the nutritional value of the hay (Bales *et al.*, 1992). A recently available slicing attachment for large round hay bales

(New Holland, 1995) offers a means of separating a bale into chunks for feeding, and may offer improved ventilation of the bale in storage to help reduce microbial respiration damage to the hay. Large round bales with hollow cores have been produced in an attempt to improve drying efficiencies of round hay bales (Bledsoe *et al.*, 1997). These bales may offer improved ventilation of the bale in storage to help reduce microbial respiration damage. An experiment was proposed to compare sliced and hollow core with traditional solid round bales for dry matter and nutritional losses during curing and storage. The experiment tested differences in maximum temperature rise during curing for these bale treatments and whether storage losses occurred in the three bale treatments. The three main objectives of this research were: 1) To compare solid, sliced, and hollow core large round alfalfa bales packaged at 15 and 20% moisture content wet basis for internal temperature variations over time during curing; 2) To compare the three types of bales packaged at the two moisture contents as specified above for nutrient losses during a five month storage period; 3) To compare specific energy required to tub grind random treatments of the bales described in objective 1 above.

Chapter 2

Review of Literature

Heat Damage

One important factor that influences nutritional degradation after hay has been cut from the field is the temperature of the mow or bale during curing and storage. High temperature from heat buildup not only affects nutrition, but can also cause spontaneous combustion. Bruhm and Koegal (1985) report that even if the hay does not get hot enough to spontaneously ignite; the feed value is reduced for animal consumption. Animals may like the flavor of the hay, but consumption of the hay provides little or no nutritional value to the consuming animal.

Tomes (1986) described the cause of heating to be from microbial respiration expedited by high moisture content of the hay. She also states that the temperature readily affects the nutritional composition of the hay. When hay temperatures exceed 50°C (122°F), the protein in the hay is bound irreversibly to the structural carbohydrates (Tomes, 1986). This protein binding results in reduced feed value of the hay. Montgomery *et al.* (1986) showed that with the increase of moisture content at baling, the internal bale temperature also increases. With the increase of bale temperature, the digestibility of the nutrients in the hay decreases.

Hall (1957) describes spontaneous heating. After hay is placed in a mow, it goes through a sweating process. This results from microbial activity, which can cause the mow to reach temperatures of 120°F (49°C) or more. The heat is not readily dissipated such that the temperature of the material continues to climb until spontaneous combustion is imminent when a ready oxygen supply is introduced.

Murphy *et al.* (1978) state that the forage plant continues to "breath" or respirate for a short time after it has been cut from the field. This respiration can cause some heating, but the microorganisms present are the major cause of the heating. If the hay is below 20% moisture content, the microorganism activity is reduced, thus reducing the heat of the hay. However, if the moisture content is above 20%, the temperature will continue to rise.

Bruhm and Koegal (1985) outline the critical temperatures of a hay bale. They state that if the temperature reaches the130°F to 140°F (54°C to 60°C) range, the temperature can continue to rise or go down. When the internal heat builds the temperature to 150°F (66°C), the internal temperature is likely to continue to climb. When the temperature reaches a range of 175°F to 180°F (79°C to 82°C), a fire is likely. If the internal temperature is 200°F (93°C) or more, glowing or smoldering spots are present inside the bale.

Nutritional Value

Bohstedt (1944) reported that the principal feed value of alfalfa hay is preserved in the leaves. The more leaves preserved in the hay, the higher the quality of forage produced. He reported that 50% of alfalfa weight is in the leaves, but the leaves contain 70% of the protein.

Barnes *et al.* (1995) state the leaves of alfalfa have a much higher concentration of protein than the stems. The digestibility of the leaves is also much higher than the stems. Of all the hay crops produced, alfalfa has the greatest feed value. Alfalfa also has a greater amount of vitamins and minerals than any other hay crop.

Martin *et al.* (1976) listed the factors affecting the quality of alfalfa to be color, leafiness, fineness of stem, and freedom from foreign matter. They also state that the protein content is closely correlated with retention of leaves during harvest. Since the leaves contain 70% of the protein, it is imperative that they remain intact during harvest.

Parker *et al* (1986) noted that there is a deficiency in high quality alfalfa in the Eastern United States. This is due to the warm humid climate in this part of the country. Adverse weather conditions such as rain can cause significant losses in a hay crop. Parker (1988) states that dry matter losses range from 4 to 15% from plant respiration, 3 to 35% from leaf shatter, and 5 to 14% from leaching by rain. Total dry matter losses for the entire harvesting period could be 15 to 65% during normal field curing operations.

Miller *et al.* (1967) and Nelson (1972) found similar results when baling hay at high moisture contents. They determined that as the moisture content of the hay increases, crude fat, carbohydrates, ash, acid detergent fiber, and lignin contents also increase, but energy and protein decrease. The increase in unwanted components is due to heating and microbial activity degrading the nutritive value of the hay.

Mechanical Losses

Buckmaster (1993) measured raking losses on artificial stubble. He found that the type of rake did not significantly affect the amount of losses. However, moisture content and the time of raking did affect the amount of losses. Raking at moisture contents greater than 35% moisture resulted in 3.1% more dry matter retention than raking at lower moisture contents. The crude protein lost during raking ranged from 11.9 to 25% with an average of 20.4%.

Savoie *et al.* (1982) determined that hay cut by a cutter bar mower had a faster drying rate than hay cut with other mowers due to the wide swath produced behind the mower. However, mower-conditioners also provided significantly drier hay than other treatments. Alfalfa cut with a conditioner or cutter bar had significantly reduced moisture contents. A tedder was also used to increase field drying, but was not as consistent or significant as conditioners and cutter bar mowers in reducing losses. Total losses from cutter bar mowers and mower-conditioners were 12 kg per hectare. In terms of total average weight per area (4900 kg/ha), the losses are relatively low. However, when these losses were added to tedding and raking losses, the total losses were approximately 11%.

Anderson *et al.* (1981) demonstrated that with increased amounts of hay in the swath, the losses from baling, and bale density, decreased. They also showed that the losses from hay stored inside averaged 3% while the losses from hay stored outside averaged 14%. However, the cumulative nutrient losses, which occurred from dry matter losses during raking through storage, were 22% for hay stored inside; and for hay stored outside, the losses were 31%.

Dobie *et al.* (1963) compared hay raked at 40 to 50% moisture content to hay raked at 12 to 15%. They found that the drier the hay when raked and packaged, the greater the dry matter losses. There was a 35% increase in dry matter preserved when the hay was raked at 40 to 50% moisture content. The loss of protein was greater than yield losses in their study. The loss in protein came predominantly from leaf loss.

Aviki *et al.* (1979) stated that the time required for conditioned alfalfa to reach a safe storage moisture content of 20% is dependant on the type of roll conditioner, the feed rate and the number of passes over the windrow. They found that hay conditioned with a steel crimp type conditioner dried 1.8 hours faster than hay treated with a plastic tine type conditioner. They also found that hay conditioned two times dried only 1/2 hour faster than hay conditioned only one time.

Halyk and Bilanski (1966) found that hay tedded immediately after mowing dried at about the same rate as mowed hay in swaths. However, the tedding removed leaves from the plant, which decreased the nutritional value of the crop.

Storage Losses

Verma and Nelson (1981, 1983) stored round bales of ryegrass hay using six different treatments. The treatments were: (1) Storage on gravel bed; (2) Storage directly on the ground; (3) Storage on elevated wooden racks; (4) Storage on elevated wooden racks with plastic covers; (5) Storage on automobile tires; (6) Storage inside a barn. The results show that large round bales stored outside unprotected from weather have larger amounts of shrinkage than bales under cover or stored inside. The results showed slight losses in quality of both hay stored inside and hay protected by plastic. There was only a 2% greater loss from hay protected by plastic than hay stored inside. Their results showed total quality losses as much as 65% in a seven-month storage period for unprotected bales stored outside. During the storage period, the hay bales stored inside retained the highest amount of protein.

Collins *et al.* (1987) show that initial moisture content of hay significantly affects the nitrogen (N), neutral detergent fiber (NDF), and acid detergent fiber (ADF) concentrations immediately following baling. Initial moisture content also affects the quality of the alfalfa hay after a three-month storage period. The proportion of acid detergent insoluble nitrogen increased as the initial moisture content increased, showing that there was significant heat damage to the hay bales. Conversely, the maximum temperature reached during storage declined as the initial moisture content decreased.

The research performed by Rotz and Abrams (1987) showed that dry matter losses for field cured hay under good drying conditions varied from –8 to 19% of the initial dry matter in the package, with an average of 3.2% (losses varied due to a large experimental error). However, under adverse conditions, these losses varied form 3 to 34%, with an average of 11.2%. Rain losses correlated directly with the amount of rainfall. For each millimeter (0.039in.) of rainfall, a 0.7% dry matter loss was observed. The rainfall also caused a decrease in all measurable nutrients in the alfalfa crop. In hay produced without rain damage, nutritional losses were proportional to the losses of total dry matter. They also determined that machine losses could amount to 7.2% of the crop. Losses from the first raking were approximately 3.2%. An additional 0.8% loss was observed from windrow turning and 2.9% loss from baling. They also showed that nutritional losses occurred during storage. The dry matter losses for alfalfa hay baled at moisture contents less than 20% were approximately 4.5%. The losses for hay baled at moisture contents greater than 25% were 10.9%. Most of storage losses occurred during the first thirty days of storage or during the curing period.

Baxter *et al.* (1986) showed that alfalfa-orchardgrass hay stored inside a shelter had cooler temperatures after five days of storage, but it took 30 days for the bale temperature to reach ambient air temperature. In bales stored outside, temperature steadily increased after rainfall rewet the hay. Dry matter losses of field cured hay from the time it is packaged and stored until it is fed to animals can be excessive even for good field drying conditions. Savoie *et al.* (1982), Rotz and Abrams (1987), Bohstedt (1944), Martin *et al.* (1976), and Buckmaster (1993) have done much research to determine the amount of losses that occur during normal harvest, storage, and feeding of hay. The losses of hay can come from a number of different processes during the harvesting. Losses occur from cutting, plant and microbial respiration, field drying, mechanical conditioning, raking, baling, storage, and feeding of hay bales.

Savoie *et al.* (1982) reported that respiration and mechanical losses of dry matter are 15 to 25 % during field drying of alfalfa under typical conditions. However, rain leaching of nutrients from the plant can greatly increase the losses in nutritional value. To decrease the amount of losses for alfalfa hay, it is imperative that a hay crop not be exposed to rain damage. Rotz and Sprott (1984) stated that losses of dry matter during harvest and storage could be very large. Losses in dry matter for the entire harvest and storage process can be from 15 to 25% of initial dry matter under good drying conditions. However, under adverse conditions, the losses can range from 35 to 100%! The portion of dry matter that is most susceptible to losses also has the highest nutritional value to the animals. Rotz and Sprott (1984) classifies dry matter losses into two categories: field losses and storage losses. The field losses occur from the time the hay is cut until the time that the hay is baled. Storage losses occur from the time the hay is baled until the time the hay is fed to livestock. Respiration losses recorded by Rotz and Sprott (1984) amounted to 5 to 10% of the dry matter. However, there is much disagreement on when respiration is actually inhibited. Most researchers agree that respiration is most likely inhibited at a moisture content between 20 and 40% (Rotz and Sprott, 1984; Bohstedt, 1944; Martin *et al.*, 1976; Buckmaster 1993).

Artificial Drying

Artificial drying is one way to decrease field losses (Bales *et al.*, (1992); Bledsoe *et al.*, (1997) and Jaggers, (1997)). The hay is baled at high moisture contents thus reducing the losses occurring during baling, and decreasing the chances for rain damage. The hay is then dried, using a solar heated dryer, until a safe storage moisture content is reached. Drying can preserve the nutrient value of the hay, because the process decreases leaf loss and retains the peak color and smell. Solar heated drying also reduces the field drying time.

Chapter 3

Methods and Procedure

Experimental Design

The experimental design incorporated three bale packages: hollow core, sliced, and solid bales produced at 15 and 20% moisture content levels, wet basis (mcwb). Two storage treatments, inside and outside, were planned. Twenty-seven bales were included in the original design. However the amount of hay produced was sufficient for only twenty-three bales. The reduced number of outside stored bales were then determined to be used only for comparison of losses as a group since there was an insufficient number to compare outside-storage losses among bale package types. The final experimental design included hollow core, sliced, and solid type bales produced at 15 and 20% initial moisture contents and stored inside. A completely randomized design was used to meet statistical analysis requirements.

Baling Procedure

After the alfalfa hay was cut, random samples were taken from swaths within the field. These samples were chopped, mixed, and aliquots tested for moisture content to determine the proper time of baling. The procedure followed was to chop the samples into 1.25-cm (.49in.) length by a gasoline engine driven 5-blade chopper. Two random

50-gram (1.76g) aliquots from each of these mixed batches of samples were weighed using a precision balance and recorded. The aliquots were then placed into microwave ovens and dried for 2-minute increments. At the end of each interval the samples were reweighed. The samples were deemed dry when the moisture content did not vary more than 0.05g (0.001oz) for successive weights. Moisture content was calculated on a wet basis by using the wet and dry masses determined (Bales, 1992). Baling started when the hay in the windrow was slightly less than 25% moisture. At the time of baling a 12-inch (30.5cm) polyvinyl chloride (PVC) pipe was inserted into the bale chamber for each hollow-core bale to be made (Figure 1). The hay was then baled around the pipe, producing a bale with a "hollow core". The pipe was removed before the bale was weighed and measured (Figure 2). Engaging the slicing attachment (control button on the liquid crystal display (LCD) readout located in the tractor) resulted in forming a sliced bale. A New Holland 644 Silage Special baler, equipped with the slicing attachment knives, produced slices approximately 4 inches (10.1cm) apart (Figure 3). Disengaging the slicing attachment produced a solid bale, the common large round bale type produced.

Sampling Method

A Penn State core-sampling tool was used to remove hay samples from completed bales. Six core samples from each bale were mixed, then used for moisture content and nutritional analysis. A randomly chosen aliquot was weighed and dried for moisture content analysis. The remainder was sent to the Dairy One Forage laboratory (Dairy One Forage laboratory, 730 Warren Road, Ithaca, NY 14850) for nutritional analysis. The latter analysis included determination of: dry matter (DM), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), available protein, soluble protein,

Figure 1. PVC pipe inserted into the bale chamber to form a hollow core bale

Figure 2. Removal of the PVC pipe from hollow core bales

Figure 3. New Holland 644 Silage Special bale chamber and slicer

nonstructural carbohydrates (NSC), total digestible nutrients (TDN), net energy for lactation (NEl), net energy for maintenance (NEm), net energy for gain (NEg), and sulfur relative feed value (RFV). The bales were weighed and measured at the time of sampling to determine the total dry matter in each bale and bale density.

Thermocouple and Storage Procedure

Three thermocouples were placed within each bale to obtain a representative internal temperature during the curing period. Thermocouples were placed at the quarter, half and three-quarter cross-sectional planes along the length of the bale. The quarter and three-quarter plane thermocouples were placed 12 inches (30.5cm) radially inward from the outer surface of the bale with diametrically opposed placement for the three quarter plane thermocouples relative to those of the quarter plane. The half plane thermocouples were placed at the radial center (for solid and sliced bales) and 4 inches (10.1cm) radially above the hollow core inner surface for hollow core bales (Figures 4 and 5). During the curing period (30 days), the bales were stored outside in a random order in their treatment groups (Figure 6). The bales were spaced approximately 2 feet (0.60 m) apart so air could move freely around the bales. After curing, the bales were ready for storage. Thermocouples were removed and core samples taken and sent to the laboratory for moisture and nutritional analysis determination. Bale weights and measurements were taken as described earlier. After the curing period the bales were stored for a period of five months. Additional core samples were then removed and sent to the laboratory for analysis. Bale weights and measurements were taken again as described above. Bales in treatment groups of 15 and 20% moisture content were stored inside in three bale high "pyramid" stacks (Figure 7). The remaining bales in the outside storage treatment were

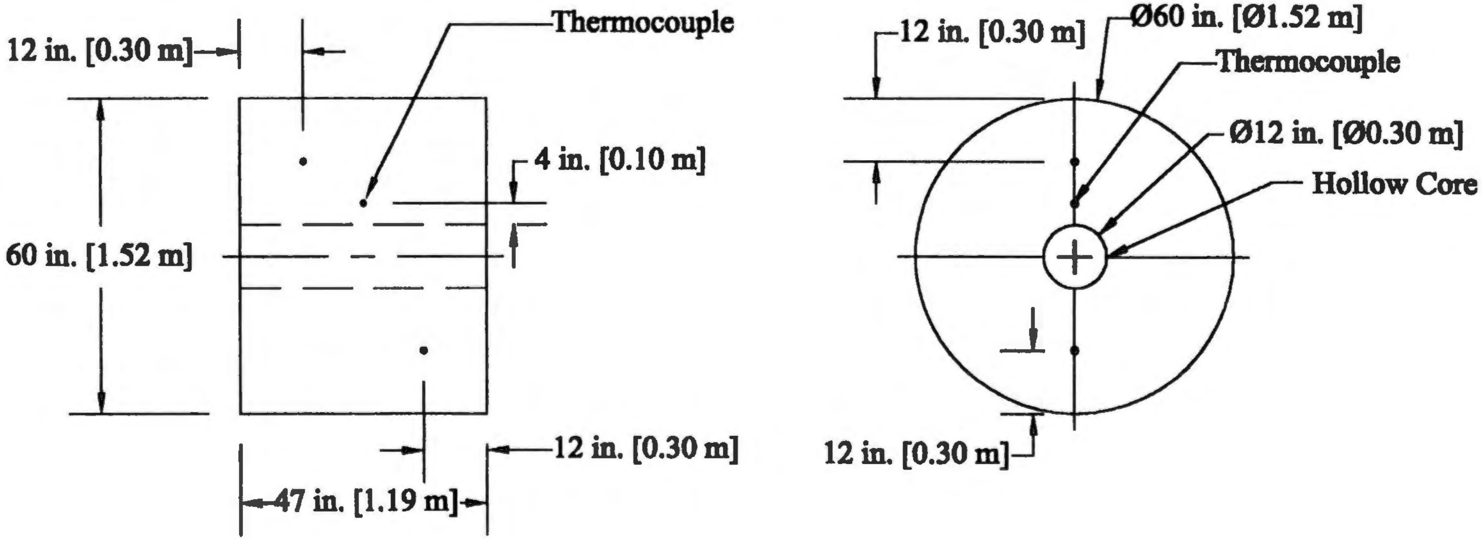

Figure 4. Thermocouple placement in hollow core bales

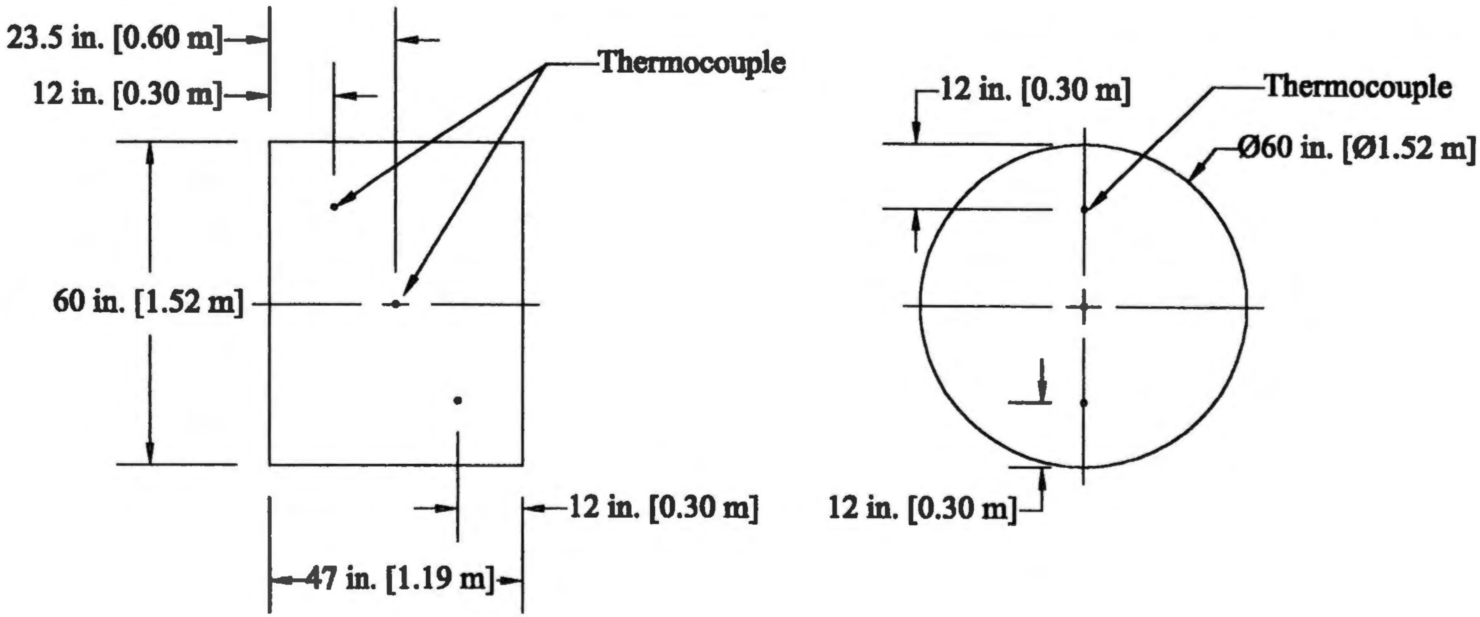

Figure 5. Thermocouple placement in solid and sliced bales

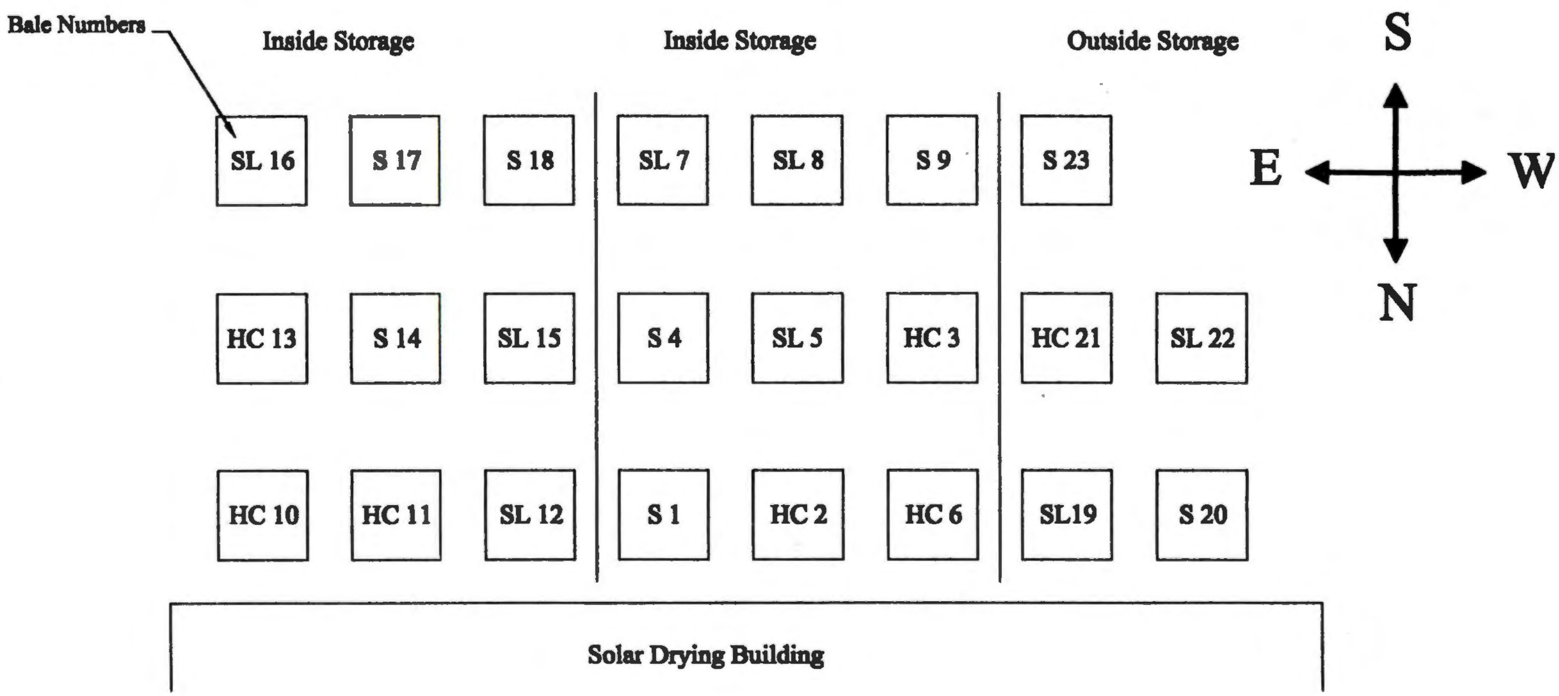

Figure 6. Location of bales during the curing period

Figure 7. Bales stacked inside the barn for storage

left unprotected from weather on a sod base for the remainder of the storage period (Figure 8).

Torque and Speed Measurement

A torque transducer and a proximity switch were added to the power take off (PTO) shaft drive line, with an associated measuring device, to measure and record torque and speed for the calculations of the energy consumed in tub grinding bales for feeding (datalogger programs can be found in Appendix D). The torque transducer (Lebow model 1105-10k) was equipped with a torque protection unit (Figure 9). The protection unit consisted of two steel plates with a shear bolt designed to fail at 9000 in-lbs torque transmitted by the drive line, which is less than the maximum torque capacity specifications for the torque transducer. The proximity switch (Electro Corporation model 58426) measures pulses. As the splined shaft rotates, the magnetic proximity switch senses when a single spline passes its position. When this spline rotates past the sensor, the switch emits one pulse which, is then counted by the datalogger. Length of the entire torque unit and proximity switch required 18 in. (0.47 m) of space between the tractor and the tub grinder; thus, the tractor draw bar had to be extended before operation was possible. A draw bar extension was made from 3x2 in. I-Beam to extend 24 in. (0.60 m) for easy hookup.

Once the transducer was set up and the calibrated, random bales were selected and tub ground to determine the specific energy required for grinding. It was assumed that the bales made at higher moisture contents would be more difficult to grind; thus, the 20% moisture treatment bales were used for the grinding energy determination. Calculations performed after data collection determined the specific energy required to grind each bale of hay. These data then were statistically analyzed.

Figure 8. Bales left outside for the five-month storage period

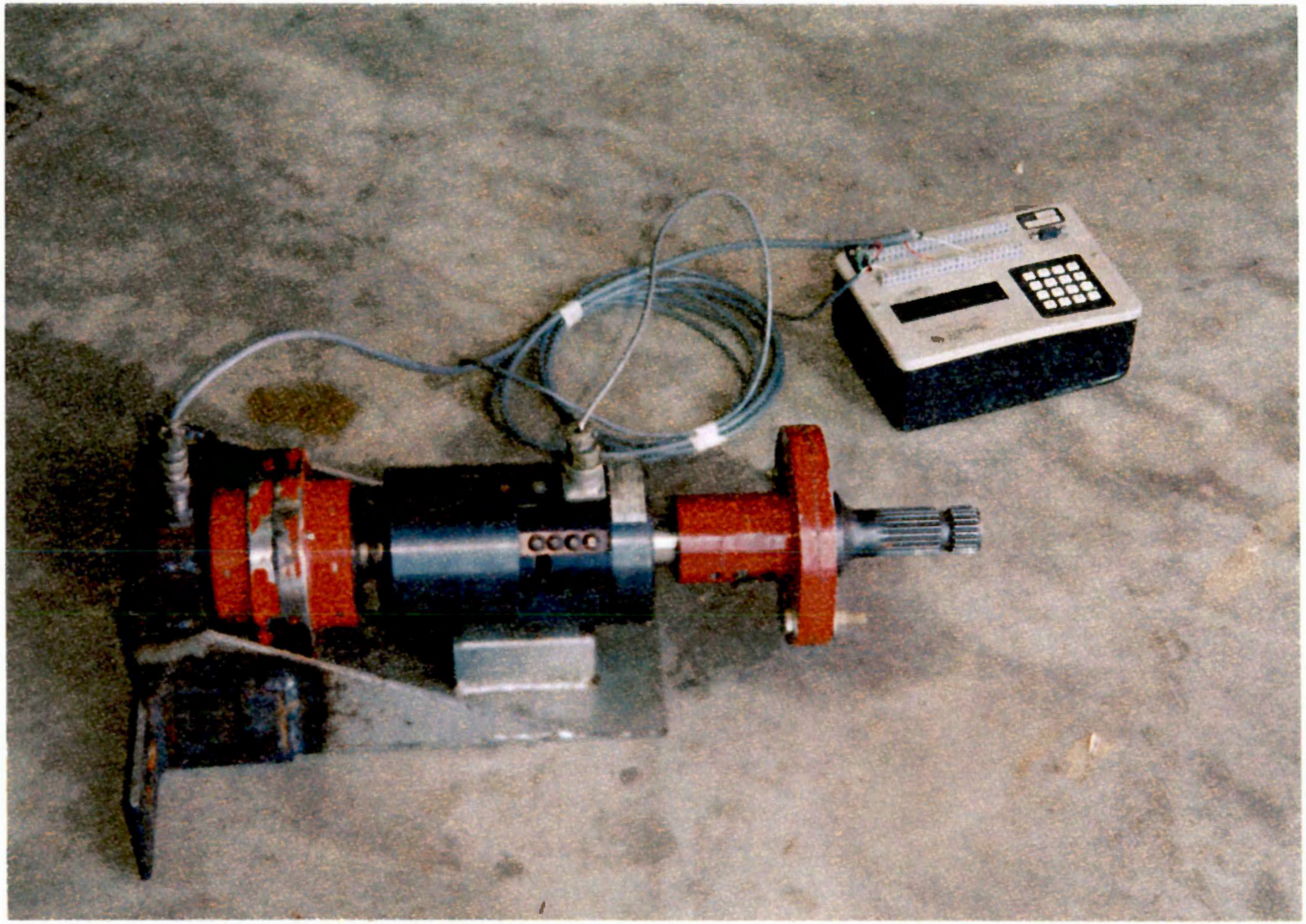

Figure 9. Torque transducer and the accompanying shear protection unit

Chapter 4

Results and Discussion

SAS (1996) was used to analyze results. Any significance reported is at the 0.05 ($p < 0.05$) probability level. Since mcwb and density are considered to have large effects on temperature buildup in large round hay bales, these parameters were used as covariates in analyzing results. This approach removed some of the variation in the data and corrected for errors. All nutritional outcomes reported are from statistical analysis and do not take into account a +/- 3 % error for Dairy One Lab reported values.

Temperature

Internal temperature of the bale is known to affect the nutritional value of the hay. Internal bale temperature is caused by heat generated from microbial respiration, which is related to mcwb of the hay. Bale density also plays a part. Microbes are present on forages, and they use the water present plus nutrients of the hay to sustain their livelihood and release heat into the process. An increase in moisture content increases microbial activity since water is essential to their life functions. High bale density helps to hold heat in the bale. Increased bale density decreases air movement through the bale, thus diminishing natural cooling effects of proper ventilation. These three factors, presence of microbes, high bale density, and high moisture content, together cause degradation in the nutritional value of hay for feeding to livestock.

Temperatures sensed by the three thermocouples placed in each bale were averaged and the averages analyzed statistically. Results show that hollow core bales in the 15% mcwb treatment had significantly lower internal temperatures than solid and sliced bales. For the 36-day period, the overall mean hollow core bale temperature was 90.8°F (32.6°C). Solid and sliced bale overall mean temperatures were 100.6°F (38.1°C) and 101.5°F (38.6°C), respectively. This difference was significant at the 0.05 level of probability (the daily bale temperatures can be found in appendix A). However, for the 15% mcwb treatment, hollow core bales reached a safe storage temperature in approximately three days. It took approximately ten days for the solid and sliced bales to reach a safe storage temperature (Figure 10). This difference may be attributed to two factors: 1) the hollow cores did provide added ventilation. (These bales experienced some air movement even through the collapsed core. The collapse occurred early in the curing period.) 2) The collapsed hollow core had a lower density and moisture content, which will be discussed later in this chapter.

All bales were formed with a new baler straight from the manufacturing plant. Unfortunately, we were unable to increase the belt tension to produce a dense bale. The manufacturer recommended that the belt tension not be increased until the baler had produced 100 bales of hay. The low tension produced a bale that "squatted" or deformed in shape (Figures 11 and 12). This caused the hollow core of the bales to collapse such that the intended cylindrical opening through the bale no longer existed.

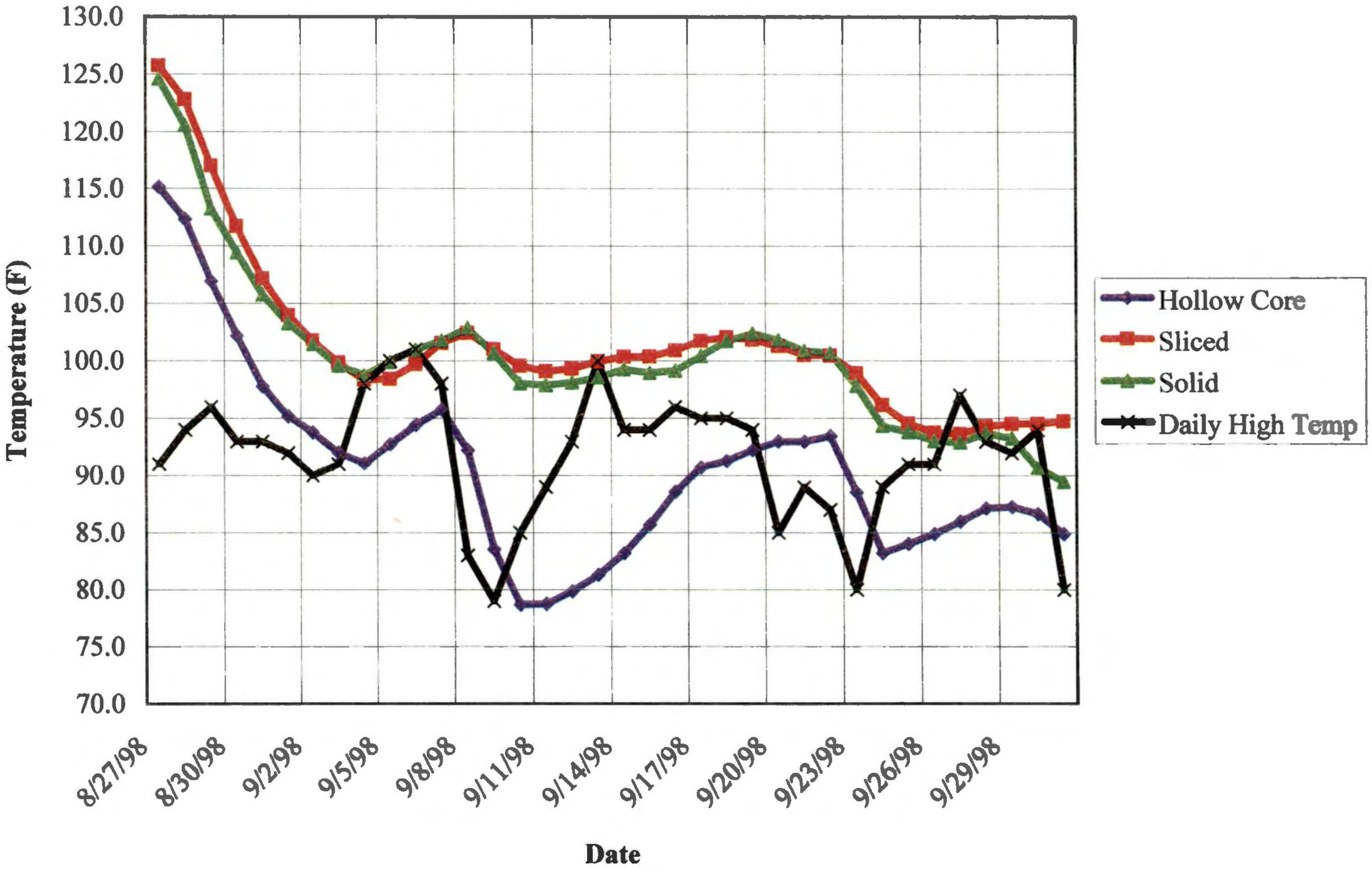

Figure 10. Average daily temperature for 15% moisture bales.

Figure 11. Collapsed hollow core bale after the 36-day curing period.

Figure 12. Collapsed hollow core bale after six months of storage

Temperature results of the 20% mcwb bale treatment showed different trends. These bales remained hotter for a longer period than the 15% mcwb bales (Compare Figures 10 and 13). The safe storage temperature was reached at day 28 in the same 36-day curing period as for the 15% mcwb bales (Figure 13). The collapsed hollow core bales in this treatment had mean temperatures higher than the sliced and solid bales. The overall means for each bale treatment were as follows: collapsed hollow core bales 112.4 °F (44.7 °C), solid bales 108.3 °F (42.4 °C), and sliced bales110.4 °F (43.6 °C). These temperatures were not statistically different at the 0.05 level of probability. The lack of significance can be attributed to decreased airflow through the collapsed hollow core bales. The decreased movement of air, coupled with increased density and moisture content, caused these bales to remain outside the realm of safe storage temperature for a longer period of time than that for the 15% mcwb bales.

Density

Dry matter density is a measure of the amount of actual dry matter per unit volume of a hay bale. In this research, the density is reported in pounds of dry matter per cubic foot or kilograms dry matter per cubic meter. The greater the dry matter densities, the higher the compaction of hay in the bale. The type of package (hollow core, solid, or sliced) significantly affected the density at the 0.05 level of probability. The sliced bales were the most dense, having mean dry matter density of 12.0 lbs/ft^3 (192.2 kg/m^3) for the 20% mcwb treatment and 12.1 lbs/ft^3 (193.8 kg/m^3) for 15% mcwb treatment. The hollow core and solid bale were significantly different from the sliced bales, but were not

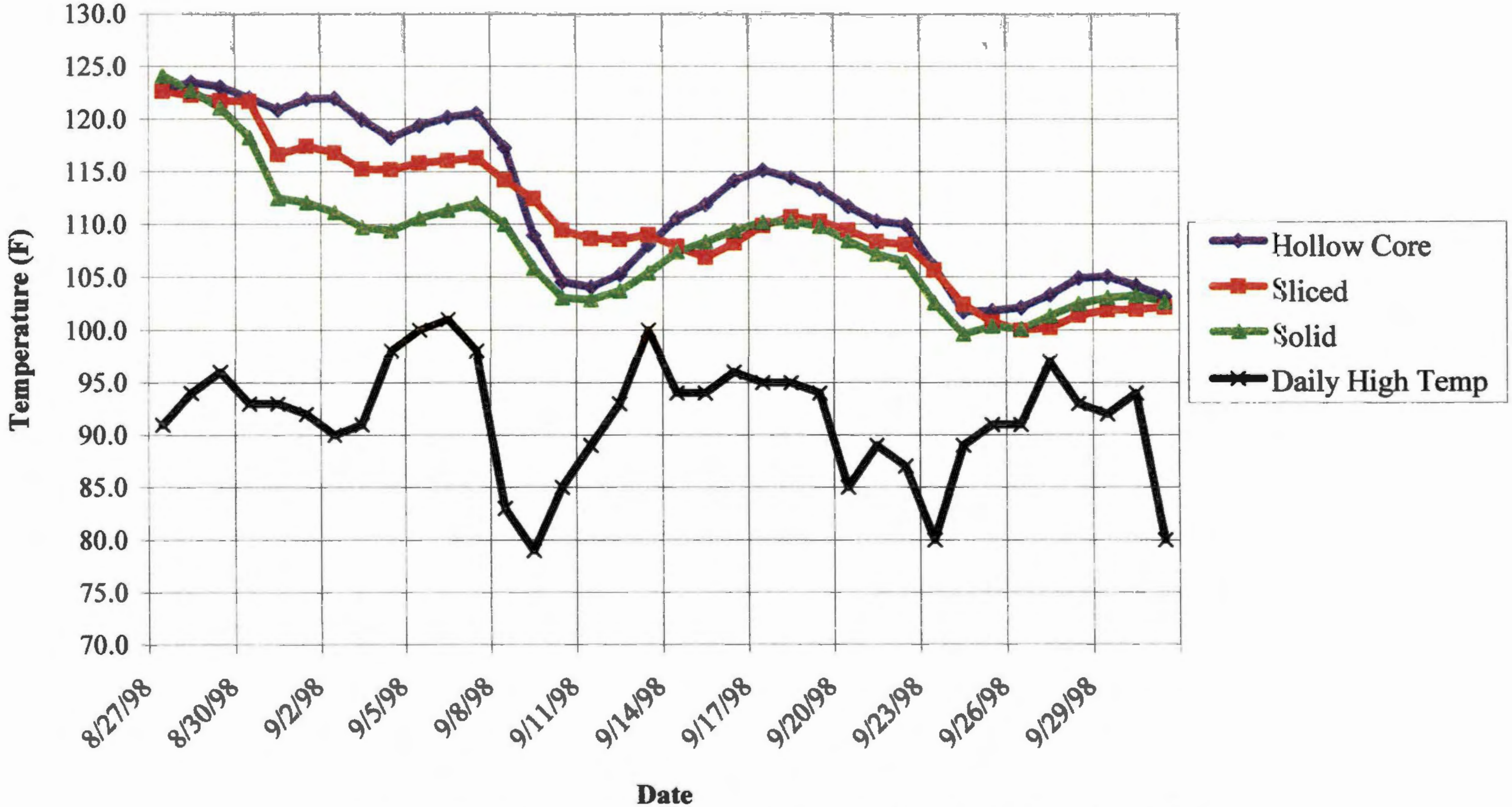

Figure 13. Average daily temperature for 20% moisture content bales

different from each other. The densities for hollow core bales were 10.3 lbs/ft^3 (165.0 kg/m^3) in the 15%mcwb treatment and 11.0 lbs/ft^3 (176.2 kg/m^3) in the 20% mcwb treatment. The solid bales were 10.8 lbs/ft^3 (173.0 kg/m^3) for both 15% mcwb treatment and the 20% mcwb treatment. When the slicing attachment was engaged, hay particle length decreased, allowing closer packing, producing a denser bale.

Moisture Content

The amount of moisture within a bale has a marked effect on the degree of microbial activity affecting degradation of the hay. At high moisture levels, microbial respiration is more prevalent and will cause the majority of damage to the hay. This research sought to compare nominal wet basis moisture contents of 15% and 20% for effects on bale temperature rise and on hay quality degradation. The 15% mcwb level is near the value at which hay is typically baled. However, many times the moisture content is misjudged so that hay is baled at 20% mcwb or higher. In this experiment, at the time of baling the actual mean mcwb of the nominal 15% mcwb treatment was 15.8%. The actual mean mcwb of the nominal 20% treatment was 22.4%. During the 36-day curing period, the bales were allowed to dry naturally from exposure to ambient weather conditions. At the end of this period, the mean bale moisture content for each bale treatment were not statistically different and ranged between 11.3 and 14.1% mcwb. This is the desired mcwb to store hay inside or covered, to minimize the storage losses (Bale mcwb and dry matter density values measured are listed in Appendix B). At the end of the six-month storage period the overall mean mcwb was not statistically different and ranged between 11.8 for 15% nominal mcwb treatment bales, and 13.7% for 20% nominal mcwb treatment bales.

Dry Matter Losses

Unfortunately, in this experiment initial dry matter available at baling was inaccurately measured. The digital scales used for the experiment were not calibrated correctly for the first weighing of bales. A statistical test was performed on the raw data to determine a factor of correction, but the test was inconclusive.

Dry matter losses are a measure of the total dry hay mass losses during curing and storage and through handling. In this experiment, the amount of dry matter losses did not significantly differ from one bale type to another (hollow core, solid, and sliced) after the 36-day curing period, but inaccurate data for initial dry matter available at baling negates any conclusions drawn from this data. The losses were significantly different between treatment after the seven-month storage period. The bales stored outside the barn on the ground lost an average of 14.1% during the first 36-days and an additional 15.0% during the next six months. The total dry matter losses for this storage treatment was 29.1%, which is similar to previous research performed by Verma and Nelson (1981,1983), and Rees (1982). The most unexplainable difference came between bales packaged at 15 and 20% mcwb. The 15% mcwb treatment, which was stored inside the barn, significantly increased in dry matter losses from day one to the end of the storage period. The total losses were 17.5% for the 15% moisture treatment stored inside. The total losses for the 20% mcwb treatment stored inside were 9.8%. These results are the complete opposite of previous research preformed. In previous research preformed by Verma and Nelson (1981,1983), Rees (1982), Rotz and Sprott (1984), and Rotz and Abrams (1988), where hay was baled at different moisture levels, the bales with the highest mcwb typically had the greatest losses of dry matter during the storage period. The results of this experiment show that there is a large experimental error due to mechanical and human error.

Nutritional Losses

Nutritional losses in this experiment were measured and are expressed as percent of total nutrient and as percent loss in each bale. All values are expressed on a dry matter basis (All nutritional analyses are listed in Appendix C). On a dry matter basis, the crude protein (CP) increased in outside storage and in inside storage bales of both 15 and 20% mcwb treatments. No significance differences were observed between storage methods; however, 20 % mcwb bales and outside stored bales increased in CP more than the 15% mcwb bales stored inside. This difference is due to all organic matter being considered as a protein source. Also, the microbe residues inside bales are sources of nitrogen, which can be misrepresented as available protein. Once the microbes are inactive or dead, they too are considered a protein source.

A good measure of heat damaged hay is the available crude protein (CP). Available CP shows the percent protein, which can be readily used by an animal. During the seven-month storage period, bales stored inside the barn at 15% nominal mcwb decreased in available CP (from 14.7 to 14.2% available CP) which was a 3.4 % loss. The

20% nominal mcwb bales stored inside had no change during the same storage period. Conversely, the outside storage bales decreased by an average of 4.5% available CP.

Unavailable protein is the amount of protein in a bale, which is bound to carbohydrates by microbial activity. This protein is not available for digestion and absorption by animals. During the same storage period, unavailable CP in this experiment increased from 1.2 to 1.8% (50.0% increase) for the 15% nominal mcwb treatment, and from 1.1 to 2.3 % unavailable CP (109.1% increase) for the 20% nominal moisture treatment. The outside storage bales increased from 1.4 to 3.0% unavailable CP (114.3% gain). Increase in unavailable CP shows that heat damage occurred and was related to moisture content. Weather conditions added to this effect for the outside storage bales.

The adjusted CP indicated that the 15% treatment decreased 4.3% while the 20% moisture treatment only decreased by 0.5%. The outside storage treatment increased (6.8%) in adjusted CP compared to other treatments. There was no significance between the 15% moisture treatment and outside stored bales.

Non-structural carbohydrates (NSC), neutral detergent fiber (NDF), and acid detergent fiber (ADF) are also used to determine the quality of the hay. In the lab NDF and ADF are tested and then the NSC is calculated by subtracting the ADF from 100%. NSC is a measure of the easily digested non-fiber carbohydrates of a forage. NDF and ADF are measures of the amount of structural components of forages that are difficult to digest. An increase in these fractions (ADF, NDF) would indicate a proportionate decrease in NSC available to animals because of previously digested NSC by microbes within the bale.

The 15% moisture bales in this experiment decreased from 37.8 to 32.1% ADF (a 17.8% decrease) during storage. In the 20% moisture and outside storage treatment bales, ADF remained unchanged for the entire storage period. The NDF increased for both 15 and 20% nominal mcwb treatment bales, about 10%. The outside storage treatment bales had a significant increase in NDF, from 45.2 to 56.8%, an increase of 25.6%. This indicates that microbes and weather conditions degraded outside stored bales more. The outside bales were not included in the temperature test; however, the temperature may have been similar to that of the 20% nominal mcwb treatment. The outside bales were subject to 33.5 inches (85.0 cm) of rain during the six-month storage period (August 27, 1998 to March 24, 1999). This accounts for the greater decrease in nutritional quality.

Total digestible nutrients (TDN) is the measure of the total nutrients available to the animals for digestion. Changes in TDN were significantly different between moisture content levels and not significant between bale package treatments. The greatest amount of change came in the first 36 days of storage. No significant difference occurred after the curing period for any treatment level. The 15% nominal mcwb treatment bales decreased significantly less ($p<0.05$) than 20% nominal mcwb treatment bales and outside stored bales during the curing period. The 15% nominal mcwb treatment bales decreased from 58.4 to 56.2% TDN (3.9% decrease) during curing. The 20% nominal mcwb treatment bales decreased from 56.9 to 54.0% TDN (5.1% decrease) during curing. The outside stored bales decreased from 59.2 to 54.1% TDN (9.4% TDN) during the same 36-day curing period.

Specific Energy

The torque and energy required to grind bales in a tub grinder are of great interest to farmers. The majority of the bales ground in this experiment were from the 20% mcwb treatment. It was thought that since bales were denser at this moisture content level, the bales would be more difficult to grind. However, no bales were difficult to grind with the Henky 600tg Tub Grinder. The average time to grind a bale was 341 s or 5.68 min. The energy values measured for grinding were essentially the same for all bales. These values ranged from 4.7 hp-hr/t (3.9 kw-hr/mt) to 5.6 hp-hr/t (4.6 kw-hr/mt). Statistical analysis showed that energy data from grinding a batch of 123 bales would be required before significant differences could be detected with the subjected lot of bales.

Summary

Temperature data for a 36-day period showed that hollow core bales, produced at 15% mcwb were significantly ($P< 0.05$) cooler (did not generate as much heat) than solid and sliced bales. Actual moisture content and density were lower for the hollow core bales than for solid and sliced bales in this treatment. Added ventilation, provided by even collapsed hollow core bales, maximized the cooling rate for such bales. The decrease in curing time was five days. This amount of time savings can help many farmers who need to get in and out of the field as quickly as possible. At 20% nominal moisture content, no differences were observed among bale types in time for cooling to safe storage temperatures. When temperature was analyzed with covariates of mcwb and density, the differences were less and still insignificant.

The nutritional differences among bale treatments were almost non-existent especially when a +/- 3% laboratory analysis error was considered. However, significant differences were observed between storage treatments (inside vs outside storage) and between mcwb treatments. All outside stored bales showed significantly greater losses than did bales stored inside. Outside bales also showed significant nutrient losses in the outer shell (Figure 14). Samples taken from outside stored bales reflect the entire bale; there was no test to differentiate between the outer shell and the inner core. Thus, increased losses for outside stored bales probably came from the outer shell of the bale. The 20% mcwb bales had greater losses than 15% mcwb bales for almost all the nutrients analyzed except for CP. The cause of increased CP, as stated earlier, is due to microbial activity producing nitrogen sources.

Discussion

The most disappointing factor influencing this experiment was the collapse of the hollow core bales. If the hollow core bales had retained their shape, significantly different results might have been observed. Under natural bale cooling, airflow through the bale is so low that only the circumferential layers of hay are able to cool quickly. In bales with "open centers" (hollow cores), airflow should also cool inner bale layers, promoting more rapid heat flow from the total bale to atmosphere. Previous research has

Figure 14. Rotten outer shell of bales stored outside for six months

proven that bales produced at higher mcwb generate heat that cannot be rapidly dissipated. Hollow core bales should help alleviate this problem.

The densities of all bales made in this experiment were considered low. If the density had been higher, would bale hollow cores have remained open? It is believed that the hollow core would have remained open if the density had been greater. However, this is one phenomenon that needs further research to prove. If hollow core bales will not remain open, and are only used for artificial drying, more research is needed to develop an economically feasible mass drying system.

The use of sliced bales is a good practice for producers trying to feed total mixed rations (TMR). These bales can be separated into several parts: outer shell, sliced disks, and inner core. These three parts can be easily fed into a mixer for timely production of hay and grain mixtures (TMR). In this research, properties of sliced bales were not significantly different from solid bales. However, sliced bales must be stored inside or covered. When sliced bales are stored outside, weather conditions degrade the outer shell of the bale. Since this is the portion of the bale that holds the sliced disks together, the sloughing off or removal of the outer shell causes the bale to fall apart. When a sliced bale was removed from outside storage in this experiment, the bale was speared incorrectly and it caused the outer shell to be broken (Figure 15). Special care must be taken not to disturb the outer shell of a sliced bale before and especially after storage. Careless operation with this type bale can increase feed cost and decrease profits to producers.

Figure 15. Sliced bale that was damaged during handling

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Appendices

Appendix A

Average Daily Temperature For Hollow Core Bales At 20 % Moisture

Date	Ambient Air Te		HC2 Temp Avg (F)	Temp Avg (C)	HC6 Temp Avg (F)	Temp Avg (C)	HC3 Temp Avg (F)	Temp Avg (C)	Hollow Core Average	
	High	Low								
8/27	91	59	120.8	49.3	124.6	51.5	122.8	50.5	122.8	50.4
8/28	94	59	124.3	51.3	123.6	50.9	122.5	50.3	123.5	50.8
8/29	96	59	127.7	53.2	120.3	49.0	121.2	49.5	123.0	50.6
8/30	93	61	128.7	53.7	117.6	47.5	119.7	48.7	122.0	50.0
8/31	93	61	129.0	53.9	117.8	47.7	115.8	46.6	120.9	49.4
9/1	92	63	128.7	53.7	119.2	48.4	117.9	47.7	121.9	50.0
9/2	90	58	126.4	52.4	120.6	49.2	118.9	48.3	121.9	50.0
9/3	91	57	121.5	49.7	120.0	48.9	118.3	48.0	120.0	48.9
9/4	98	57	118.6	48.1	119.7	48.7	116.3	46.9	118.2	47.9
9/5	100	61	120.2	49.0	122.0	50.0	115.9	46.6	119.4	48.5
9/6	101	64	121.4	49.7	123.3	50.7	115.7	46.5	120.1	49.0
9/7	98	65	122.2	50.1	124.1	51.1	115.3	46.3	120.5	49.2
9/8	83	49	116.6	47.0	120.3	49.1	114.9	46.1	117.3	47.4
9/9	79	42	105.1	40.6	111.7	44.3	110.0	43.3	108.9	42.7
9/10	85	43	100.2	37.9	107.7	42.1	105.7	40.9	104.5	40.3
9/11	89	49	99.0	37.2	108.3	42.4	104.9	40.5	104.1	40.0
9/12	93	59	98.2	36.8	111.6	44.2	105.9	41.0	105.2	40.7
9/13	100	60	98.6	37.0	117.9	47.7	107.5	41.9	108.0	42.2
9/14	94	61	101.3	38.5	122.6	50.3	107.8	42.1	110.6	43.6
9/15	94	64	105.6	40.9	122.5	50.3	107.4	41.9	111.9	44.4
9/16	96	63	110.8	43.8	123.3	50.7	108.2	42.4	114.1	45.6
9/17	95	67	113.8	45.5	122.6	50.3	109.0	42.8	115.1	46.2
9/18	95	68	113.9	45.5	120.3	49.0	109.0	42.8	114.4	45.8
9/19	94	69	114.2	45.6	118.3	47.9	107.6	42.0	113.3	45.2
9/20	85	71	112.7	44.8	116.0	46.7	106.3	41.3	111.7	44.3
9/21	89	68	110.9	43.8	114.8	46.0	105.1	40.6	110.3	43.5
9/22	87	61	109.6	43.1	114.4	45.8	105.8	41.0	109.9	43.3
9/23	80	48	102.6	39.2	110.4	43.5	104.8	40.4	105.9	41.1
9/24	89	49	98.7	37.0	106.9	41.6	99.6	37.5	101.7	38.7
9/25	91	57	99.2	37.3	107.8	42.1	98.5	37.0	101.8	38.8
9/26	91	58	99.2	37.3	109.4	43.0	97.7	36.5	102.1	38.9
9/27	97	67	99.7	37.6	112.0	44.5	98.3	36.8	103.3	39.6
9/28	93	65	100.7	38.2	115.0	46.1	98.9	37.2	104.9	40.5
9/29	92	64	101.0	38.3	116.3	46.8	97.8	36.6	105.0	40.6
9/30	94	65	100.8	38.2	116.0	46.7	95.6	35.3	104.2	40.1
10/1	80	42	100.9	38.3	115.6	46.4	93.0	33.9	103.1	39.5

Average Daily Temperature For Solid Bales At 20 % Moisture

			S1		S4		S9		Solid	
Date	Ambient Air Te		Temp	Temp	Temp	Temp	Temp	Temp	Average	
	High	Low	Avg (F)	Avg (C)	Avg (F)	Avg (C)	Avg (F)	Avg (C)		
8/27	91	59	131.1	55.1	131.0	55.0	110.2	43.4	124.1	51.2
8/28	94	59	129.8	54.3	130.3	54.6	107.9	42.2	122.7	50.4
8/29	96	59	126.8	52.7	129.9	54.4	106.5	41.4	121.1	49.5
8/30	93	61	124.1	51.2	129.0	53.9	101.6	38.7	118.2	47.9
8/31	93	61	121.8	49.9	125.3	51.8	90.4	32.4	112.5	44.7
9/1	92	63	119.8	48.8	126.1	52.3	90.3	32.4	112.1	44.5
9/2	90	58	118.4	48.0	126.0	52.2	89.0	31.7	111.1	44.0
9/3	91	57	116.9	47.2	124.7	51.5	87.6	30.9	109.7	43.2
9/4	98	57	116.0	46.7	123.1	50.6	89.0	31.7	109.4	43.0
9/5	100	61	117.5	47.5	122.7	50.4	91.5	33.0	110.6	43.6
9/6	101	64	118.6	48.1	122.4	50.2	93.0	33.9	111.3	44.1
9/7	98	65	119.8	48.8	121.8	49.9	94.3	34.6	112.0	44.4
9/8	83	49	118.2	47.9	119.8	48.8	91.9	33.3	110.0	43.3
9/9	79	42	112.0	44.5	115.3	46.3	90.3	32.4	105.9	41.0
9/10	85	43	108.8	42.7	111.3	44.0	89.1	31.7	103.0	39.5
9/11	89	49	108.3	42.4	109.3	42.9	91.0	32.8	102.9	39.4
9/12	93	59	109.8	43.2	108.8	42.7	92.5	33.6	103.7	39.8
9/13	100	60	112.8	44.9	109.7	43.1	93.6	34.2	105.4	40.8
9/14	94	61	116.7	47.1	111.6	44.2	93.8	34.3	107.4	41.9
9/15	94	64	119.4	48.6	113.2	45.1	92.3	33.5	108.3	42.4
9/16	96	63	120.9	49.4	114.7	46.0	92.6	33.7	109.4	43.0
9/17	95	67	121.0	49.4	116.1	46.7	93.5	34.1	110.2	43.4
9/18	95	68	120.0	48.9	116.7	47.1	94.1	34.5	110.3	43.5
9/19	94	69	118.6	48.1	116.6	47.0	94.2	34.6	109.8	43.2
9/20	85	71	116.9	47.2	115.7	46.5	92.7	33.7	108.4	42.5
9/21	89	68	115.4	46.3	114.4	45.8	91.7	33.2	107.2	41.8
9/22	87	61	114.1	45.6	113.6	45.3	91.6	33.1	106.4	41.3
9/23	80	48	109.8	43.2	111.0	43.9	86.8	30.5	102.6	39.2
9/24	89	49	106.7	41.5	107.7	42.1	84.4	29.1	99.6	37.6
9/25	91	57	106.4	41.4	107.5	42.0	87.2	30.6	100.4	38.0
9/26	91	58	106.8	41.6	107.5	42.0	86.0	30.0	100.1	37.8
9/27	97	67	108.3	42.4	108.6	42.6	87.2	30.6	101.4	38.5
9/28	93	65	110.7	43.7	109.6	43.1	87.1	30.6	102.5	39.1
9/29	92	64	112.7	44.8	109.5	43.0	87.0	30.5	103.0	39.5
9/30	94	65	114.0	45.6	109.1	42.8	86.6	30.4	103.3	39.6
10/1	80	42	114.5	45.9	108.4	42.5	85.0	29.4	102.6	39.2

Average Daily Temperature For Sliced Bales At 20 % Moisture

Date	Ambient Air Te		SL7 Temp Avg (F)	Temp Avg (C)	SL5 Temp Avg (F)	Temp Avg (C)	SL8 Temp Avg (F)	Temp Avg (C)	Sliced Average	
	High	Low								
8/27	91	59	119.5	48.6	119.7	48.7	128.7	53.7	122.6	50.3
8/28	94	59	119.6	48.7	118.8	48.2	128.2	53.4	122.2	50.1
8/29	96	59	120.0	48.9	117.2	47.4	127.8	53.2	121.7	49.8
8/30	93	61	120.8	49.3	116.1	46.7	128.1	53.4	121.6	49.8
8/31	93	61	115.1	46.2	114.1	45.6	120.6	49.2	116.6	47.0
9/1	92	63	116.3	46.9	114.7	46.0	121.1	49.5	117.4	47.4
9/2	90	58	115.9	46.6	115.0	46.1	119.4	48.6	116.8	47.1
9/3	91	57	114.5	45.8	114.2	45.7	117.0	47.2	115.2	46.2
9/4	98	57	114.6	45.9	113.0	45.0	117.9	47.7	115.2	46.2
9/5	100	61	115.3	46.3	113.1	45.1	119.0	48.3	115.8	46.6
9/6	101	64	115.7	46.5	113.3	45.2	119.1	48.4	116.0	46.7
9/7	98	65	115.8	46.6	113.5	45.3	119.5	48.6	116.3	46.8
9/8	83	49	114.2	45.6	112.6	44.8	115.7	46.5	114.2	45.7
9/9	79	42	114.4	45.8	108.9	42.7	114.0	45.7	112.4	44.7
9/10	85	43	112.2	44.6	104.8	40.5	111.1	44.0	109.4	43.0
9/11	89	49	112.6	44.8	102.4	39.1	110.8	43.8	108.6	42.6
9/12	93	59	113.3	45.2	101.0	38.3	111.2	44.0	108.5	42.5
9/13	100	60	114.1	45.6	100.5	38.0	112.3	44.6	109.0	42.8
9/14	94	61	111.2	44.0	100.3	37.9	112.1	44.5	107.9	42.1
9/15	94	64	108.2	42.3	100.2	37.9	112.0	44.5	106.8	41.6
9/16	96	63	109.3	42.9	100.8	38.2	114.4	45.8	108.2	42.3
9/17	95	67	111.1	43.9	101.6	38.7	116.8	47.1	109.8	43.2
9/18	95	68	112.1	44.5	102.1	38.9	117.9	47.7	110.7	43.7
9/19	94	69	111.2	44.0	102.2	39.0	117.3	47.4	110.2	43.5
9/20	85	71	110.5	43.6	102.2	39.0	115.4	46.4	109.4	43.0
9/21	89	68	110.1	43.4	101.6	38.7	113.2	45.1	108.3	42.4
9/22	87	61	110.2	43.5	101.8	38.8	112.1	44.5	108.0	42.2
9/23	80	48	108.6	42.5	100.8	38.2	107.5	42.0	105.6	40.9
9/24	89	49	105.0	40.6	97.5	36.4	104.7	40.4	102.4	39.1
9/25	91	57	102.3	39.0	96.7	35.9	103.3	39.6	100.8	38.2
9/26	91	58	101.2	38.5	96.8	36.0	101.9	38.8	100.0	37.8
9/27	97	67	101.7	38.7	97.4	36.3	101.4	38.6	100.2	37.9
9/28	93	65	103.3	39.6	98.8	37.1	102.1	38.9	101.4	38.5
9/29	92	64	104.0	40.0	99.2	37.3	102.5	39.2	101.9	38.8
9/30	94	65	104.2	40.1	99.1	37.3	102.5	39.2	101.9	38.8
10/1	80	42	104.5	40.3	99.4	37.4	102.5	39.2	102.1	39.0

Average Daily Temperature For Hollow Core Bales At 15 % Moisture

Ambient Air Te			HC10		HC13		HC11		Hollow Core Average	
			Temp	Temp	Temp	Temp	Temp	Temp		
High	Low	Date	Avg (F)	Avg (C	Avg (F)	Avg (C	Avg (F)	Avg (C	(F)	(C)
91	59	8/27	116.4	46.9	115.6	46.4	113.5	45.3	115.2	46.2
94	59	8/28	115.6	46.5	111.3	44.1	110.0	43.4	112.3	44.6
96	59	8/29	111.7	44.3	104.0	40.0	105.1	40.6	106.9	41.6
93	61	8/30	106.8	41.6	99.2	37.3	100.6	38.1	102.2	39.0
93	61	8/31	101.3	38.5	95.2	35.1	96.9	36.1	97.8	36.5
92	63	9/1	98.9	37.2	92.4	33.6	94.2	34.6	95.2	35.1
90	58	9/2	97.8	36.6	90.7	32.6	93.0	33.9	93.8	34.3
91	57	9/3	96.5	35.8	88.4	31.3	91.2	32.9	92.0	33.4
98	57	9/4	97.7	36.5	86.4	30.2	89.0	31.7	91.1	32.8
100	61	9/5	102.3	39.1	86.5	30.3	89.6	32.0	92.8	33.8
101	64	9/6	105.8	41.0	87.0	30.6	90.6	32.5	94.5	34.7
98	65	9/7	107.9	42.1	87.9	31.0	91.6	33.1	95.8	35.4
83	49	9/8	99.2	37.3	87.3	30.7	90.3	32.4	92.3	33.5
79	42	9/9	83.5	28.6	82.9	28.3	84.4	29.1	83.6	28.7
85	43	9/10	77.2	25.1	78.9	26.0	80.1	26.7	78.7	26.0
89	49	9/11	79.4	26.3	77.9	25.5	79.1	26.1	78.8	26.0
93	59	9/12	82.5	28.1	78.1	25.6	79.0	26.1	79.9	26.6
100	60	9/13	85.5	29.7	78.8	26.0	79.7	26.5	81.3	27.4
94	61	9/14	88.9	31.6	80.3	26.8	80.4	26.9	83.2	28.5
94	64	9/15	94.3	34.6	81.8	27.7	81.0	27.2	85.7	29.8
96	63	9/16	100.1	37.8	83.4	28.5	82.2	27.9	88.6	31.4
95	67	9/17	103.3	39.6	85.1	29.5	83.8	28.8	90.7	32.6
95	68	9/18	102.4	39.1	86.6	30.3	84.9	29.4	91.3	33.0
94	69	9/19	103.4	39.7	87.7	31.0	85.6	29.8	92.3	33.5
85	71	9/20	104.8	40.4	88.4	31.4	85.8	29.9	93.0	33.9
89	68	9/21	104.7	40.4	88.4	31.3	86.0	30.0	93.0	33.9
87	61	9/22	104.3	40.2	89.1	31.7	87.1	30.6	93.5	34.2
80	48	9/23	92.1	33.4	87.5	30.8	86.0	30.0	88.5	31.4
89	49	9/24	83.3	28.5	84.3	29.0	82.1	27.9	83.2	28.5
91	57	9/25	85.6	29.8	84.8	29.3	81.7	27.6	84.0	28.9
91	58	9/26	87.2	30.7	85.4	29.7	82.0	27.8	84.9	29.4
97	67	9/27	89.0	31.7	86.5	30.3	82.4	28.0	86.0	30.0
93	65	9/28	91.2	32.9	88.0	31.1	82.2	27.9	87.1	30.6
92	64	9/29	91.3	33.0	88.6	31.5	81.8	27.7	87.3	30.7
94	65	9/30	89.0	31.7	89.0	31.7	81.8	27.7	86.6	30.4
80	48	10/1	85.2	29.6	89.4	31.9	80.0	26.7	84.9	29.4

Average Daily Temperature
For
Solid Bales
At 15 % Moisture

			S14		S17		S18		Solid	
Ambient Air Te			Temp	Temp	Temp	Temp	Temp	Temp	verage	
High	Low	Date	Avg (F)	Avg (C	Avg (F)	Avg (C	Avg (F)	Avg (C	(F)	(C)
91	59	8/27	127.2	52.9	115.8	46.6	130.8	54.9	124.6	51.4
94	59	8/28	122.3	50.2	111.5	44.2	127.9	53.3	120.6	49.2
96	59	8/29	114.3	45.7	106.6	41.4	118.9	48.3	113.3	45.2
93	61	8/30	107.4	41.9	103.1	39.5	117.9	47.7	109.5	43.0
93	61	8/31	101.8	38.8	100.3	37.9	115.2	46.2	105.8	41.0
92	63	9/1	97.9	36.6	98.5	37.0	113.4	45.2	103.3	39.6
90	58	9/2	96.0	35.6	97.8	36.6	110.6	43.6	101.5	38.6
91	57	9/3	95.1	35.0	96.3	35.7	107.4	41.9	99.6	37.6
98	57	9/4	95.5	35.3	94.1	34.5	106.7	41.5	98.8	37.1
100	61	9/5	98.8	37.1	93.7	34.3	107.2	41.8	99.9	37.7
101	64	9/6	102.0	38.9	93.7	34.3	107.2	41.8	101.0	38.3
98	65	9/7	104.9	40.5	92.9	33.8	107.5	41.9	101.8	38.8
83	49	9/8	106.4	41.3	91.7	33.1	110.5	43.6	102.9	39.4
79	42	9/9	104.6	40.3	87.3	30.7	110.2	43.4	100.7	38.1
85	43	9/10	104.4	40.2	83.0	28.4	106.8	41.5	98.1	36.7
89	49	9/11	106.7	41.5	81.7	27.6	105.3	40.7	97.9	36.6
93	59	9/12	108.6	42.5	81.5	27.5	104.3	40.1	98.1	36.7
100	60	9/13	109.3	43.0	82.2	27.9	104.1	40.1	98.6	37.0
94	61	9/14	109.8	43.2	83.0	28.3	105.0	40.6	99.3	37.4
94	64	9/15	109.2	42.9	83.7	28.7	104.0	40.0	99.0	37.2
96	63	9/16	108.0	42.2	85.5	29.7	104.0	40.0	99.1	37.3
95	67	9/17	107.2	41.8	87.8	31.0	106.3	41.3	100.4	38.0
95	68	9/18	106.4	41.3	89.5	31.9	109.3	43.0	101.7	38.7
94	69	9/19	106.0	41.1	90.2	32.3	111.0	43.9	102.4	39.1
85	71	9/20	105.2	40.7	90.7	32.6	109.6	43.1	101.8	38.8
89	68	9/21	103.9	39.9	91.0	32.8	107.7	42.1	100.9	38.3
87	61	9/22	103.1	39.5	92.0	33.3	106.8	41.6	100.7	38.1
80	48	9/23	100.4	38.0	90.2	32.3	103.0	39.4	97.9	36.6
89	49	9/24	97.4	36.3	86.1	30.1	99.7	37.6	94.4	34.7
91	57	9/25	97.2	36.2	86.0	30.0	98.4	36.9	93.8	34.4
91	58	9/26	97.0	36.1	86.3	30.2	95.9	35.5	93.1	33.9
97	67	9/27	97.3	36.3	87.1	30.6	94.4	34.7	93.0	33.9
93	65	9/28	98.4	36.9	88.6	31.5	94.3	34.6	93.8	34.3
92	64	9/29	97.0	36.1	88.9	31.6	94.0	34.5	93.3	34.1
94	65	9/30	89.4	31.9	88.9	31.6	93.8	34.3	90.7	32.6
80	48	10/1	85.4	29.7	89.3	31.8	93.7	34.3	89.5	31.9

Average Daily Temperature For Sliced Bales At 15 % Moisture

			SL16		SL12		SL15		Sliced	
Ambient Air Te			Temp	Temp	Temp	Temp	Temp	Temp	Average	
High	Low	Date	Avg (F)	Avg (C	Avg (F)	Avg (C	Avg (F)	Avg (C	(F)	(C)
91	59	8/27	119.4	48.5	129.6	54.2	128.3	53.5	125.7	52.1
94	59	8/28	118.4	48.0	125.1	51.7	124.8	51.6	122.8	50.4
96	59	8/29	114.2	45.6	117.7	47.6	119.1	48.4	117.0	47.2
93	61	8/30	110.5	43.6	111.6	44.2	113.1	45.1	111.7	44.3
93	61	8/31	107.6	42.0	106.4	41.3	107.5	41.9	107.2	41.8
92	63	9/1	105.7	41.0	102.5	39.2	103.6	39.8	103.9	40.0
90	58	9/2	104.2	40.1	100.1	37.8	100.9	38.3	101.7	38.7
91	57	9/3	102.7	39.3	98.6	37.0	98.2	36.8	99.8	37.7
98	57	9/4	101.5	38.6	97.5	36.4	95.9	35.5	98.3	36.8
100	61	9/5	101.4	38.5	98.1	36.7	95.7	35.4	98.4	36.9
101	64	9/6	101.9	38.8	100.0	37.8	97.0	36.1	99.7	37.6
98	65	9/7	102.4	39.1	102.4	39.1	99.7	37.6	101.5	38.6
83	49	9/8	100.6	38.1	104.1	40.1	102.4	39.1	102.4	39.1
79	42	9/9	97.3	36.3	102.9	39.4	102.7	39.3	101.0	38.3
85	43	9/10	94.9	34.9	100.9	38.3	102.8	39.3	99.5	37.5
89	49	9/11	93.0	33.9	100.1	37.8	104.1	40.1	99.1	37.3
93	59	9/12	91.6	33.1	100.3	37.9	106.0	41.1	99.3	37.4
100	60	9/13	91.1	32.8	101.2	38.5	107.4	41.9	99.9	37.7
94	61	9/14	91.0	32.8	101.5	38.6	108.4	42.5	100.3	38.0
94	64	9/15	90.9	32.7	101.4	38.6	108.7	42.6	100.3	38.0
96	63	9/16	91.6	33.1	102.2	39.0	108.8	42.6	100.9	38.3
95	67	9/17	93.0	33.9	103.3	39.6	108.8	42.6	101.7	38.7
95	68	9/18	94.3	34.6	103.6	39.8	108.2	42.3	102.0	38.9
94	69	9/19	95.3	35.2	102.5	39.2	107.6	42.0	101.8	38.8
85	71	9/20	95.7	35.4	101.4	38.6	106.6	41.5	101.2	38.5
89	68	9/21	95.7	35.4	100.3	38.0	105.3	40.7	100.5	38.0
87	61	9/22	96.4	35.8	100.1	37.8	104.8	40.4	100.4	38.0
80	48	9/23	94.1	34.5	99.2	37.4	103.3	39.6	98.9	37.2
89	49	9/24	92.9	33.8	95.5	35.3	100.1	37.8	96.2	35.6
91	57	9/25	92.2	33.4	92.9	33.9	98.6	37.0	94.6	34.8
91	58	9/26	91.6	33.1	91.9	33.3	97.8	36.6	93.8	34.3
97	67	9/27	91.8	33.2	91.6	33.1	97.5	36.4	93.6	34.2
93	65	9/28	92.8	33.8	92.2	33.5	97.9	36.6	94.3	34.6
92	64	9/29	93.4	34.1	92.3	33.5	97.9	36.6	94.5	34.7
94	65	9/30	93.7	34.3	92.2	33.5	97.7	36.5	94.5	34.7
80	48	10/1	94.1	34.5	92.5	33.6	97.7	36.5	94.8	34.9

Appendix B

BALE		FIELD			HAY TYPE		
	S1		GOAT LOT			ALFALFA GRASS MIX	

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT	
		WEIGHTS					
Date	Initial	Final	%WET	%DRY		DATE	WEIGHT lbs
8/27/98	53.30	39.78	25.37	33.99		8/27/98	928
10/1/98	50.13	42.93	14.36	16.77		10/1/98	862
3/24/99	49.98	44.37	11.22	12.64		3/24/99	826

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	59	MEAN maj (in.)	D1	47	MEAN maj (in.)	D1	46	MEAN maj (in.)
D2	53	58	D2	65	61.63	D2	65	61.375
D3	58	MEAN min (in.	D3	50	MEAN min (in.	D3	48	MEAN min (in.
D4	58	54.5	D4	64	48.5	D4	65	47
D5	56		D5	59.25		D5	57.5	
D6	57	MEAN L (in.)	D6	58.25	MEAN L (in.)	D6	58	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		67.49	VOL =cu ft		63.81	VOL =cu ft		61.59
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	10.26	9.08		11.57	11.24		11.91	11.72

BALE		FIELD			HAY TYPE		
	HC2		GOAT LOT			ALFALFA GRASS MIX	

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT	
		WEIGHTS					
Date	Initial	Final	%WET	%DRY		DATE	WEIGHT lbs
8/27/98	50.21	39.07	22.19	28.51		8/27/98	912
10/1/98	50.00	43.71	12.58	14.39		10/1/98	814
3/24/99	49.98	43.67	12.63	14.45		3/24/99	796

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	51	MEAN maj (in.)	D1	46	MEAN maj (in.)	D1	48	MEAN maj (in.)
D2	60	58.5	D2	57	59.38	D2	64	61.625
D3	50.5	MEAN min (in.)	D3	47	MEAN min (in.)	D3	44	MEAN min (in.)
D4	59	50.75	D4	65	46.50	D4	68	46
D5	58		D5	58		D5	57	
D6	57	MEAN L (in.)	D6	57.5	MEAN L (in.)	D6	57.5	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		63.39	VOL =cu ft		58.95	VOL =cu ft		60.53
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	11.20	10.29		12.07	11.82		11.49	11.25

BALE		FIELD			HAY TYPE		
	HC3		GOAT LOT			ALFALFA GRASS MIX	

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT				BALE WEIGHT	
		WEIGHTS				
Date	Initial	Final	%WET	%DRY	DATE	EIGHT lbs
8/27/98	50.39	38.08	24.43	32.33	8/27/98	994
10/1/98	50.00	43.24	13.52	15.63	10/1/98	890
3/24/99	50.14	43.95	12.35	14.08	3/24/99	866

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	52	MEAN maj (in.)	D1	48	MEAN maj (in.)	D1	45	MEAN maj (in.)
D2	59.5	58	D2	68	63.75	D2	69	63.875
D3	52	MEAN min (in.	D3	45	MEAN min (in.	D3	47	MEAN min (in.
D4	57	52	D4	68	46.5	D4	68	46
D5	58		D5	59		D5	59	
D6	57.5	MEAN L (in.)	D6	60	MEAN L (in.)	D6	59.5	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		64.40	VOL =cu ft		63.29	VOL =cu ft		62.74

DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	11.66	10.45		12.16	11.86		12.10	11.86

BALE		FIELD			HAY TYPE		
	S4		GOAT LOT			ALFALFA GRASS MIX	

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT	
		WEIGHTS					
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs
8/27/98	50.68	37.72	25.57	34.36		8/27/98	1006
10/1/98	50.00	43.85	12.30	14.03		10/1/98	894
3/24/99	50.01	43.95	12.12	13.79		3/24/99	836

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	52	MEAN maj (in.)	D1	48.5	MEAN maj (in.)	D1	47	MEAN maj (in.)
D2	59	57.875	D2	64	61.38	D2	65	61.5
D3	51.5	MEAN min (in.	D3	44.5	MEAN min (in.	D3	47	MEAN min (in.
D4	58.5	51.75	D4	65	46.5	D4	65	47
D5	57		D5	58.5		D5	57.5	
D6	57	MEAN L (in.)	D6	58	MEAN L (in.)	D6	58.5	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		63.95	VOL =cu ft		60.94	VOL =cu ft		61.72
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	11.71	10.33		12.87	12.61		11.90	11.68

BALE		FIELD			HAY TYPE			
	SL5		GOAT LOT				ALFALFA GRASS MIX	

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT	
		WEIGHTS					
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs
8/27/98	51.78	41.95	18.98	23.43		8/27/98	1042
10/1/98	50.00	43.52	12.96	14.89		10/1/98	980
3/24/99	50	43.98	12.04	13.69		3/24/99	962

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	55	MEAN maj (in.)	D1	50	MEAN maj (in.)	D1	49	MEAN maj (in.)
D2	56	56.38	D2	61	59.44	D2	63	60.50
D3	51.5	MEAN min (in.	D3	51	MEAN min (in.	D3	48	MEAN min (in.
D4	56.5	53.25	D4	60	50.50	D4	62	48.50
D5	56.5		D5	58.25		D5	58	
D6	56.5	MEAN L (in.)	D6	58.5	MEAN L (in.)	D6	59	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		64.09585476	VOL =cu ft		64.08784804	VOL =cu ft		62.65
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	13.17	12.45		13.31	13.01		13.51	13.25

BALE		FIELD		HAY TYPE	
	HC6	GOAT LOT		ALFALFA GRASS MIX	

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT			
		WEIGHTS		
Date	INITIAL	FINAL	%WET	%DRY
8/27/98	50.43	38.85	22.96	29.81
10/1/98	50.00	43.24	13.52	15.63
3/24/99	50.00	43.98	12.04	13.69

BALE WEIGHT	
DATE	WEIGHT lbs
8/27/98	986
10/1/98	812
3/24/99	796

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	55.5	MEAN maj (in.	D1	47	MEAN maj (in.	D1	47	MEAN maj (in.
D2	60	59.25	D2	66	61.75	D2	65	61.125
D3	53.5	MEAN min (in.	D3	45	MEAN min (in.	D3	44	MEAN min (in.
D4	59	54.5	D4	65	46	D4	64	45.5
D5	59		D5	58		D5	57.5	
D6	59	MEAN L (in.)	D6	58	MEAN L (in.)	D6	58	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
OL =cu ft		68.95	OL =cu ft		60.65	OL =cu ft		59.38
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	11.02	10.04		11.58	11.30		11.79	11.57

BALE		FIELD			HAY TYPE			
	SL7		GOAT LOT			ALFALFA GRASS MIX		

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT		
		WEIGHTS						
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT	lbs
8/27/98	50.39	39.79	21.04	26.64		8/27/98	1106	
10/1/98	50.00	42.11	15.78	18.74		10/1/98	976	
3/24/99	49.99	44.1	11.78	13.36		3/24/99	944	

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	54.5	MEAN maj (in.	D1	52	MEAN maj (in.	D1	53	MEAN maj (in.
D2	59	57.875	D2	69	62.5	D2	66	61.5
D3	51	MEAN min (in.	D3	48	MEAN min (in.	D3	48	MEAN min (in.
D4	58	52.75	D4	64	50	D4	65	50.5
D5	57.5		D5	59		D5	57.5	
D6	57	MEAN L (in.)	D6	58	MEAN L (in.)	D6	57.5	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
OL =cu ft		65.18	OL =cu ft		66.72	OL =cu ft		66.31
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	13.40	12.45		12.32	11.89		12.56	12.33

BALE		FIELD			HAY TYPE			
	SL8		**GOAT LOT**			**ALFALFA GRASS MIX**		

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT	
		WEIGHTS					
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs
8/27/98	50.09	38.42	23.30	30.37		8/27/98	1000
10/1/98	50.38	43.27	14.11	16.43		10/1/98	908
3/24/99	50.02	43.98	12.08	13.73		3/24/99	900

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	52	MEAN maj (in.	D1	49.5	MEAN maj (in.	D1	52	MEAN maj (in.
D2	59	58.25	D2	63	60.38	D2	65	61.5
D3	57.5	MEAN min (in.	D3	51	MEAN min (in.	D3	50	MEAN min (in.
D4	57.5	52	D4	62	50.25	D4	64	51
D5	52		D5	58.5		D5	58.5	
D6	59	MEAN L (in.)	D6	58	MEAN L (in.)	D6	58.5	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
OL =cu ft		64.67	OL =cu ft		64.78	OL =cu ft		66.97
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	11.86	10.77		12.04	11.71		11.82	11.59

BALE		FIELD			HAY TYPE		
	S9		GOAT LOT			ALFALFA GRASS MIX	

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT	
		WEIGHTS					
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs
8/27/98	50.45	41.31	18.12	22.13		8/27/98	870
10/1/98	50.00	44.4	11.20	12.61		10/1/98	792
3/24/99	49.99	44.17	11.64	13.18		3/24/99	788

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	52	MEAN maj (in.)	D1	48	MEAN maj (in.)	D1	48	MEAN maj (in.)
D2	58.5	58.25	D2	63	60.25	D2	63	61.75
D3	50.5	MEAN min (in.)	D3	49	MEAN min (in.)	D3	47	MEAN min (in.)
D4	57	51.25	D4	63	48.5	D4	69	47.5
D5	57		D5	57.5		D5	57	
D6	60.5	MEAN L (in.)	D6	57.5	MEAN L (in.)	D6	58	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
OL =cu ft		63.74	OL =cu ft		62.39	OL =cu ft		62.63
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	11.18	10.63		11.27	11.09		11.12	10.92

BALE		FIELD			HAY TYPE		
	HC10		**GOAT LOT**			**ALFALFA GRASS MIX**	

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT	
		WEIGHTS					
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs
8/27/98	50.29	42.1	16.29	19.45		8/27/98	824
10/1/98	50.00	44.86	10.28	11.46		10/1/98	748
3/24/99	50.13	44.13	11.97	13.60		3/24/99	728

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	51.5	MEAN maj (in.	D1	43.5	MEAN maj (in.	D1	48	MEAN maj (in.
D2	66	65.5	D2	67	62.75	D2	68	63.75
D3	46.5	MEAN min (in.	D3	49	MEAN min (in.	D3	44	MEAN min (in.
D4	65	49	D4	67	46.25	D4	69	46
D5	65		D5	59		D5	60	
D6	66	MEAN L (in.)	D6	58	MEAN L (in.)	D6	58	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
OL =cu ft		68.53	OL =cu ft		61.97	OL =cu ft		62.61
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	10.07	9.69		10.83	10.69		10.24	10.05

BALE		FIELD			HAY TYPE			
	S11		GOAT LOT			ALFALFA GRASS MIX		

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT		
		WEIGHTS						
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs	
8/27/98	50.00	43.96	12.08	13.74		8/27/98	776	
10/1/98	50.00	43.6	12.80	14.68		10/1/98	752	
3/24/99	50.14	44.52	11.21	12.62		3/24/99	748	

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	52	MEAN maj (in.	D1	44	MEAN maj (in.	D1	47	MEAN maj (in.
D2	60	60.875	D2	66	61.75	D2	63	61
D3	49.5	MEAN min (in.	D3	47.5	MEAN min (in.	D3	45	MEAN min (in.
D4	62	50.75	D4	65	45.75	D4	65	46
D5	62		D5	58		D5	58	
D6	59.5	MEAN L (in.)	D6	58	MEAN L (in.)	D6	58	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
OL =cu ft		65.96	OL =cu ft		60.32	OL =cu ft		59.91
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	10.34	10.15		10.87	10.64		11.09	10.91

BALE		FIELD			HAY TYPE			
	SL12		GOAT LOT			ALFALFA GRASS MIX		

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT		
		WEIGHTS						
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs	
8/27/98	50.39	42.21	16.23	19.38		8/27/98	960	
10/1/98	50.00	44.34	11.32	12.76		10/1/98	898	
3/24/99	50.10	42.98	14.21	16.57		3/24/99	886	

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	50	MEAN maj (in.	D1	47.5	MEAN maj (in.	D1	45	MEAN maj (in.
D2	60	59.875	D2	64	61	D2	64	61.5
D3	52	MEAN min (in.	D3	49.5	MEAN min (in.	D3	50	MEAN min (in.
D4	60	51	D4	64	48.5	D4	64	47.5
D5	59.5		D5	58		D5	59.5	
D6	60	MEAN L (in.)	D6	58	MEAN L (in.)	D6	58.5	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
OL =cu ft		65.20	OL =cu ft		63.17	OL =cu ft		62.37
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	12.33	11.87		12.61	12.40		12.19	11.85

BALE		FIELD			HAY TYPE			
	HC13		GOAT LOT			ALFALFA GRASS MIX		

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT		
		WEIGHTS						
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs	
8/27/98	50.03	42.74	14.57	17.06		8/27/98	832	
10/1/98	50.00	44.57	10.86	12.18		10/1/98	784	
3/24/99	50.49	44.14	12.58	14.39		3/24/99	776	

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	54.5	MEAN maj (in.	D1	45.5	MEAN maj (in.	D1	51	MEAN maj (in.
D2	64	63.5	D2	67	63.5	D2	66	62.875
D3	48	MEAN min (in.	D3	49.5	MEAN min (in.	D3	46	MEAN min (in.
D4	64	51.25	D4	68	47.5	D4	67	48.5
D5	63		D5	60		D5	59.5	
D6	63	MEAN L (in.)	D6	59	MEAN L (in.)	D6	59	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
OL =cu ft		69.49	OL =cu ft		64.40	OL =cu ft		65.11
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	10.23	9.93		10.85	10.69		10.42	10.20

BALE		FIELD			HAY TYPE		
	S14		GOAT LOT			ALFALFA GRASS MIX	

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT	
		WEIGHTS					
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs
8/27/98	50.57	42.76	15.44	18.26		8/27/98	850
10/1/98	50.00	44.55	10.90	12.23		10/1/98	862
3/24/99	50.01	44.73	10.56	11.80		3/24/99	788

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	50	MEAN maj (in.)	D1	50.5	MEAN maj (in.)	D1	49	MEAN maj (in.)
D2	59.5	60.25	D2	64	61.0625	D2	63	61.25
D3	48	MEAN min (in.	D3	44.5	MEAN min (in.	D3	47	MEAN min (in.
D4	62	49	D4	64	47.5	D4	65	48
D5	59.5		D5	58.25		D5	58.5	
D6	60	MEAN L (in.)	D6	58	MEAN L (in.)	D6	58.5	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		63.03	VOL =cu ft		61.93	VOL =cu ft		62.77
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	11.40	11.02		12.40	12.22		11.23	11.07

BALE		FIELD			HAY TYPE		
	SL15		GOAT LOT			ALFALFA GRASS MIX	

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT	
		WEIGHTS					
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs
8/27/98	50.07	41.83	16.46	19.70		8/27/98	1002
10/1/98	50.00	43.82	12.36	14.10		10/1/98	928
3/24/99	50.02	43.92	12.20	13.89		3/24/99	846

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	51	MEAN maj (in.)	D1	48	MEAN maj (in.)	D1	48	MEAN maj (in.)
D2	60	59.25	D2	65	61.4375	D2	67	61.625
D3	51.5	MEAN min (in.	D3	49.5	MEAN min (in.	D3	49	MEAN min (in.
D4	61	51.25	D4	64	48.75	D4	63	48.5
D5	58.5		D5	58.5		D5	58	
D6	57.5	MEAN L (in.)	D6	58.25	MEAN L (in.)	D6	58.5	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		64.83	VOL =cu ft		63.95	VOL =cu ft		63.81
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	12.91	12.41		12.72	12.47		11.64	11.42

BALE		FIELD			HAY TYPE			
	SL16		**GOAT LOT**			**ALFALFA GRASS MIX**		

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT		
		WEIGHTS						
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs	
8/27/98	50.00	40.17	19.66	24.47		8/27/98	1014	
10/1/98	50.00	43.92	12.16	13.84		10/1/98	926	
3/24/99	49.67	44.06	11.29	12.73		3/24/99	916	

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	54	MEAN maj (in.)	D1	51	MEAN maj (in.)	D1	52	MEAN maj (in.)
D2	61	59.625	D2	67	62.875	D2	68	63.25
D3	51	MEAN min (in.	D3	47	MEAN min (in.	D3	47	MEAN min (in.
D4	61	52.5	D4	66	49	D4	65	49.5
D5	58		D5	59.5		D5	60	
D6	58.5	MEAN L (in.)	D6	59	MEAN L (in.)	D6	60	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		66.84	VOL =cu ft		65.78	VOL =cu ft		66.85
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	12.19	11.46		12.37	12.13		12.16	11.96

BALE		FIELD			HAY TYPE			
	S17		GOAT LOT			ALFALFA GRASS MIX		

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT		
		WEIGHTS						
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs	
8/27/98	50.88	42.54	16.39	19.61		8/27/98	848	
10/1/98	50.00	44.91	10.18	11.33		10/1/98	794	
3/24/99	50.00	44.05	11.90	13.51		3/24/99	778	

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	53.5	MEAN maj (in.)	D1	49	MEAN maj (in.)	D1	52	MEAN maj (in.)
D2	59	60.75	D2	64	60.6875	D2	60	60.375
D3	48.5	MEAN min (in.	D3	56.5	MEAN min (in.	D3	48	MEAN min (in.
D4	63	51	D4	62	52.75	D4	63	50
D5	60.5		D5	58.25		D5	59.5	
D6	60.5	MEAN L (in.)	D6	58.5	MEAN L (in.)	D6	59	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		66.15	VOL =cu ft		68.35	VOL =cu ft		64.45
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	10.72	10.31		10.43	10.30		10.63	10.44

BALE		FIELD			HAY TYPE			
	S18		GOAT LOT			ALFALFA GRASS MIX		

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT		
		WEIGHTS						
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs	
8/27/98	49.98	42.33	15.31	18.07		8/27/98	862	
10/1/98	50.00	43.18	13.64	15.79		10/1/98	790	
3/24/99	50.10	43.55	13.07	15.04		3/24/99	798	

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	52.5	MEAN maj (in.)	D1	47.5	MEAN maj (in.)	D1	48	MEAN maj (in.)
D2	60	61.625	D2	69	62.375	D2	57	59.75
D3	49	MEAN min (in.	D3	48.5	MEAN min (in.	D3	50	MEAN min (in.
D4	65	50.75	D4	62	48	D4	62	49
D5	59.5		D5	60.5		D5	60	
D6	62	MEAN L (in.)	D6	58	MEAN L (in.)	D6	60	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		66.78	VOL =cu ft		63.93	VOL =cu ft		62.51
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	10.93	10.58		10.67	10.41		11.10	10.85

BALE		FIELD			HAY TYPE			
	SL19		GOAT LOT			ALFALFA GRASS MIX		

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT		
		WEIGHTS						
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs	
8/27/98	50.02	42.38	15.27	18.03		8/27/98	982	
10/1/98	50.15	44.04	12.18	13.87		10/1/98	912	
3/24/99	50.01	44.25	11.52	13.02		3/24/99	884	

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	50	MEAN maj (in.)	D1	48	MEAN maj (in.)	D1	44	MEAN maj (in.)
D2	60	61.25	D2	64	61.5625	D2	62	59.5
D3	47.5	MEAN min (in.	D3	45.5	MEAN min (in.	D3	42	MEAN min (in.
D4	64	48.75	D4	66	46.75	D4	60	43
D5	59.5		D5	58.25		D5	58	
D6	61.5	MEAN L (in.)	D6	58	MEAN L (in.)	D6	58	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		63.75	VOL =cu ft		61.45	VOL =cu ft		54.63
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	13.05	12.63		13.03	12.78		14.32	14.08

BALE		FIELD			HAY TYPE		
	S20		GOAT LOT			ALFALFA GRASS MIX	

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT				BALE WEIGHT	
		WEIGHTS				
Date	INITIAL	FINAL	%WET	%DRY	DATE	WEIGHT lbs
8/27/98	50.25	40.72	18.97	23.40	8/27/98	886
10/1/98	49.78	42.94	13.74	15.93	10/1/98	774
3/24/99	50.08	41.42	17.29	20.91	3/24/99	770

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	51	MEAN maj (in.)	D1	50	MEAN maj (in.)	D1	44	MEAN maj (in.)
D2	60.5	60.625	D2	63	61.25	D2	65	61.5
D3	49.5	MEAN min (in.	D3	44.5	MEAN min (in.	D3	42	MEAN min (in.
D4	62	50.25	D4	66	47.25	D4	64	43
D5	58.5		D5	58		D5	59	
D6	61.5	MEAN L (in.)	D6	58	MEAN L (in.)	D6	58	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		65.04	VOL =cu ft		61.79	VOL =cu ft		56.46
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	11.04	10.43		10.80	10.53		11.28	10.79

BALE		FIELD			HAY TYPE		
	HC21		GOAT LOT			ALFALFA GRASS MIX	

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT	
		WEIGHTS					
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT lbs
8/27/98	50.43	40.94	18.82	23.18		8/27/98	838
10/1/98	49.65	43.7	11.98	13.62		10/1/98	742
3/24/99	50.12	34.47	31.23	45.40		3/24/99	708

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	49	MEAN maj (in.)	D1	46	MEAN maj (in.)	D1	43	MEAN maj (in.)
D2	61.5	60.875	D2	65	62.06	D2	60	60.125
D3	46.5	MEAN min (in.	D3	42	MEAN min (in.	D3	41	MEAN min (in.
D4	62.5	47.75	D4	67	44	D4	63	42
D5	59		D5	58.25		D5	58.5	
D6	60.5	MEAN L (in.)	D6	58	MEAN L (in.)	D6	59	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		62.06	VOL =cu ft		58.30	VOL =cu ft		53.92
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	10.96	10.37		11.20	10.99		9.03	7.17

BALE		FIELD			HAY TYPE		
	SL22		GOAT LOT			ALFALFA GRASS MIX	

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT			
		WEIGHTS		
Date	INITIAL	FINAL	%WET	%DRY
8/27/98	50.11	39.39	21.39	27.22
10/1/98	49.34	42.56	13.74	15.93
3/24/99	34.44	28.85	16.23	19.38

BALE WEIGHT	
DATE	WEIGHT lbs
8/27/98	1034
10/1/98	920
3/24/99	887

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	49.5	MEAN maj (in.)	D1	44.5	MEAN maj (in.)	D1	na	MEAN maj (in.)
D2	61	61.25	D2	65	62.125	D2	na	na
D3	47.5	MEAN min (in.	D3	45	MEAN min (in.	D3	na	MEAN min (in.
D4	64	48.5	D4	66.5	44.75	D4	na	na
D5	59		D5	58.5		D5	na	
D6	61	MEAN L (in.)	D6	58.5	MEAN L (in.)	D6	na	MEAN L (in.)
L1	47	47	L1	47	47	L1	na	na
L2	47		L2	47		L2	na	
L3	47		L3	47		L3	na	
VOL =cu ft		63.43	VOL =cu ft		59.36	VOL =cu ft		na
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	12.81	11.87		13.37	13.03		na	na

BALE		FIELD			HAY TYPE			
	S23		GOAT LOT			ALFALFA GRASS MIX		

FORAGE MOISTURE CONTENT AND BALE DENSITY

	FORAGE MOISTURE CONTENT					BALE WEIGHT		
		WEIGHTS						
Date	INITIAL	FINAL	%WET	%DRY		DATE	WEIGHT	lbs
8/27/98	50.54	35.93	28.91	40.66		8/27/98	1028	
10/1/98	48.94	41.91	14.36	16.77		10/1/98	814	
3/24/99	51.06	41.82	18.10	22.09		3/24/99	776	

BALE DENSITY

DATE	8/27/98		DATE	10/1/98		DATE	3/24/99	
	SIZE in.			SIZE in.			SIZE in.	
D1	52	MEAN maj (in.)	D1	45	MEAN maj (in.)	D1	49	MEAN maj (in.)
D2	61	61.375	D2	68	62.625	D2	59	59.375
D3	48	MEAN min (in.	D3	45.5	MEAN min (in.	D3	44	MEAN min (in.
D4	63	50	D4	65	45.25	D4	61	46.5
D5	60.5		D5	59		D5	58.5	
D6	61	MEAN L (in.)	D6	58.5	MEAN L (in.)	D6	59	MEAN L (in.)
L1	47	47	L1	47	47	L1	47	47
L2	47		L2	47		L2	47	
L3	47		L3	47		L3	47	
VOL =cu ft		65.52	VOL =cu ft		60.50	VOL =cu ft		58.95
DENSITY	lbs / cu ft		DENSITY	lbs / cu ft		DENSITY	lbs / cu ft	
	w.b	d.b		w.b	d.b		w.b	d.b
	11.15	9.31		11.52	11.20		10.78	10.26

Appendix C

		Bale Nutritional Values					
		Field	Measure	Lab	Lab	As Fed	DM
		Wet	Dry	Moisture	Dm	Cp	Cp
Date	BALE	%	%	%	%	%	%
8/27/98	S1	25.4	34.0	24.8	75.2	11.6	15.4
8/27/98	HC2	22.2	28.5	24.9	75.1	11.9	15.8
8/27/98	HC3	24.4	32.3	26.9	73.1	10.9	14.9
8/27/98	S4	25.6	34.4	26.5	73.5	9.7	13.2
8/27/98	SL5	19.0	23.4	21.3	78.7	13.4	17.0
8/27/98	HC6	23.0	29.8	24.1	75.9	11.8	15.5
8/27/98	SL7	21.1	26.7	24.6	75.4	11.6	15.4
8/27/98	SL8	23.3	30.4	25.7	74.3	10.5	14.1
8/27/98	S9	18.1	22.1	20.3	79.7	12.0	15.1
8/27/98	HC10	16.3	19.5	9.7	90.3	13.8	15.3
8/27/98	HC11	12.1	13.7	9.1	90.9	15.5	17.1
8/27/98	SL12	16.2	19.4	9.4	90.6	13.2	14.6
8/27/98	HC13	14.6	17.1	9.6	90.4	13.7	15.1
8/27/98	S14	15.4	18.3	10.2	89.8	15.6	17.4
8/27/98	SL15	16.5	19.7	9.3	90.7	13.2	14.6
8/27/98	SL16	18.5	22.7	9.7	90.3	14.1	15.6
8/27/98	S17	16.4	19.6	10.0	90.0	14.9	16.6
8/27/98	S18	15.3	18.1	9.6	90.4	14.6	16.2
8/27/98	SL19	15.2	18.0	10.3	89.7	14.5	16.2
8/27/98	S20	18.9	23.4	10.9	89.1	14.3	16.0
8/27/98	HC21	18.8	23.1	10.2	89.8	14.7	16.4
8/27/98	SL22	21.4	27.2	10.5	89.5	14.1	15.8
8/27/98	S23	28.9	40.6	12.1	87.9	13.8	15.7

		Bale Nutritional Values					
	As Fed	DM	As Fed	DM	As Fed	DM	As Fed
	Aval Cp	Aval Cp	Unaval Cp	Unaval Cp	Adj Cp	Adj Cp	ADF
BALE	%	%	%	%	%	%	%
S1	10.8	14.3	0.8	1.1	11.6	15.4	25.5
HC2	11.0	14.6	0.9	1.2	11.9	15.8	25.8
HC3	10.1	13.8	0.8	1.1	10.9	14.9	23.6
S4	9.0	12.2	0.7	1.0	9.7	13.2	25.7
SL5	12.6	16.0	0.8	1.0	13.4	17.0	26.4
HC6	10.9	14.3	0.9	1.2	11.8	15.5	25.4
SL7	10.8	14.3	0.8	1.1	11.6	15.4	24.4
SL8	9.5	12.8	1.0	1.3	10.5	14.1	26.1
S9	11.2	14.0	0.9	1.1	12.0	15.1	27.0
HC10	12.7	14.3	1.1	1.2	13.8	15.3	32.1
HC11	14.6	16.1	0.9	1.0	15.5	17.1	32.7
SL12	12.3	13.6	0.9	1.0	13.2	14.6	36.8
HC13	12.7	14.0	1.0	1.1	13.7	15.1	34.5
S14	14.6	16.3	1.0	1.1	15.6	17.4	32.5
SL15	12.2	13.4	1.1	1.2	13.2	14.6	35.3
SL16	12.8	14.2	1.3	1.4	14.1	15.6	35.5
S17	13.8	15.3	1.2	1.3	14.9	16.6	34.9
S18	13.4	14.8	1.3	1.4	14.6	16.2	33.4
SL19	13.4	14.9	1.2	1.3	14.5	16.2	33.5
S20	13.1	14.7	1.2	1.3	14.3	16.0	35.2
HC21	13.5	15.0	1.3	1.4	14.7	16.4	32.7
SL22	13.0	14.5	1.2	1.3	14.1	15.8	34.2
S23	12.5	14.2	1.3	1.5	13.8	15.7	33.3

		Bale Nutritional Values					
	DM	As Fed	DM	As Fed	DM	As Fed	DM
	ADF	NDF	NDF	NSC	NSC	TDN	TDN
BALE	%	%	%	%	%	%	%
S1	33.9	37.6	50.0	17.8	23.7	43.0	57.0
HC2	34.3	36.4	48.5	18.6	24.8	43.0	57.0
HC3	32.3	37.2	50.9	17.0	23.3	42.0	57.0
S4	35.0	40.3	54.8	15.5	21.1	40.0	55.0
SL5	33.5	33.8	42.9	23.0	29.2	46.0	59.0
HC6	33.4	37.2	49.0	18.7	24.6	43.0	57.0
SL7	32.4	36.0	47.8	19.5	25.9	44.0	58.0
SL8	35.1	40.9	55.0	14.9	20.0	41.0	55.0
S9	25.4	38.7	48.6	20.2	25.4	45.0	57.0
HC10	35.5	45.9	50.8	20.8	23.8	51.0	57.0
HC11	36.0	37.7	41.5	27.7	30.5	55.0	60.0
SL12	40.6	46.5	51.3	21.0	23.2	52.0	57.0
HC13	38.2	43.5	48.1	23.4	25.9	52.0	58.0
S14	36.2	39.0	43.4	25.4	28.3	54.0	60.0
SL15	38.9	45.4	50.0	22.2	24.5	53.0	58.0
SL16	39.3	43.0	47.6	23.4	25.9	52.0	58.0
S17	38.8	41.4	48.0	23.9	26.5	53.0	59.0
S18	37.0	40.7	45.0	25.2	27.9	53.0	59.0
SL19	37.4	41.1	45.8	24.3	27.1	53.0	59.0
S20	39.5	39.8	44.7	25.3	28.4	53.0	59.0
HC21	36.4	39.1	43.5	26.2	29.2	54.0	60.0
SL22	38.2	40.5	45.2	25.1	28.1	53.0	59.0
S23	37.9	42.6	48.5	21.9	24.9	51.0	58.0

		Bale Nutritional Values					
	As Fed	DM	As Fed	DM	As Fed	DM	
	NEl	NEl	NEm	NEm	NEg	NEg	RFV
BALE	MCAL / lb	MCAL / lb	MCAL / lb	MCAL / lb	MCAL / lb	MCAL / lb	$
S1	0.44	0.59	0.42	0.56	0.23	0.30	116
HC2	0.44	0.59	0.43	0.57	0.23	0.31	119
HC3	0.42	0.58	0.40	0.55	0.22	0.30	116
S4	0.42	0.57	0.40	0.54	0.21	0.28	105
SL5	0.48	0.61	0.46	0.59	0.26	0.33	136
HC6	0.45	0.59	0.43	0.56	0.24	0.31	119
SL7	0.44	0.59	0.43	0.57	0.23	0.31	124
SL8	0.42	0.57	0.40	0.54	0.21	0.28	104
S9	0.47	0.59	0.45	0.56	0.25	0.31	120
HC10	0.53	0.59	0.51	0.57	0.28	0.31	112
HC11	0.56	0.62	0.55	0.61	0.32	0.35	136
SL12	0.53	0.59	0.51	0.56	0.28	0.31	104
HC13	0.54	0.60	0.52	0.58	0.29	0.32	114
S14	0.56	0.62	0.54	0.60	0.31	0.34	130
SL15	0.54	0.59	0.52	0.57	0.28	0.31	109
SL16	0.54	0.60	0.52	0.58	0.29	0.32	114
S17	0.55	0.61	0.53	0.59	0.30	0.33	119
S18	0.55	0.61	0.53	0.59	0.30	0.33	124
SL19	0.55	0.61	0.53	0.59	0.30	0.33	121
S20	0.54	0.61	0.53	0.59	0.29	0.33	121
HC21	0.55	0.61	0.54	0.60	0.31	0.34	129
SL22	0.55	0.61	0.53	0.59	0.30	0.33	122
S23	0.53	0.60	0.51	0.58	0.28	0.32	114

		Bale Nutritional Values					
		Field	Measure	Lab	Lab	As Fed	DM
		Wet	Dry	Moisture	Dm	Cp	Cp
Date	BALE	%	%	%	%	%	%
10/1/98	S1	25.4	34.0	9.7	90.3	14.1	15.6
10/1/98	HC2	22.2	28.5	9.3	90.7	16.1	17.8
10/1/98	HC3	24.4	32.3	9.7	90.3	15.7	17.4
10/1/98	S4	25.6	34.4	9.2	90.8	14.8	16.3
10/1/98	SL5	19.0	23.4	9.8	90.2	14.8	16.4
10/1/98	HC6	23.0	29.8	9.4	90.6	14.9	16.5
10/1/98	SL7	21.1	26.7	9.7	90.3	14.8	16.4
10/1/98	SL8	23.3	30.4	8.4	91.6	14.3	15.6
10/1/98	S9	18.1	22.1	8.6	91.4	14.1	15.4
10/1/98	HC10	16.3	19.5	8.1	91.9	13.1	14.3
10/1/98	HC11	12.1	13.7	9.0	91.0	13.2	14.5
10/1/98	SL12	16.2	19.4	8.5	91.5	14.9	16.3
10/1/98	HC13	14.6	17.1	8.7	91.3	13.1	14.3
10/1/98	S14	15.4	18.3	9.2	90.8	14.4	15.9
10/1/98	SL15	16.5	19.7	8.8	91.2	12.7	13.9
10/1/98	SL16	18.5	22.7	8.9	91.1	14.8	16.3
10/1/98	S17	16.4	19.6	8.6	91.4	14.3	15.6
10/1/98	S18	15.3	18.1	9.4	90.6	15.2	16.8
10/1/98	SL19	15.2	18.0	9.6	90.4	15.3	16.9
10/1/98	S20	18.9	23.4	9.2	90.8	14.3	15.8
10/1/98	HC21	18.8	23.1	9.2	90.8	15.4	17.0
10/1/98	SL22	21.4	27.2	9.8	90.2	14.6	16.2
10/1/98	S23	28.9	40.6	9.7	90.3	14.9	16.5

		Bale Nutritional Values					
	As Fed	DM	As Fed	DM	As Fed	DM	As Fed
	Aval Cp	Aval Cp	Unaval Cp	Unaval Cp	Adj Cp	Adj Cp	ADF
BALE	%	%	%	%	%	%	%
S1	12.6	14.0	1.4	1.6	13.5	15.0	31.2
HC2	14.2	15.7	1.9	2.1	15.1	16.7	34.4
HC3	13.7	15.2	2.0	2.2	14.6	16.2	33.4
S4	13.1	14.4	1.7	1.9	14.0	15.4	32.4
SL5	13.5	15.0	1.3	1.4	14.8	16.4	31.6
HC6	13.4	14.8	1.5	1.7	14.3	15.8	31.3
SL7	12.8	14.2	2.0	2.2	13.7	15.2	32.1
SL8	12.4	13.5	1.9	2.1	13.3	14.5	33.7
S9	12.6	13.8	1.5	1.6	13.5	14.8	33.5
HC10	11.3	12.3	1.8	2.0	12.2	13.3	33.5
HC11	11.7	12.9	1.5	1.6	12.6	13.9	31.1
SL12	13.4	14.6	1.6	1.7	14.3	15.6	36.1
HC13	11.8	12.9	1.3	1.4	13.1	14.3	31.5
S14	13.0	14.3	1.5	1.6	13.9	15.3	31.1
SL15	10.9	11.9	1.8	2.0	11.8	12.9	34.9
SL16	13.2	14.5	1.6	1.8	14.1	15.5	30.6
S17	12.6	13.8	1.6	1.8	13.5	14.8	34.1
S18	13.0	14.3	2.3	2.5	13.9	15.3	31.8
SL19	13.6	15.0	1.7	1.9	14.5	16.0	31.5
S20	12.2	13.4	2.2	2.4	13.1	14.4	34.2
HC21	13.4	14.8	2.0	2.2	14.3	15.8	33.2
SL22	12.6	14.0	2.0	2.2	13.5	15.0	34.1
S23	12.1	13.4	2.8	3.1	13.0	14.4	34.7

		Bale Nutritional Values					
	DM	As Fed	DM	As Fed	DM	As Fed	DM
	ADF	NDF	NDF	NSC	NSC	TDN	TDN
BALE	%	%	%	%	%	%	%
S1	34.6	48.7	53.9	19.1	21.2	51	56
HC2	37.9	47.1	51.9	19.5	21.5	51	56
HC3	37.0	51.4	56.9	15.4	17.0	50	55
S4	35.7	50.8	55.9	17.1	18.8	50	55
SL5	35.0	48.6	53.9	18.2	20.2	51	56
HC6	34.5	48.5	53.5	18.8	20.8	51	56
SL7	35.6	48.5	53.7	19.1	21.2	51	56
SL8	36.8	56.0	61.1	13.3	14.5	49	54
S9	36.7	50.8	55.6	18.0	19.7	51	56
HC10	36.4	49.9	54.3	20.7	22.5	51	55
HC11	34.2	42.2	46.4	27.1	29.8	53	58
SL12	39.5	53.8	58.8	14.4	15.7	50	55
HC13	34.5	46.5	50.9	23.1	25.3	52	57
S14	34.3	48.0	52.9	19.9	21.9	51	56
SL15	38.3	51.0	55.9	19.4	21.3	50	55
SL16	33.6	49.3	54.1	18.7	20.5	51	56
S17	37.3	45.4	49.7	23.4	25.6	52	57
S18	35.1	45.2	49.9	22.6	24.9	52	57
SL19	34.9	44.0	48.7	23.0	25.4	52	57
S20	37.7	48.9	53.8	19.9	21.9	50	55
HC21	36.6	48.4	53.3	19.1	21.0	51	56
SL22	37.8	48.6	53.9	19.1	21.2	51	56
S23	38.4	52.1	57.7	16.3	18.0	49	54

		Bale Nutritional Values					
	As Fed	DM	As Fed	DM	As Fed	DM	
	NEI	NEI	NEm	NEm	NEg	NEg	RFV
BALE	MCAL / lb	MCAL / lb	MCAL / lb	MCAL / lb	MCAL / lb	MCAL / lb	$
S1	0.52	0.58	0.50	0.55	0.26	0.29	107
HC2	0.53	0.58	0.50	0.55	0.26	0.29	106
HC3	0.51	0.56	0.48	0.53	0.24	0.27	98
S4	0.52	0.57	0.48	0.53	0.25	0.28	102
SL5	0.52	0.58	0.50	0.55	0.26	0.29	106
HC6	0.53	0.58	0.50	0.55	0.26	0.29	108
SL7	0.51	0.57	0.49	0.54	0.25	0.28	106
SL8	0.50	0.55	0.47	0.51	0.24	0.26	92
S9	0.52	0.57	0.49	0.54	0.26	0.28	101
HC10	0.52	0.57	0.50	0.54	0.26	0.28	104
HC11	0.55	0.60	0.53	0.58	0.29	0.32	125
SL12	0.51	0.56	0.48	0.53	0.25	0.27	92
HC13	0.54	0.59	0.51	0.56	0.27	0.30	113
S14	0.53	0.58	0.50	0.55	0.26	0.29	109
SL15	0.51	0.56	0.48	0.53	0.25	0.27	98
SL16	0.52	0.57	0.49	0.54	0.26	0.29	108
S17	0.54	0.59	0.51	0.56	0.27	0.30	112
S18	0.53	0.58	0.50	0.55	0.27	0.30	115
SL19	0.53	0.59	0.52	0.57	0.28	0.31	118
S20	0.52	0.57	0.49	0.54	0.25	0.28	103
HC21	0.52	0.57	0.49	0.54	0.26	0.29	105
SL22	0.51	0.57	0.49	0.54	0.25	0.28	103
S23	0.50	0.55	0.46	0.51	0.23	0.26	95

		Bale Nutritional Values					
		Field	Measure	Lab	Lab	As Fed	DM
		Wet	Dry	Moisture	Dm	Cp	Cp
Date	BALE	%	%	%	%	%	%
3/24/99	S1	25.4	34.0	10.2	89.8	14.8	16.5
3/24/99	HC2	22.2	28.5	10.4	89.6	14.7	16.4
3/24/99	HC3	24.4	32.3	10.7	89.3	15.9	17.8
3/24/99	S4	25.6	34.4	10.1	89.9	14.4	16
3/24/99	SL5	19.0	23.4	10.5	89.5	15.3	17.1
3/24/99	HC6	23.0	29.8	9.3	90.7	14.1	15.5
3/24/99	SL7	21.1	26.7	9.7	90.3	14.3	15.8
3/24/99	SL8	23.3	30.4	10	90	14.2	15.8
3/24/99	S9	18.1	22.1	9.4	90.6	14.4	15.9
3/24/99	HC10	16.3	19.5	9.1	90.9	12.7	14
3/24/99	HC11	12.1	13.7	9.1	90.9	15.4	16.9
3/24/99	SL12	16.2	19.4	9.6	90.4	13.4	14.8
3/24/99	HC13	14.6	17.1	9.2	90.8	13.6	15
3/24/99	S14	15.4	18.3	9.5	90.5	15.2	16.8
3/24/99	SL15	16.5	19.7	8.9	91.1	13.3	14.6
3/24/99	SL16	18.5	22.7	9.7	90.3	15.1	16.7
3/24/99	S17	16.4	19.6	10.1	89.9	15.9	17.7
3/24/99	S18	15.3	18.1	9.7	90.3		
3/24/99	SL19	15.2	18.0	27.8	72.2	12.2	16.9
3/24/99	S20	18.9	23.4	12.9	87.9	14.9	17.1
3/24/99	HC21	18.8	23.1	11.6	88.4	16.3	18.4
3/24/99	SL22	21.4	27.2	11	89	15.9	17.9
3/24/99	S23	28.9	40.6	21.6	78.4	10.7	13.6

		Bale Nutritional Values					
	As Fed	DM	As Fed	DM	As Fed	DM	As Fed
	Aval Cp	Aval Cp	Unaval Cp	Unaval Cp	Adj Cp	Adj Cp	ADF
BALE	%	%	%	%	%	%	%
S1	12.4	13.8	2.4	2.7	13.3	14.8	30.8
HC2	13	14.5	1.7	1.9	13.9	15.5	29.3
HC3	13.7	15.3	2.2	2.5	14.6	16.3	29.3
S4	12	13.4	2.3	2.6	12.9	14.4	28.9
SL5	13.7	15.3	1.6	1.8	14.6	16.3	28.6
HC6	11.9	13.1	2.2	2.4	12.8	14.1	31.9
SL7	12.1	13.4	2.2	2.4	13	14.4	31
SL8	12.1	13.4	2.2	2.4	13	14.4	30.2
S9	12.9	14.2	1.5	1.7	13.8	15.2	29.2
HC10	11.3	12.4	1.5	1.6	12.2	13.4	29.8
HC11	13.9	15.3	1.5	1.6	14.8	16.3	29.2
SL12	11.8	13	1.6	1.8	12.7	14	29.6
HC13	12.3	13.5	1.4	1.5	13.2	14.5	27.4
S14	13.7	15.1	1.5	1.7	14.6	16.1	27.5
SL15	11.8	12.9	1.5	1.7	12.7	13.9	31
SL16	13	14.4	2.1	2.3	13.9	15.4	28.8
S17	14.4	16	1.5	1.7	15.3	17	27.9
S18			1.7	1.9			30.7
SL19	8.7	12	3.5	4.9	9.4	13	31.8
S20	12.4	14.2	2.5	2.9	13.2	15.2	31
HC21	14.1	15.9	2.2	2.5	14.9	16.9	29.7
SL22	13.5	15.2	2.4	2.7	14.4	16.2	30.2
S23	8.8	11.2	1.9	2.4	9.6	12.2	35.2

		Bale Nutritional Values					
	DM	As Fed	DM	As Fed	DM	As Fed	DM
	ADF	NDF	NDF	NSC	NSC	TDN	TDN
BALE	%	%	%	%	%	%	%
S1	34.3	50.3	56	17.3	19.3	49	55
HC2	32.7	47.6	53.1	19.3	21.5	50	56
HC3	32.8	43.9	49.2	22	24.6	51	57
S4	32.2	50.3	56	17.7	19.7	49	55
SL5	32	46.4	51.8	19.7	22	51	57
HC6	35.2	51.6	56.9	17.3	19.1	49	54
SL7	34.3	48.8	54	19.6	21.7	50	55
SL8	33.6	51.8	57.5	16.4	18.2	49	54
S9	32.2	48.2	53.2	19.7	21.7	51	56
HC10	32.8	53.8	59.2	15.9	17.5	50	55
HC11	32.1	41.7	45.9	25.4	27.9	54	59
SL12	32.7	50.4	55.8	18.4	20.3	50	55
HC13	30.2	48.3	53.2	20.3	22.4	51	56
S14	30.4	43.8	48.4	23.2	25.6	52	58
SL15	34	52.7	57.8	16.8	18.4	50	55
SL16	31.9	43.2	47.8	24.3	26.9	51	57
S17	31	42.8	47.6	22.9	25.5	52	58
S18	34	48.2	53.4	27.2	30.1	50	55
SL19	44	40.3	55.8	15.4	21.3	38	52
S20	35.6	48.6	55.8	16.6	19.1	47	54
HC21	33.6	47.6	53.9	17.1	19.3	50	56
SL22	33.9	49.8	55.9	16	18	49	55
S23	44.9	51.4	65.6	9.6	12.3	40	51

		Bale Nutritional Values					
	As Fed	DM	As Fed	DM	As Fed	DM	
	NEl	NEl	NEm	NEm	NEg	NEg	RFV
BALE	MCAL / lb	MCAL / lb	MCAL / lb	MCAL / lb	MCAL / lb	MCAL / lb	$
S1	0.46	0.51	0.42	0.47	0.2	0.22	103
HC2	0.48	0.54	0.45	0.5	0.22	0.25	111
HC3	0.5	0.56	0.46	0.52	0.23	0.26	120
S4	0.47	0.52	0.42	0.47	0.2	0.22	106
SL5	0.49	0.55	0.46	0.51	0.23	0.26	115
HC6	0.46	0.51	0.43	0.47	0.2	0.22	100
SL7	0.48	0.53	0.44	0.49	0.22	0.24	107
SL8	0.46	0.51	0.42	0.47	0.2	0.22	101
S9	0.49	0.45	0.45	0.5	0.23	0.25	112
HC10	0.45	0.5	0.43	0.47	0.2	0.22	100
HC11	0.54	0.59	0.5	0.55	0.26	0.29	129
SL12	0.47	0.52	0.44	0.49	0.21	0.23	106
HC13	0.49	0.54	0.45	0.5	0.23	0.25	114
S14	0.52	0.57	0.48	0.53	0.25	0.28	125
SL15	0.46	0.51	0.44	0.48	0.21	0.23	100
SL16	0.51	0.57	0.47	0.52	0.24	0.27	125
S17	0.52	0.58	0.49	0.54	0.25	0.28	127
S18	0.48	0.53	0.43	0.48	0.21	0.23	109
SL19	0.35	0.49	0.31	0.43	0.13	0.18	91
S20	0.44	0.51	0.41	0.47	0.19	0.22	102
HC21	0.47	0.53	0.43	0.49	0.21	0.24	108
SL22	0.46	0.52	0.43	0.48	0.2	0.23	104
S23	0.34	0.43	0.32	0.41	0.13	0.16	76

Appendix D

{21x}
Program For Bale Temperature
James Bedford
7/24/98

```
*Table 1 Program
        01: 60          Execution Interval

1:      Batt Voltage (P10)
        1: 1            Loc. ( Battvolts)

2:      Internal Temperature (P71)
        1: 2            Loc. ( PanelTemp )
3:      Set Port (P20)
        1: 1            set High
        1: 1            Port Number

4:      Beginning of Loop (P87)
        1: 0            Delay
        2: 22           Loop Count

5:      Excitation with Delay (P22)
        1: 1            Ex Channel
        2: 1            Delay w/Ex ( Units = 0.01 sec )
        3: 0            Delay After Ex (Units = 0.01 sec )
        4: 5000         mV Excitation

6:      Thermocouple Temp ( DIFF ) (P14)
        1: 1            Reps
        2: 1            5 mV Slow Range
        3: 1            DIFF Channel
        4: 1            Type T ( Copper-Constantan )
        5: 2            Ref Temp ( Deg. C ) Loc. ( PanelTemp )
        6: 3--          Loc. ( Temperature )
        7: 1            Multi
        8: 0            Offset

7:      End (P71)

8:      Set Port (P20)
        1: 0            Option
        2: 1            Port Number

9:      If Time Is (P92)
        1: 0            Minutes Into A
        2: 60           Minute Interval
        3: 10           Set Output Flag High
```

10: Real Time (P77)
    1: 110 Day, Hour/Minute (Midnight = 0000)

11: Average (P71)
    1: 29 Reps
    2: 1 Loc. (BattVolt)

End Program

```
21x}
Datalogger program for Torque and Speed
James Bedford
3/18/99

*Table 1 Program
01: 1          Execution Interval (seconds)

1:      Set Port (P20)
        1: 1          Set High
        2: 1          Port Number

2:      Pulse (P3)
        1: 1          Reps
        2: 1          Pulse Input Channel
        3: 2          Switch Closure, All Counts
        4: 1          Loc.    ( Speed )
        5: 1.0        Multi
        6: 0.0        Offset

3:      Full Bridge (P6)
        1: 1          Reps
        2: 3          50 mV Slow Range
        3: 1          DIFF Channel
        4: 1          Excite All Reps w/Exchan 1
        5: 5000       mV Excitation
        6: 2          Loc.    ( Force )
        7: 1.0        Multi
        8: 0.0        Offset

4:      If Flag/Port (P91)
        1: 11         Do If Flag 1 Is High
        2: 10         Set Output Flag High

5:      Real Time (P77)
        1: 0011       Hour/Minute, Seconds ( Midnight = 0000 )

6:      Sample (P70)
        1: 2          Reps
        2: 1          Loc. ( Speed )

7:      Sample (P70)
        1: 1          Reps
        2: 2          Loc. ( Force )

End Program
```

Vita

James W. Bedford was born in Tullahoma, Tennessee on August 4, 1972. He grew up on a small family dairy farm in Lynchburg, TN. He attended Lynchburg Elementary School and Moore County High School. In August of 1991, after graduating from high school, he attended Motlow State Community College. In August of 1993, he transferred to The University of Tennessee, Knoxville. He received a Bachelor of Science degree in Agriculture Extension Education in May of 1997. Immediately following graduation he enrolled in the graduate program at The University of Tennessee. He received a Master of Science degree, with a major in Agriculture and Biosystems Engineering Technology, in August of 1999.