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I am submitting herewith a thesis written by Alfredo A. Tineo entitled "Effect of Moisture Content and Method of Baling of Alfalfa-Orchardgrass Hay on Chemical Composition and Digestibility." I have examined the final 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 Animal Science.

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Accepted for the Council:

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Vice Chancellor
Graduate Studies and Research

A

EFFECT OF MOISTURE CONTENT AND METHOD OF BALING OF
ALFALFA-ORCHARDGRASS HAY ON CHEMICAL
COMPOSITION AND DIGESTIBILITY



Master of Science

Degree

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ABSTRACT

A total-collection digestion trial with 15 mature wether sheep was conducted using a completely randomized design to determine the digestibility of alfalfa orchardgrass hay comparing conventional bales vs. large round bales at 24 and 17 percent moisture content at baling. In addition, data were collected to determine the effect of heating as a result of high moisture content on digestibility of the inside core and the outside shell of large round bales.

Third cutting alfalfa-orchardgrass hay at the 1/10 bloom stage of maturity was used. Thermocouples were placed inside bales to determine temperature. Hay treatments consisted of inside core and outside shell from large round bales, and conventional bales at 24 and 17 percent moisture content. Crude protein was found to be similar at high or low moisture content. Acid detergent fiber was 47.93, 41.16, 37.41; and 38.89, 37.98 and 37.10, respectively. Acid insoluble lignin was 20.01, 10.34, 6.90; 7.54, 7.31 and 6.79. Acid detergent fiber-nitrogen was 45.86, 24.03, 27.32; 13.60, 13.17 and 9.66. Dry matter intakes were similar at both moisture levels for inside core, outside shell and conventional. Nutrient digestibility coefficients were: dry matter 48.12, 56.78, 63.78; 60.64, 62.36 and 64.08; Protein 33.23, 55.30, 71.00; 65.96, 72.52 and 74.78; Acid insoluble lignin 19.56, 18.67, 9.09; 14.00, 10.49 and 4.47; Acid detergent fiber 39.29, 51.64, 54.70; 55.39, 54.69 and 55.19; Acid detergent fiber-nitrogen 18.89, 41.07, 69.48; 48.82, 45.50 and 32.98 for the hay treatments, respectively.

Temperature inside bales reached the highest of approximately 90°C at 24 percent moisture and remained high for a period of 30 days. The low moisture level only reached a high of approximately 53°C and decreased rapidly.

The nitrogen intake and fecal nitrogen were higher in round bales than in conventional bales. Urinary nitrogen and nitrogen retention were lowest in inside core at high moisture level and increased as dry matter increased. Metabolic fecal nitrogen and endogenous urinary nitrogen were found similar among treatments. True nitrogen digestibility was 47.60, 69.53, 87.53; 82.86, 87.88 and 89.58 for inside core, outside shell and conventional at 75.9 and 84.2 percent DM, respectively. Absorbed nitrogen retained was 83.42, 81.54, 77.77; 78.91, 81.39 and 78.32. Intake nitrogen retained was 27.72, 45.11, 55.22; 52.07, 59.03, and 58.58; Net protein utilization was 48.80, 66.47, 80.41; 77.94, 80.69 and 81.74; and Net protein value was 9.24, 17.70, 13.21; 12.54, 14.28 and 15.01 for hay treatments.



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CHAPTER 1

INTRODUCTION

Since man first began raising cattle, he has been interested in ways to produce, handle, store, and feed hay. This has involved handling hay in a great variety of ways. In recent years, there has been a great increase in the number of large package forage harvesting systems. This trend has been brought about by the increased size of farm operations and costs, decreased labor supply, and the high probability of rain during hay harvesting. Major advantages of large hay package systems are their greater capacity and ability to withstand prolonged exposure to weather without a significant decrease in hay quality. Because of this ability, the large packages have typically been either left in the field or transported to a fence row at the edge of the field (Currence et al. 1976). There is usually no effort to shelter the packages. As a result, labor requirements in handling, harvesting, storing, and feeding have been reduced.



CHAPTER II

REVIEW OF LITERATURE

Storage of Large Round Bales

An important asset of large round bales is that they survive outside storage without severe loss of quality. Slight to heavy deterioration of the exterior surface of these bales does occur, however, depending on storage and weather conditions. Weathering not only reduces the dry weight of outside stored hay bales, but also results in changes in the composition of the weathered hay. These compositional changes may drastically reduce the nutritive value of the hay. Additional deterioration occurs where the bale contacts the moist ground. In view of these problems, a number of researchers in different parts of the United States have conducted experiments to determine the best method of storing large round bales.

Results from a two year study at the Alabama Black Belt Substation (Stallings et al. 1973, 1974) compared three systems of storage and feeding large round bales: System I, baler producing conventional bales, hay fed once a day without panels; System II, baler producing large round bales, hay fed free choice without panels; System III, same as System II but using panels to help control hay waste. The results indicated that total hay cost per ton (total hay cost included all costs of machinery, labor, harvesting, storing, and feeding but did not consider losses from feeding or by spoilage) harvested and fed was cheaper for System II than for the other two systems. The conventional bale had the highest cost. When the study

included losses from feeding and by spoilage, a distinct advantage in total cost per hundredweight gain for System III was observed. System II had the highest cost (Stalling et al. 1973, 1974). Renoll et al. (1971) compared the stack system to the conventional system and found similar results as above. In another study comparing large and small automatic bale wagons and large and small bale thrower wagons it was found that costs of the automatic bale wagon system was higher than those of bale thrower wagons even though the wagons required more manual labor (Dobberpuhl and Finner, 1973).

Bell and Martz (1977) have found that weathering losses from outside storage vary according to the coarseness of the material baled. Second cutting orchardgrass bales stored outside for six months received 30.8 inches of rain and had a weathered outside layer of about an inch. This very fine, leafy hay prevented rain from penetrating the bales. First cutting orchardgrass bales receiving 25.5 inches and 23.8 inches of rain in 1975 and 1976 respectively, had weathered layers of four to six inches. This hay was rain damaged, mature and coarse when baled allowing rain to penetrate further into the bales than into second cutting orchardgrass bales. In the same study, seven bales stored on the ground had 13.8 percent dry matter loss compared to 14.6 percent dry matter loss for four bales stored six inches off the ground on oak posts.

In an attempt to minimize the quality and weight loss of large round bales, Lechtenberg et al. (1980) conducted a study in Southern Indiana. They placed large hay bales on crushed rock to prevent soil contact. The results showed that storing bales on crushed rock increase the unweathered fraction from 76.8 to 85.5 percent of the original bale

weight. An eight percent storage loss was observed when hay was stored inside. Based on these observations, they calculated that 57 percent of the weather deterioration can be prevented by storing bales on rock.

In addition to the precipitation, the wind is another factor influencing the deterioration of large round bales stored outside. Studies by Fairbanks et al. (1981) and Bell and Martz (1977, 1978) indicated that wind blew the tops off the round bales causing considerable loss. Thus, it is recommended to locate and orient the bales where the prevailing winds blow over with the direction the bale is rolled.

A study by Anderson et al. (1981) compared round bales of alfalfa hay stored outdoors to those of the same kind stored indoors. The results indicate dry matter losses of three percent of initial bale DM weight for indoor-stored bales and 14 percent for outdoor-stored bales. Cumulative dry matter losses from raking through storage totaled 22 percent for indoor-stored bales and 31 percent for outdoor-stored bales. A previous study by the same group showed storage losses during six months outdoor exposure average 12 percent for big round bales and only eight percent for conventional bales (Anderson et al. 1980).

Perhaps one of the most recent studies in order to decrease the quality losses and methods of storing large round bales outside is the use of plastic covers. In certain areas, the high humidity and rainfall often prevents harvested forage from reaching the desired moisture content (15 percent) before it is baled. Verma and Nelson (1981) conducted a study to evaluate inexpensive, simple methods of storing large round

bales of ryegrass hay. Six methods were used in the study. Four bales each were stored on (1) a gravel bed, (2) directly on the ground, (3) on elevated wooden racks with plastic covers, (4) without plastic covers, (5) on automobile tires, and (6) inside a barn. Rainfall measured 20 inches during the complete study period. The results indicated that storage loss was minimal for bales stored in the barn. Total losses were greatest for bales stored on the ground. Bales on gravel ranked second, followed by bales on tires and bales on racks without covers. Total losses were much lower for bales stored off the ground and protected from rain than they were for bales stored on the ground, on tires, or on racks without covers. Dry matter values of bales stored on racks with plastic covers (87.5 percent) and those stored in the barn (89.6 percent) were higher than all others.

A similar experiment was conducted by Rider and Boyer (1974). They selected three storage conditions: (1) bales stored outside on the ground, (2) bales stored outside, elevated eight inches above the ground surface with railroad ties, and (3) bales stored inside a barn, placed on the ground. Alfalfa and bermudagrass were used for this study. Storing period was 280 days and 250 days with rainfall measure of 30.4 inches and 27.0 inches, respectively. For both types of forage, the results obtained indicated that barn storage had the least loss followed by elevated outside storage and finally storage on the ground. In further studies, Rider and McMurphy (1979) compared the use of wrapping large round bales with plastic stored outside to those stored inside barns. The results indicated that there was less than one percent difference in moisture content between bales stored

indoors and those that were wrapped and left outside. The researchers suggest that even with wrapped bales, it is important that hay be stored in a well drained site to reduce moisture buildup in the bottom of the bale. Raising the bales may be of value in high rainfall areas.

Feeding Large Round Bales

Another important factor in the management of large round bales of hay is method of feeding which varies widely and is important in the efficiency of utilization.

Several studies have indicated that placing large round bales in the pasture free choice, without a feeder, results in much waste of hay. In a study conducted by Rorie et al. (1979) dry matter losses of 40 percent for hybrid sorghum-sudan cross bales and 30 percent for orchardgrass/native grass hay bales were noted when hay was fed free choice on concrete slabs. Another undesirable method of feeding large round bales is by unrolling the bales on the ground. Previous research by the same group has demonstrated hay dry matter losses of 31.6 percent with this feeding method.

One of the most efficient feeding systems for large round bales is with the use of barriers or panels to provide semi-controlled access to the hay. Several types of large round bale feeders are available to livestock managers. Portable feeders consisting of panels of square, rectangular, or circular shape are prevalent. These feeders serve the same basic function: they prevent animals from trampling or lying on the bale, which would destroy the bale's conformation and cause contamination. Such exposure results in decreased acceptability and intake of hay, lowered weight gains, and increased hay losses.

Rorie et al. (1979) compared two methods of feeding large round bales to dairy heifers using hybrid sorghum-sudan cross hay and orchard-grass native grass hay. The methods consisted of feeding hays stored in metal pallets in a building to that fed outside on the ground. The results indicated that the feeders reduced dry matter waste by 25.3 percent and 22 percent for the hybrid sorghum-sudan grass hay and orchard-grass/native grass hay, respectively, compared to no feeder. Other researchers indicate similar results as above and thus the need for some method to restrict the access of animals to large round bales during feeding (Renoll et al. 1976; Bell and Martz 1973, 1976 and 1977).

Effect of Moisture Content on Hay Quality

Several studies have demonstrated that quality of hay is determined by Moisture content at baling. Miller et al. (1967) indicated that the higher the moisture content the lower the hay quality. Results from the same study using alfalfa hay baled at average moisture contents of 26.2, 35.2, 53.4 and 58.5 and an average density of 407 kg per m³ wet basis indicates a cause and effect relationship between the moisture content of the hay at the time of baling and the temperature rise in the bales following baling.

The quantity of spontaneous heat generated by hay during storage is important because when more heat is generated, lower retention of important nutrients results (Hoffman and Bradshaw, 1937). Heat generation and the resulting high temperatures are known to reduce the digestibility of certain nutrients, including protein (Bohstedt, 1944; Cashmore, 1938; and Woods et al. 1962). Spontaneous heating is also the cause of spontaneous combustion. The color of hay

varies from its original to black depending upon the amount of heat developed during storage (Shedd and Barger, 1947). Excessive heating may result in brown hay, which has a pleasing sweet aroma, and which may be more palatable to cattle than green hay (Maynard et al. 1932). More intensive heating may result in black, undesirable hay. Researchers have studied this process and identified it as the condensation of carbonyl group with amino groups of proteins, amino acids, and other compounds to form a dark-colored polymer. Various terms for this phenomenon are the Maillard reaction, non-enzymic browning reaction and the browning reaction. Van Soest (1965) indicated that the dark colored polymer accumulates in the lignin fraction of acid detergent insoluble fiber.

Nelson (1966, 1968, 1972) has demonstrated that internal temperature of baled hay increases rapidly immediately after baling. The temperature then decreases approximately four days after baling and increases again approximately six days after baling and starts decreasing to ambient temperature three weeks after baling.

In another study, Goering et al. (1973) determined the effect of moisture content on the extent of heat damage. Orchardgrass was placed in Erlenmeyer flasks exposed to 80°C for 24 to 48 hours with moistures ranging from 7 to 82 percent. The nitrogen content of acid detergent fiber was the assay of heat damage. The results indicated that browning occurred when moisture contents were in the range of 20 to 70 percent.

Along with the heating factor and consequently so, molding occurs at higher moisture contents. Miller (1967); Shedd and Barger (1947); Mohanty (1967); Dawson et al. (1950); and Gregory et al. (1963) reported

studies indicating that hay baled at higher moisture contents contained more evidence of mold than hay baled at lower moisture contents.

Chemical Composition of Hay

A number of studies have shown nutritive losses due to moisture content and storage. A comparison between rectangular bales and large round bales showed no major differences in crude protein, ash, and dry matter digestibility at baling time or by feeding time six months later. However, major differences were observed when bales were resting on the ground indicating a higher moisture content (Renoll et al. 1976).

Nutritive properties of alfalfa large round bales stored inside and outside were determined through chemical analyses. Analyses were made for crude protein (CP), acid detergent fiber, (ADF), unavailable protein (ADF-P), and in vitro dry matter disappearance (IVDMD). Results indicated that feed quality was reduced significantly as a result of ADF, ADF-P, and IVDMD changes in outdoor stored bales. Similar results were observed when exterior vs. interior quality of outdoor bales were compared. Practically all storage nutrient losses occurred in the exterior layer (Anderson et al. 1981).

Verma and Nelson (1981) evaluated several nutrient components in ryegrass hay stored by different methods. The components included neutral detergent fiber (NDF), hemicellulose, acid detergent fiber (ADF), crude protein (CP), available protein and in vitro digestible dry matter (IVDMD). The methods of storage selected were on gravel, ground, rack, rack with cover, on tires and in a barn. The results indicated no significant differences in NDF, hemicellulose, ADF, cellulose or crude

protein. However, there was a significant change in the lignin content of hay. High lignin content was observed in hay stored on gravel, ground and tires compared to the rest. Significant differences were also observed in available protein. Highest available protein was found in hay stored in rack with cover, followed by hay stored in barn and gravel, and finally the one stored on the ground, rack and tires. Hay stored in the barn and hay stored on racks covered with plastic exhibited no change in vitro digestible dry matter during storage. Conversely, hay from all other storage systems presented a lower IVDMD.

Miller et al. (1967) compared alfalfa hay and native hay at moisture contents ranging from 19.2 to 58.5 percent. The results indicated that the percentage of crude protein was relatively constant regardless of moisture content at the time of baling. There was more ash, cell wall constituents, cellulose, acid detergent fiber, and lignin in the hays baled at the higher moisture content. There was little difference in the water soluble carbohydrate fraction. Hoffman and Bradshaw (1937) found a decrease in the organic matter of alfalfa stored at high moisture contents. Swanson et al. (1919) and Bechtel et al. (1945) observed similar results. Bechtel et al. (1945) also observed an increased percentage of lignin, ash, and crude fiber in brown and black hays. Miller et al. (1967) results also indicated that the digestibility of the dry matter, crude protein, water-soluble carbohydrates and gross energy was higher in the hays baled at the lower moisture contents. There were no apparent differences in the digestibility of the fibrous fractions of the hays as influenced by moisture content at the time of baling.

Effect of Organic Preservatives on Hay

Hay is often baled before it is adequately cured, due to poor drying conditions after cutting. Consequently molding and heating occur leading to dry matter losses, compositional changes and decreases in digestibility (Hoffman and Bradshaw, 1937; Bechtel et al. 1945; Moore, 1965; Miller, 1971). These decreases in hay quality are particularly serious if the hay is baled at moisture contents higher than 25 percents, based on studies stated previously. It has also been stated that mold growth not only decreases hay quality but is primarily responsible for the heating of hay which causes deterioration (Mohanty et al. 1967). Even during ideal weather conditions, determination of the moisture content of hay is a subjective procedure.

Several studies have been conducted to evaluate the feasibility of using organic preservatives to reduce quality losses in hay. Organic acids and some ammonia compounds have been used successfully to reduce mold formation and to preserve high moisture hay. Propionic acid in several commercial compounds have been extensively used for grain preservation (Jone et al. 1970; Young et al. 1970; Alexander, 1972; and Nelson et al. 1973). Propionic acid and ammonium isobutyrate were found equally effective in decreasing heating and preserving the quality of high moisture hay. Hay baled at the higher moisture levels required increased rates of preservatives (application rate of 1.5 percent for preserving hay of approximately 30 percent moisture) in order to prevent heating. Halosyn, a compound containing 20 percent propionic acid, was ineffective in preserving hay containing up to 34 percent moisture when sprayed at rates from 0.5 to 2.0 percent (Sheaffer et al. 1975, 1976).

Jorgensen et al. (1978) reported that milk production and milk fat of lactating cows fed alfalfa hay (30 percent moisture at harvest) treated with one percent propionic acid were similar to those cows consuming field-dried hay (17 percent moisture at harvest). However, daily dry matter intake by cows was significantly higher for field-dried hay. In another study, Knapp et al. (1976) shows that hay baled at 32.4 percent and not treated with a preservative became visibly moldy and musty in storage. However, propionic acid treatment at concentrations of 0.2, 0.5 and 1.0 percent successfully reduced visible mold. Dry matter losses significantly decreased with increasing propionic acid concentrations. Similar results were observed by Roeth (1937). Knapp et al. (1976) also reported that ammonia nitrogen decreases as the rate of propionic acid increases. Concentration of acid detergent fiber nitrogen (ADF-N) increased slightly during storage but it was inversely proportional to the concentration of propionic acid. In vitro dry matter disappearance at baling declined from 70.5 percent to 60.5 percent when hay was stored without acid treatment. Treated hay was about 4.5 percentage unit higher than control hay. Similar results were reported by Nehrir et al. (1978).

CHAPTER III

EXPERIMENTAL PROCEDURE

Objective

The purpose of this study was to determine the digestibility of alfalfa-orchardgrass hay comparing conventional bales vs. large round bales at two different moisture levels. In addition, data were collected to determine the effect of heating as a result of high moisture content on digestibility of inside core and outside shell of large round bales.

Description of Hay Produced

Third-cutting alfalfa-orchardgrass hay in the 1/10 bloom stage of maturity was used for this experiment. The hay consisted of 10-20 percent orchardgrass (Dactylis glomerata) and 80-90 percent alfalfa (Medicago sativa). The hay was grown at the Dairy Experiment Station of the University of Tennessee in Lewisburg, Tennessee. The hay was baled at two different moisture contents (17 and 24 percent) and was stored inside a barn on tires. Large round bales and conventional bales from low moisture level were baled on July 10, 1980 while the ones from high moisture level were baled on July 15, 1980. The equipment used was a New Holland model 850 for large round bales and a John Deere model 337 for the conventional bales. Large round bales at low moisture level had an average diameter of 160.5 cm (137 cm - 184 cm) and an average length of 180 cm (179 cm - 181 cm). The average volume was 3.61 m^3 and the wet weight density was 245.25 kg/m^3 (238.80 kg/m^3 - 251.70 kg/m^3). The average dry weight density was 186.2 kg/m^3 .

(183.6 kg/m³ - 188.8 kg/m³). The large round bales with high moisture level had an average diameter of 165 cm (144 cm - 185 cm) and an average length of 174.5 cm (174 cm - 175 cm). The average volume was 3.67 m³ (3.66 m³ - 3.68 m³) and the average wet weight density was 194 kg/m³ (188.3 kg/m³ - 199.7 kg/m³). The average dry weight density was 163.5 kg/m³ (155.3 kg/m³ - 171.6 kg/m³).

Internal bale temperatures were recorded by placing a thermocouple (copper contained 10) in the center of the bales. Bale temperatures were recorded at one hour intervals until the bales had reached ambient temperature.

A. DIGESTIBILITY TRIAL

Preparation of Hay

Large round bales of hay were unfolded in approximately one-half to make the outside shell and the inside core for both moisture levels. All hay was chopped approximately 5 cm in length and stored in containers. The conventional bales of hay harvested at both moisture contents were also chopped and stored in containers.

Description of Digestion and Nitrogen Metabolism Trial

Fifteen mature wether sheep (74 to 112 kg) were divided into three groups of five animals in each group. They were selected at random and placed in metabolism crates (Briggs and Gallup, 1949) for a 8-day adjustment period on the respective treatments, followed by a 7-day intake period at which maximum hay consumption was determined. The animals were fed one-half their daily ration at 8 a.m. and one-half

8 p.m. Water was offered for one-half hour period prior to each feeding and trace mineralized salt block was offered free choice. The intake period was followed by a 7-day collection period during which feed, feces, and urine samples were collected. Feed samples were composited daily. Daily fecal output was measured and a 10 percent aliquot was composited daily for each sheep. A few crystals of thymol were added daily to the aliquot for preservation purposes. Daily urine excretions were measured and 10 percent aliquot was composited daily for each sheep. Ten ml of 6N hydrochloric acid was added daily to collecting containers to preserve the urine from which samples were obtained. All composite samples were kept under refrigeration until analyzed.

Chemical Analyses

Fecal samples were dried at 60°C for seven days then allowed to air equilibrate. The samples were then ground through a one mm mesh screen of a Wiley Mill. Feed, fecal and urine samples were analyzed for nitrogen according to A.O.A.C. (1975). Acid detergent fiber acid detergent fiber-nitrogen and acid insoluble lignin were determined on feed and fecal samples according to Van Soest (1963). Digestibility coefficients of each respective nutrient, percent digestible nutrients, and nitrogen utilization parameters were calculated.

Statistical Analyses

A completely randomized design was selected for this study. The data were analyzed by the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS) (Barr et al. 1979).

The independent variables used in the regression analysis were moisture level and sample location (outside shell, inside core and conventional). The dependent variables were all the variables measured in the digestibility and Nitrogen Metabolism trial. Duncan's procedure was used to separate means when significant F values indicated differences among means (Steel and Torrie, 1960).



CHAPTER IV

RESULTS AND DISCUSSION

Hay Composition

The nutrient composition of alfalfa-orchardgrass hay is presented in Table I. Results of the crude protein analyses indicate that protein level was higher than the average found in most samples of alfalfa-orchardgrass hay. On a dry matter basis (DMB), crude protein from large round or conventional bales was similar at high or low moisture content. This is in agreement with results reported by Renoll et al. (1976), Verma and Nelson (1981) and Miller et al. (1967). The acid detergent fiber (ADF) from the inside core and outside shell of large round bales was higher in hay containing higher moisture content than that of lower moisture content (47.93 and 41.16 vs. 38.89 and 37.98). It was also observed that ADF was higher in inside cores than the outside shells within the respective moisture contents. No difference was observed between conventional hays; however, ADF was lower in conventional bales compared to large round bales. These results are comparable to those reported by Miller et al. (1967) and Bechtel et al. (1945); however, results reported by Verma and Nelson (1981) indicated no significant differences between large round bales and conventional bales. The acid insoluble lignin (lignin) was higher in large round bales of hay containing high moisture content (wet) than that of lower moisture content (medium). Larger differences were observed between inside core and outside shell of wet hay (20.01 and 10.34) but not on the medium hay (7.54 and 7.31). Conventional hays

TABLE I
CHEMICAL COMPOSITION OF ALFALFA-ORCHARDGRASS HAY

Moistures and Sample Locations	Crude ^a Protein	Acid ^a Detergent Fiber	Acid ^a Insoluble Lignin	Acid ^a Detergent Fiber-Nitrogen % of Total N
		%		
<u>Wet, (75.9% DM)</u>				
Inside Core	18.93	47.93	20.01	45.86
Outside Shell	19.11	41.16	10.34	24.03
Conventional	16.44	37.41	6.90	27.32
<u>Medium, (84.2% DM)</u>				
Inside Core	16.09	38.89	7.54	13.60
Outside Shell	17.70	37.98	7.31	13.17
Conventional	18.37	37.10	6.79	9.66

^aDry Matter basis

contained the lowest lignin percentage and were similar at both levels of moisture. These results are in accordance with those reported by Miller et al. (1967); Swanson et al. (1919); Bechtel et al. (1945) and Verma and Nelson (1981). The amount of unavailable nitrogen or acid detergent fiber-Nitrogen (ADF-N) as percent of total Nitrogen was found to be higher on hay with higher moisture content than that of lower moisture content. A larger difference in ADF-N was observed between inside core and outside shell of wet hay (45.86 and 24.03) than the medium hay (13.60 and 13.17). An unexplainable higher ADF-N value in wet conventional hay as compared to outside shell was obtained. Results from inside core and outside shell of medium hay were very similar. ADF-N in conventional hay at the lower moisture content was 9.66, which is comparable to values reported by Montgomery et al. (1980). The higher values of lignin and ADF-N in the high moisture hay are evidence that heating occurred as a result of the moisture content. The inside cores of large round bales were observed to be burnt; more so in the bales at higher moisture contents than at lower moisture contents. Bechtel et al. (1945) observed similar results.

Heating Effect

The relationship of temperature and days after packaging is shown in Figure 1. There was a cause and effect relationship between the moisture content of the hay at the time of baling and the temperature rise in the bales following baling. Changes in chemical composition were a result of the increase in internal temperature due to increased bacterial fermentation at high moisture content at time of baling (Table 1).

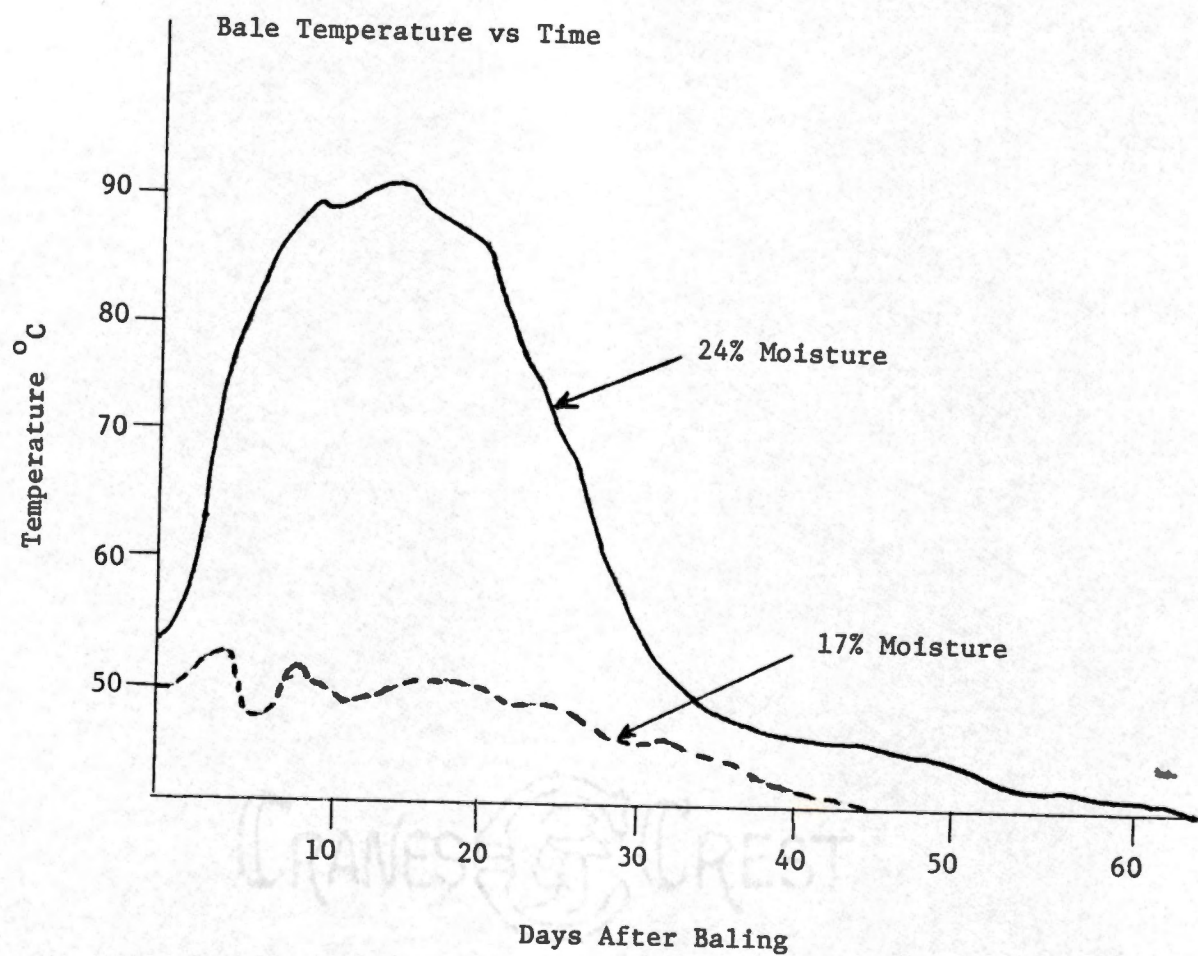


Figure 1. Effect of Temperature and Days After Baling on Bales 24 and 17 Percent Moisture Content.

These results are comparable to those by Miller et al. (1967) and Bledsoe et al. (1980). The fact that the percent of protein remained relatively constant while the percentage of ADF, lignin, and ADF-N increased as the moisture content at time of baling increased indicated that the remaining portion of the forage, primarily readily fermentable carbohydrates, decreased as the moisture content at time of baling increased. The heat liberated during the fermentation process was due to the oxidation of the readily fermentable carbohydrates, thus producing the dark hay observed in the inside of the large round bales. Shedd and Barger (1947), Miller et al. (1967), Goering and Van Soest (1973) and Bledsoe et al. (1980) reported similar results in a study of hay baled at a high moisture content.

Apparent Nutrient Digestibilities

Dry matter intakes (DMI) and apparent nutrient digestibilities are presented in Table II and Table III, respectively. Analysis of variance for the effects of moisture and location on nutrient digestibilities are presented in Table IV. DMI results indicate that palatability of the high moisture hay was not affected. Similar results were indicated by Maynard et al. (1932). Dry matter digestibility (DMD) and protein digestibility were found to be significantly higher ($P < .05$) for the large round bales of hay harvested at the lower moisture content compared with the higher moisture content. Significant differences were also found between inside core and outside shell within treatments (62.36 vs. 60.64) and (56.78 vs. 48.12). DMD was not significantly different between conventional hays from high and low

TABLE II
 DRY MATTER INTAKE OF ALFALFA-ORCHARDGRASS HAY AT
 MOISTURE LEVELS AND SAMPLE LOCATIONS^a

Sample Locations	Moisture Levels	
	WET (75.9% DM)	MEDIUM (84.2% DM)
Inside Core	1.76	1.51
Outside Shell	1.63	1.92
Conventional	1.52	1.42

^aDry Matter Intake as% of B.W.

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TABLE III
NUTRIENT DIGESTIBILITY COEFFICIENTS OF ALFALFA-ORCHARDGRASS HAY

Moistures and Samples Location	Dry Matter	Protein	Acid Insoluble Lignin	Acid Detergent Fiber	Acid Detergent Fiber-Nitrogen
%					
<u>Wet, (75.9% DM)</u>					
Inside Core	48.12 ^e	33.23 ^e	19.56 ^a	39.39 ^c	18.89 ^d
Outside Shell	56.78 ^d	55.30 ^d	18.67 ^a	51.64 ^b	41.07 ^b
Conventional	63.78 ^{a,b}	71.00 ^b	9/09 ^{b,c}	54.70 ^a	69.48 ^a
<u>Medium, (84.2% DM)</u>					
Inside Core	60.64 ^c	65.96 ^c	14.00 ^{a,b}	55.39 ^a	48.82 ^b
Outside Shell	62.36 ^b	72.52 ^b	10.49 ^b	54.69 ^a	45.50 ^b
Conventional	64.08 ^a	74.78 ^a	4.47 ^c	55.19 ^a	31.98 ^c
<u>Moisture Levels</u>					
Wet, (75.9% DM)	56.23 ^a	53.18 ^a	15.77 ^a	48.54 ^a	43.48 ^a
Medium, (84.2% DM)	59.57 ^b	63.91 ^b	14.58 ^a	53.16 ^b	43.28 ^b
<u>Sample Locations</u>					
Inside Core	54.38 ^a	49.59 ^a	16.78 ^a	47.34 ^a	31.35 ^a
Outside Core	59.57 ^b	63.91 ^b	14.58 ^a	53.16 ^b	43.28 ^b
Conventional	63.93 ^c	72.89 ^c	6.78 ^b	54.95 ^c	50.73 ^c

a,b,c,d,e Means in a column with different superscripts differ significantly ($P < .05$).

TABLE IV
ANALYSIS OF VARIANCE FOR THE EFFECTS
OF MOISTURE AND LOCATION ON
NUTRIENT DIGESTIBILITIES

Source	df	Mean Squares				
		Dry Matter	Crude Protein	Acid Detergent Fiber	Acid Detergent Fiber-Nitrogen	Acid Insoluble Lignin
Moisture	1	281.62***	2405.50***	321.26***	85.76 #	280.93***
Location	2	228.61***	1380.24***	158.11***	955.02***	276.25***
Moisture x Location	2	93.81***	525.16***	150.15***	2396.71***	8.56
Error	24	1.39	2.15	3.34	30.32	17.17

P < .10
***p < .001

moisture levels; however, a significantly higher ($P < .05$) protein digestibility was obtained in conventional bales from low moisture hay when compared to high moisture hay (74.78 and 71.00, respectively). These results are similar to those obtained by Nelson (1968 and 1972), Currence et al. (1976) and Verma and Nelson (1981). The lower digestion coefficients in large round bales containing high moisture contents were due to the higher temperature inside the bale. Heat generated inside bales binds protein to the fiber, making it unavailable to the animal. However, results from Smith et al. (1975), Renoll et al. (1976) and Thorlacius et al. (1978) indicated no significant difference in dry matter digestibility nor in crude protein digestibility.

Acid insoluble lignin digestibility (AIL-Dig.) was significantly higher ($P < .05$) in high moisture hay than low moisture hay (15.77 and 9.65). It was, however, not significantly different from inside core to outside shell of large round bales (16.78 and 14.58) but large round bales were significantly higher ($P < .05$) than conventional bales. Acid detergent fiber digestibility (ADF-Dig.) was found to be significantly higher in low moisture content hay than high moisture content hay as well as in conventional bales as compared to large round bales. A significant difference was also found between inside cores and outside shells of large round bales, the latter being higher. Acid detergent fiber-Nitrogen digestibility (ADF-N. Dig.) was significantly higher ($P < .05$) in high moisture hay (43.38) than in low moisture hay (40.10). Conventional bales (50.73) were significantly higher ($P < .05$) than large round bales in both outside shell (43.28) and inside cores (31.35). The significance of the rather high ADF-N digestibility is unknown.

Nitrogen Utilization

Table V presents nitrogen (N) utilization parameters at the two moisture levels. Analysis of variance for the effects of moisture and location on nitrogen utilization is presented in Table VI. The nitrogen intake was determined by the dry matter consumed and the crude protein of the feed. It has been stated previously that heated hay seemed to be more palatable than hay not subjected to high internal temperature. This is supported by the fact that nitrogen intake was higher in hay from the inside core than that of the outside shell and conventional. A high intake value (53.34) for outside shell from the medium hay was observed. This value affected the rest of the parameters measured, although some of the expected trends were still observed. Nitrogen intake from the inside core and conventional bales was very similar perhaps due to the lower moisture content and type of bales. Fecal nitrogen was found to be higher in animals fed hay at higher moisture content. Nitrogen retention was lowest in the inside core at the high moisture content and progressively increased as percentage of moisture decreased. Miller *et al.* (1967) observed similar results in which nitrogen retention decreased as percent of moisture content at baling time increased. True nitrogen digestibility, intake nitrogen retained, net protein utilization, and net protein value were significantly higher ($P < .05$) for hay harvested at low moisture contents. On the other hand, absorbed nitrogen retained was significantly higher ($P < .50$) in large round bales of high moisture hay when compared with conventional hay at the same moisture, but there was not any significant difference among conventional bales between treatments.

TABLE V
NITROGEN UTILIZATION PARAMETERS

Variable	Wet (75.9% DM)			Medium (84.2% DM)		
	Inside Core	Outside Shell	Conventional	Inside	Outside	Conventional
DM Intake, g/day	1605.29	1388.83	1423.44	1377.57	1883.56	1298.38
N Intake, g/day	48.62	42.46	37.44	35.46	53.34	38.16
Fecal N, g/day	32.50	18.86	10.84	12.08	14.68	9.64
Urinary N, g/day	2.64	4.31	5.91	4.88	7.21	6.18
Digested N, g/day	16.16	23.59	26.59	23.38	38.66	28.51
Metabolic fecal N, g/day ¹	7.00	6.04	6.19	5.99	8.19	5.64
Endogenous Urinary N, g/day ²	3.10	2.92	3.13	3.07	3.34	3.15
True N digestibility, % ³	47.60 ^e	69.53 ^d	87.53 ^b	82.86 ^c	87.88 ^{a,b}	89.58 ^a
Absorbed N retained, % ⁴	83.42 ^a	81.54 ^d	77.77 ^c	78.91 ^c	81.39 ^b	78.32 ^c
Intake N retained, % ⁵	27.72 ^e	45.11 ^d	55.22 ^b	52.07 ^c	59.03 ^a	58.58 ^a
Net Protein utilization, % ⁶	48.80 ^d	66.47 ^c	80.41 ^{a,b}	77.94 ^b	80.69 ^a	81.75 ^a
Net Protein value %	9.24 ^e	12.70 ^d	13.21 ^c	12.54 ^d	14.28 ^b	15.01 ^a

¹Metabolic fecal N = 4.35 x Kg DM intake per day (Anderson et al., 1959).

²Endogenous urinary N = 0.034 x Kg body weight (Anderson et al., 1959).

³True N digestibility = N intake - (fecal N - metabolic fecal N) / N intake x 100.

⁴Biological value of proteins (Anderson et al., 1969) calculated by the Thomas-Mitchell method.

⁵Intake N retained = N intake - fecal N - Urinary N/N intake.

⁶Net protein utilization = absorbed N retained x True N digestibility/100.

a,b,c,d,e Means on the same line with different superscripts are significantly different (P<.05).

TABLE VI
ANALYSIS OF VARIANCE FOR THE EFFECTS OF MOISTURE AND LOCATION
ON TRUE NITROGEN DIGESTIBILITY, ABSORBED NITROGEN
RETAINED UNCORRECTED, INTAKE NITROGEN RETAINED,
ABSORBED NITROGEN DIGESTIBILITY

Source	df	Mean Squares			
		True nitrogen digestibility	Absorbed nitrogen retained uncorrected	Intake nitrogen retained	Absorbed nitrogen digestibility
Moisture	1	2581.80***	14.04***	1443.90***	2405.50***
Location	2	1372.02***	35.08***	767.91***	1380.24***
Moisture X Location	2	690.42***	18.81***	275.38***	525.16***
Error	24	2.16	2.01	2.97	2.15

***p < .01

***p < .001

CHAPTER V

SUMMARY AND CONCLUSIONS

A digestibility and Nitrogen utilization trial was conducted using a completely randomized design with 15 mature wether sheep to determine the digestibility of alfalfa-orchardgrass hay comparing conventional bales vs. large round bales at 25 and 17 percent moisture content. In addition, data were collected to determine the effect of heating as a result of high moisture content on digestibility in inside core and outside shell of large round bales.

Third cutting alfalfa-orchardgrass hay in the 1/10 bloom stage of maturity was used. Large round bales of hay were unfolded in approximately one-half to make the outside shell and the inside core for both moisture levels. Thermocouples were placed inside bales to determine temperature. Hay treatments consisted of inside core, outside shell from large round bales and conventional bales at 25 and 17 percent moisture content.

Results from chemical analyses indicate: crude protein quality was very good and with no apparent change among treatments. Acid detergent fiber, acid insoluble lignin and acid detergent fiber-nitrogen were higher in large round bales (especially the inside core) than conventional when comparing the high moisture level with the low moisture level.

- The heating effect was more noticable in the inside core of the large round bales at the higher moisture level; thus, affecting nutrient composition. However, palatability was not affected in view of dry matter intake results.

Dry matter and protein digestibility were significantly lower ($P < .05$) for the large bales compared to conventional baling. The inside core of the bales was significantly lower than the outside shell in both dry matter and protein digestibility. Acid insoluble lignin, acid detergent fiber and acid detergent fiber-nitrogen were significantly higher ($P < .05$) in large round bales than conventional bales at both moisture levels. All measures of nitrogen utilization were depressed for the bales stored at high moisture level.

These data suggest that under these conditions, conventional bales are not as subject to adverse heating and subsequently the nutritional value is not as severely affected as similar hay stored in high density large round bales. If the large bale system is used, care should be taken to insure the moisture content is less than 18 percent at baling to minimize problems with protein utilization (protein binding).

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