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# Evaluation of the feeding efficiency of three systems in feeding large roll hay packages

Babatunde A. Adeyemo

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B. L. Bledsoe, Major Professor

We have read this thesis and recommend its acceptance:

J. H. Reynolds, J. W. Holloway

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

To the Graduate Council:

I am submitting herewith a thesis written by Babatunde A. Adeyemo entitled "Evaluation of the Feeding Efficiency of Three Systems Used in Feeding Large Roll Hay Packages." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Mechanization.

B. L. Bledsoe

B. L. Bledsoe, Major Professor

We have read this thesis
and recommend its acceptance:

John H Reynolds

J. W. Holloway

Accepted for the Council:

L Evans Roth

Vice Chancellor
Graduate Studies and Research

# EVALUATION OF THE FEEDING EFFICIENCY OF THREE SYSTEMS USED IN FEEDING LARGE ROLL HAY PACKAGES

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Babatunde A. Adeyemo
March 1980

DEDICATED TO ALHAJA JARAWU,

SHERI AND BABATUNDE, JR.

# ACKNOWLEDGEMENTS

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I am deeply indebted to my parents for making my education possible, and to the government of my home country for giving me the opportunity to study in the United States of America.

My last and most important words of appreciation must go to my wife, Sheri and my son, Babatunde Jr. for their love, understanding and encouragement throughout my graduate work.

# ABSTRACT

This experiment dealt with three systems for feeding large round hay packages to beef animals and with animal performance (weight gain) associated with outside-stored and inside-stored large round bales of bermudagrass hay.

Feeding trials were conducted at the end of a four-month storage period to determine the amount of hay refused and tramped into the mud by cattle. The amount of hay wasted during the feeding trials was used to determine the cost-benefit ratio for each type of feeding equipment.

Results indicated that larger amounts of hay were wasted from the panel feeder than from the roofed or unroofed feeder (17 percent, 7 percent and 9 percent dry matter loss respectively). Cattle fed inside-stored hay performed better (gained more weight per day) than cattle fed outside-stored hay. Based on the data collected from this study, hay saved by the roofed feeder did not justify the cost of using the roofed bunk for bermudagrass hay (at $46/ton, annual value of hay saved amounted to $74 compared to an annual cost for the roofed feeder above that of the panel of $108. Annual value of hay saved by the unroofed feeder amounted to $59 compared to an annual cost for the unroofed feeder above that of the panel of $64).

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# CHAPTER I

# INTRODUCTION

Farm labor has become an increasingly costly and less available commodity over the past two decades. At the same time, new technology which reduces the amount of labor or the drudgery associated with farm work has continually been tested and adopted. The high cost of hired farm labor in industrialized nations and the strong competition for good quality labor by the non-farm labor market have pressured many farmers into adopting labor-saving equipment even when farm size is relatively small. As a result, work has been focused towards the complete mechanization of economical hay production, storing and feeding to animals. Recent development of large hay package machines has reduced labor requirements substantially and has provided for open-field outside-storage and feeding of the large hay packages.

The total tonnage of hay produced and its farm value in dollars remain high and gradually are increasing. According to USDA sources, hay production in the U. S. A. has gone from 108 million tons in 1954 to 127.9 million tons in 1970 with no evidence that this uptrend will stop in the foreseeable future. Hay produced in Tennessee reached a total value of 95 million dollars in 1978, while beef cattle increased to over one million head by July 1, 1978 (27).

Forages supply about 90 percent of nutrients required by beef cattle and about 20 percent of diary animal nutrient requirements in Tennessee. Since forage is such a widely-used source of feed in livestock production and because of the recent acceptance of large roll hay packages by farmers, there is need to develop an efficient system or technique to feed these large packages to farm animals with minimum waste.

The main objective of this study was to evaluate the feeding efficiency of three systems used in feeding large roll hay packages. The three feeding systems used were: 1) floored and roofed feed bunk with one movable metal head gate and one fixed wooden head gate; 2) floored and unroofed feed bunk with one movable metal head gate and one fixed wooden head gate; and 3) simple metal panel encircling a single roll bale placed on the sod. The systems were compared for the amount of hay refused and trampling losses incurred when large rolls of Midland bermudagrass hay were fed to yearling Black Angus steers during a 42-day feeding trial. A second objective was to compare the differnce in animal performance (gain) resulting from feeding inside- and outside-stored bermudagrass hay.

# CHAPTER II

# REVIEW OF LITERATURE

## A. THE DEVELOPMENT OF LARGE HAY PACKAGING SYSTEMS

Farmers have long endured the tremendous labor associated with conventional hay making. This man-power requirement is one major concern in the haying operation. These labor pressures have made farmers and machinery manufacturers develop necessary equipment for reducing the drudgery associated with hay making.

The development of the large hay packaging system has given farmers additional alternatives for mechanical hay handling and for outside storage of hay. Large hay packages generally are stored outside, hence they are subjected to weathering losses and spoilage from time of harvest until they are fed to the cattle. For efficient mechanical handling, hay packages should be reasonably large, should be dense and should be shaped to withstand the natural environment of outside storage. Large round bales have been stored outside on old automobile tires or on a layer of crushed rock to reduce spoilage, especially of the portion which contacts the ground.

Storage of hay in stacks was common in semi-arid areas where outside storage of hay was suitable. In 1958 C. L. Martin, Jr. (18) described a hay cage that was developed to form stacks to a desirable size and shape. This hay cage reduced the time and labor required to make the stack. Bowers _et al_. (5) in 1974 reported that the use of the mobile stack wagon to pick up hay from the windrow and form stacks reduced labor. Typical labor requirements for the 1, 3, and 6 ton stack wagon systems were 0.8, 0.6 and 0.4 man-hours per ton, respectively. The labor requirement for the traditional bale system was 2.5 man-hours per ton from harvest through feeding on the farm. Other advantages for the stack wagon system mentioned by Bowers included flexibility of the stack wagon to make hay from grass, alfalfa, or straw and to form stacks or corn or milo stover. Stacks of all material were weather resistant, hence no special storage facilities was required.

The first work on large roll bales was by Haverdink and Buchele (13) of Iowa State University in the mid '60's. Their main objective was to produce large roll bales that could be stored and fed on an open field. Their research uncovered the problem of maintaining uniformly formed large roll bales. Farm equipment manufacturers became interested in large roll bales and developed successful machines. Floyd (10) reported two successful machine designs that could be used to produce large roll bales. The Vermeer Manufacturing Company of Pella, Iowa built a baler that would pick up the hay from the windrow and roll the hay between a series of belts. The Vermeer package was 1.8 meters (6 ft.) long and 1.5 to 2.1 meters (5 to 7 ft.) in diameter and around 900 kg. (2000 lbs.) in weight. The second design was developed by the Hawk Bilt Company. This machine rolled the windrow on the ground, similar to rolling up a carpet. This package was 2.1 meters (7 ft.) long and one to two meters (3 to 6 ft.) in diameter and weighed between 450 to 680 kg (1000 to 1500 lbs.).

## B. HANDLING AND STORAGE CHARACTERISTICS OF LARGE HAY PACKAGES

A wide variety of large roll hay handling and storage systems have been developed. Bowers _et al_. (5) reporting on a three-year field study in Oklahoma, stated that roll bales were moved twice - from baling to a storage area and later from the storage to the feeding area. This handling routine was similar to the hauling, storing, and feeding associated with traditional rectangular bales. Large roll bales can be moved with a spear-type bale mover attached to a tractor-mounted front-end-loader. The large round bales do not stack effectively; therefore, the recommended outside storage method was to place bales in a row on a well-drained sod. The thatch formed on the outer surface of the round bale gives protection against weather. Bledsoe _et al_. (1) reported that packaging and handling capacity increased with increase of hay moisture content for the roll bale system, and that the roll bale system had the lowest cost per ton for packaging and handling operations compared with the stacker and the conventional baler.

Rider and Boyer (24) compared three storage methods for effect on quality of large roll bales. They used bales stored outside on the ground, bales stored outside 0.2 m (8 inches) above the ground, and bales stored inside shelter. They concluded that inside-storage was the best method for preserving protein in both alfalfa and bermudagrass hay. Barn storage of alfalfa was most effective in maintaining total digestible nutrients, minimizing dry matter losses, and preventing an increase in crude fiber percentage. The alfalfa hay stored outside on the ground accumulated additional moisture, especially in the lower six inches of the roll bales. It was also noted that bermudagrass bales did not retain moisture except in the areas in immediate contact with the ground. These observations led to the conclusion that outside storage of bermudagrass hay was feasible and could reduce the storage cost and labor for handling hay. Bledsoe et al. (1) stated in their 1972 and 1973 hay season studies that the overall quality ratings of the hay favored the inside storage of the large hay packages, although hay was preserved at a medium quality with outside storage of hay baled at a moisture content of up to 28 percent for roll bales and up to 31 percent moisture content for stacks.

Based on the finding at the Eastern Pasture Research Station in Oklahoma, Rider and Boyer (24) made the following recommendations for large package hay unit storage:

1. Store large hay units on a well-drained site to prevent concentration of moisture in the lower portion of the packages.
2. Allow a minimum space of one foot between the packages in storage.
3. Use twine on roll to reduce losses from wind. Plastic twine will not deteriorate, and must be removed from the bale before feeding.
4. Select a storage site near the feeding area to reduce feeding labor.
5. Do not store all hay in one stack yard because of fire hazard and use fire guards to reduce fire hazards.

## C. CHARACTERISTICS OF BERMUDAGRASS HAY

Bermudagrass is a perennial, warm-season grass. It is mostly used in the southern half of Tennessee as a forage plant because fescue and other cool-season pasture plants do not produce well in summer in this area. Fribourg (11) reported that research with bermudagrass started in Tennessee in 1957. It was determined from a number of experiments established at several locations in Tennessee that Midland bermudagrass was well adapted throughout the state at elevations up to 1,500 feet; hence Midland bermudagrass has been recommended for hay and pasture in Tennessee during the last decade.

Burns (7) recommended the following varieties for hay and pasture:

<u>Midland</u> - This is hybrid bermudagrass produced by crossing Coastal with a winter hardy strain of common from Indiana. The Midland variety is a tall leafy grass that produces an open sod. It is very winter hardy. Midland inherited its winter hardiness from its Indiana parent, hence can withstand kill farther north than Coastal.

<u>Tifton 44</u> - A hybrid bermudagrass produced by crossing Coastal with a winter hardy common from Berlin, Germany. It is winter hardy, about same production potential as Midland or Coastal but with a slightly higher quality than Midland or Coastal bermudagrass.

<u>Coastal</u> - This is a hybrid produced by crossing Georgia common with African common.

Midland, Tifton 44 and Coastal can be easily cut for hay, and will produce twice as much hay or grazing than the Common in West Tennessee. Although Common bermudagrass is the best choice for soil erosion control, most Common bermudagrass does not grow as tall and leafy as the improved varieties and is more difficult to mow and bale for hay. Burns recommended to cut the bermudagrass hybrids for hay when the first spring growth reaches 38 to 46 centimeters (15 to 18 inches) in height. Subsequent cuttings should be at four or five week intervals, and the grass should be mowed five to eight centimeters (two to three inches) above the ground. Old growth of bermudagrass is tough and of low quality.

Kilgore _et al_. (16) reported the effects of moisture content in Midland bermudagrass hay on the performance characteristics of three hay-making systems. They concluded that the packaging capacity of the conventional baler increased linearly with the moisture, but the handling capacity decreased with high moisture. Since bales were unloaded from wagons by hand, the heavier, higher moisture bales required more unloading time. Overall packaging and handling capacity for both the roll baler and stack systems generally increased linearly with the moisture content over a range of 8 to 46 percent moisture content (wet basis). But the packaging capacity of the stacker was slightly decreased when the hay moisture content was about 30 percent (wet basis).

## D. FEEDING LARGE HAY PACKAGES

Hay losses during feeding to livestock can be expected with any feeding method or system. The amount of waste varies with the particular system used. The primary aim of any feeding system is to keep the waste due to trampling hay into the mud and due to refusal to a minimum level, thus permitting animals to eat the majority of hay provided at feeding. Rider and Boyer (24) reported the feeding trials with Common bermudagrass hay and with sorghum-sudan grass hay conducted during January, February, and March of 1974 at Oklahoma State University. They used three feeding methods: 1) Daily hand feeding in a bunk with hay from a large roll bale; 2) Free access to roll bale placed on sod; and 3) Controlled access with the bale confined inside slant bar collapsable feeder panels. The study established that 14.6 percent (dry matter) of bermudagrass was wasted from free access feeding, 5.5 percent was wasted from controlled access feeding of bales in panels, while only 2.6 percent was wasted from daily hand feeding in bunks. A similar result was also observed with sorghum-sudan grass hay, which resulted in a 36 percent dry matter loss from free access feeding on sod. The animal performance for the two types of hay was an average daily weight gain of 0.34 kg (0.74 pounds) and 0.045 kg (0.10 pounds) for the bermudagrass hay and sorghum-sudan grass hays respectively. Rider and Boyer concluded that the controlled feeding resulted in less wastage of hay because trampling of the hay was prevented. Covered feed bunks were reported to further reduce losses by keeping moisture from entering the bale during feeding.

Renoll et al. (22) reported a feeding trial in which loose stacks were fed free-choice; hay losses as high as 46 percent were reported. Field condition of the feeding area was very muddy during the winter rain. In studies using large round bales fed free-choice, losses were considered excessive Renoll, et al., (22). In later studies using feeding panels around the large packages, hay waste was significantly reduced.

Gill, (12) in Ohio found that limited feeding or use of panels with large hay packages reduced hay waste in feeding beef cattle and sheep.

Lechtenberg et al. (17) conducted feeding trials at Purdue University to determine the amount of wastage during feeding large package hay to beef cattle. They used round bales and compressed stacks which had been stored outside for a period of about six months. Cattle were fed three package types. One group of cattle was fed free-choice on sod, the other group was fed large packages in four-sided fenceline feeding racks built on concrete. A second feeding experiment was also conducted in which only Vermeer round bales were fed to groups of cattle. One group was fed on concrete without racks, similar to the group fed free-choice on sod in the previous feeding study. The purpose of the concrete floor was to determine whether eliminating wet soil conditions would keep hay wastage below that obtained from large packages placed on sod. A second group of cattle was fed large packages with controlled access by use of an electric wire. Conventional bales were also fed to a group of cattle on concrete without a rack at the rate of 6.83 kg

(15 pounds) dry matter/cow-day. Based on this study, Lectenberg and associates concluded that when the three types of large hay packages were fed to beef animals without feeding racks, the amount of hay required per cow-day ranged from 10.91 to 12.90 kg (24 to 28.4 lb.) dry matter. When the large hay packages were fed in racks the hay requirement per cow-day decreased to an average of 9.2 kg (20.1 pounds) dry matter. Hay refused by animals averaged 3.72 percent dry matter. The hay requirement per cow-day without racks was significantly greater ($P < .05$) than with racks for all three package types. These researchers further stated that between 22.6 to 38.6 percent additional hay per cow-day would be required if large hay packages were fed without controlled access.

This study also indicated no significant difference between large bales fed on concrete and bales fed on sod. This result suggested that the wet soil condition was not a factor in the feeding wastage.

In Tennessee, Robertson _et_ _al_. (25) used stacks and large bales in a series of feeding trials with beef cattle. They reported hay trampling losses of below 5 percent when feed bunks with sliding head gates were used. They also found that animals preferred low density hay packages. High density bales were more readily eaten by the cattle when the bale was placed on end in the feeding bunk.

Walton (29) carried out a study with non-lactating dairy cows on a private farm in East Tennessee. He learned that the dry matter losses for large round bales of sorghum-sudengrass hay fed in feeding panels was only one-third of the dry matter losses without panels.

A recent experiment at Middle Tennessee Experiment Station (3) compared the effect on animal performance of two hay storage methods. An estimated trampling loss was found to be below 5 percent, and animals fed on inside - stored hay gained more weight than animals fed on outside - stored hay.

Rider and Boyer (24) gave the following guidelines that can be adopted to minimize the losses associated with feeding large hay packages:

1. Control access to large hay packages.
2. Feed high quality hay which will be readily consumed by cattle with less wastage than poor quality hay.
3. Select a well-drained feeding site to prevent wet, muddy locations.
4. Limit the amount of hay fed at one time to the quantity cattle will consume within seven days.
5. Force clean-up of hay fed free choice before a fresh package of hay is made available for consumption.
6. Use slant bar collapsible feeder panels to combine the advantages of labor savings and reduced hay wastage.

# CHAPTER III

# PROCEDURE

## A. DESCRIPTION OF FEED BUNKS USED

The three feeding methods used in this study were: 1) roofed feed bunk with one moveable metal head gate and one fixed wooden head gate, 2) unroofed feed bunk with one movable metal head gate and one fixed wooden head gate, and 3) feeding panels placed on sod. Eight feed bunks (four roofed, four unroofed) were built at the station before the feeding trial began.

The roofed feed bunk is shown in Figure 1. This bunk measured 3 m (10 ft.) in length x 2.4 m (8 ft.) in width x 1.2 m (4 ft.) in height to accomodate one small round bale at a time. The round bales were 1.6 m (5 ft.) in diameter and 1.8 m (6 ft.) long weighing between 270 to 360 kg (600 to 800 pounds). The roof stands 2.74 m (9 ft.) above the bunk floor and was constructed of #29 gage corrugated metal roofing. Treated lumber was used to build the bunk to prolong the physical life of the system. Previous large bale feeding studies indicated that the feeding area always became wet and muddy during the winter rain, hence two 10.2 cm (4 in.) x 15.2 cm (6 in.) lumber runners were used to raise the bunk floor above the ground and also to provide means to move the bunk about the field. To withstand the impact loads imposed by jousting of 272 kg (600 pound) steers, four pieces of 8.9 cm (3 ½ in.) x 8.9 cm (3 ½ in.) x 0.6 cm (¼ in.) steel angle 27.9 cm (11 in.) long were used at each corner to give the bunk more strength and rigidity.

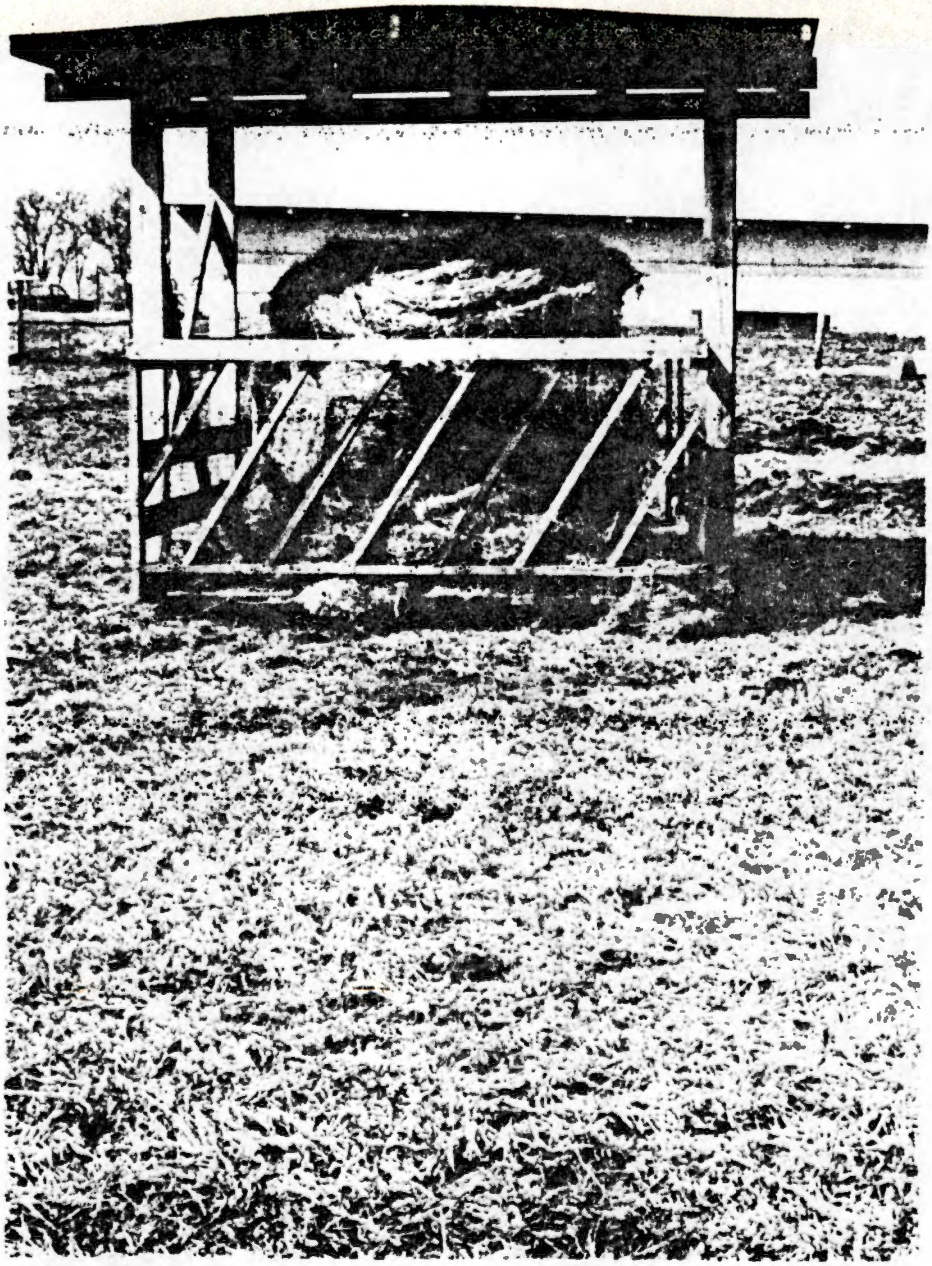

Figure 1. Roofed feed bunk with round bale positioned on end.

This bunk permits the animal to eat only from two sides. Six lumber end pieces were positioned in such a way that cattle would not be able to feed on hay from the bunk ends. The head gate suspension linkages were attached to the center end piece which was 60.9 cm (2 ft.) above the bunk floor. Floor boards were placed on edge at intervals to keep the bale of hay above the bunk floor for adequate air circulation under the hay package during the feeding period.

The unroofed feed bunk, pictured in Figure 2, was made with materials similar to the roofed bunk. It had the same dimensions and features as the roofed bunk shown in Figure 1 with the exception of the top cover to keep moisture from entering the bale during feeding. One advantage of the unroofed bunk was the ability to load the bunk without taking out the steel head gate.

The third feeding system used in the study is shown in Figure 3. This was a simple rectangular metal panel placed on bermudagrass sod. The panel had neither floor nor roof. The animal had access to the hay from all four sides of the feeding panel

## B. DESCRIPTION OF THE MOVABLE HEAD GATE WITH THE LINKAGE SUSPENSION

The movable head gate was made from 3.2 cm (1.2 in.) square steel tubing. The head gate, shown in Figure 4, measured 2.2 m (7.2 ft.) in length and 1.0 m (3.2 ft.) in height. Slanted-bar access openings prevented cattle from backing away from the gate while eating and pulling hay outside where it could be trampled into the soil. These bars were

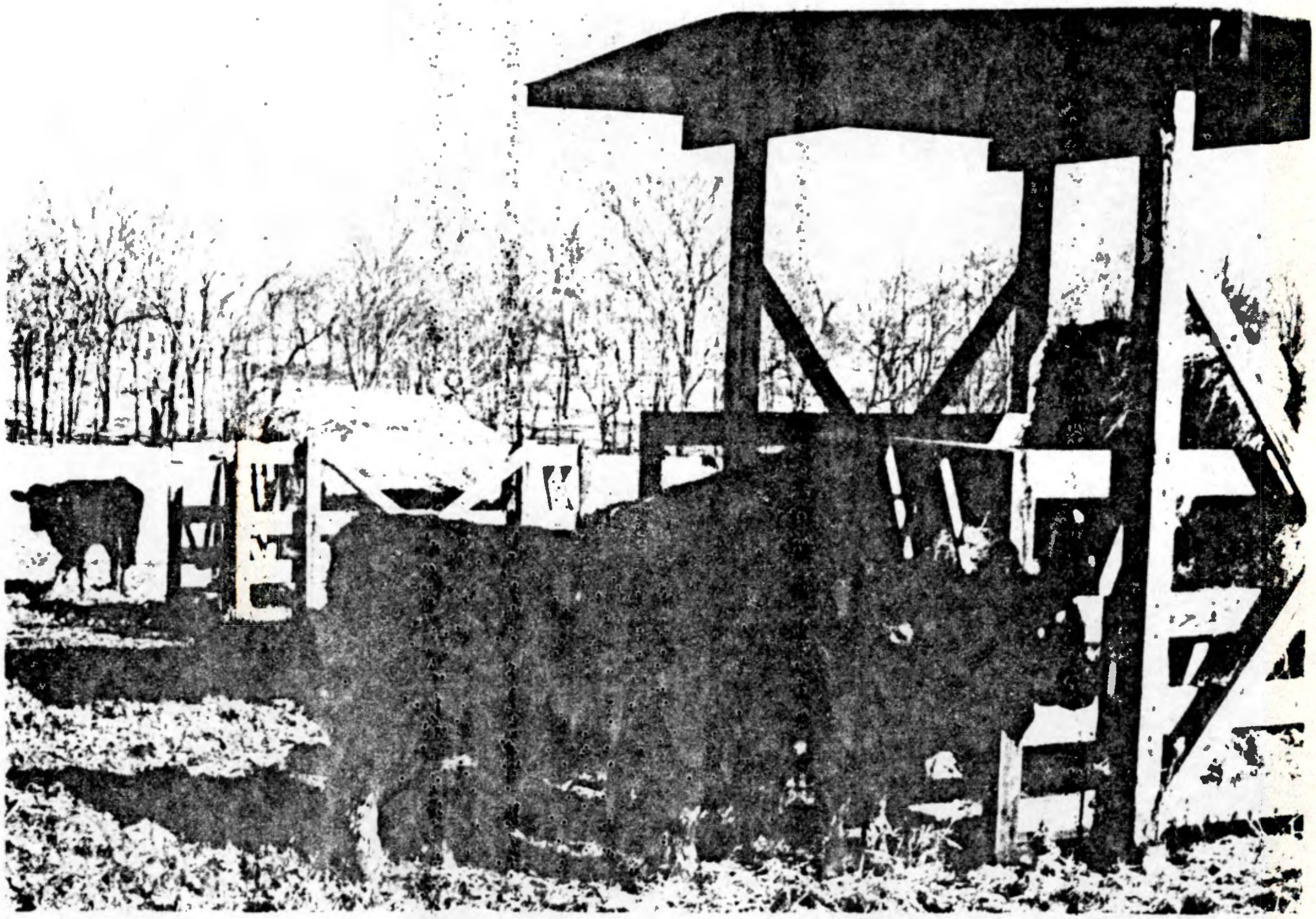

Figure 2. Roofed and unroofed bunks.

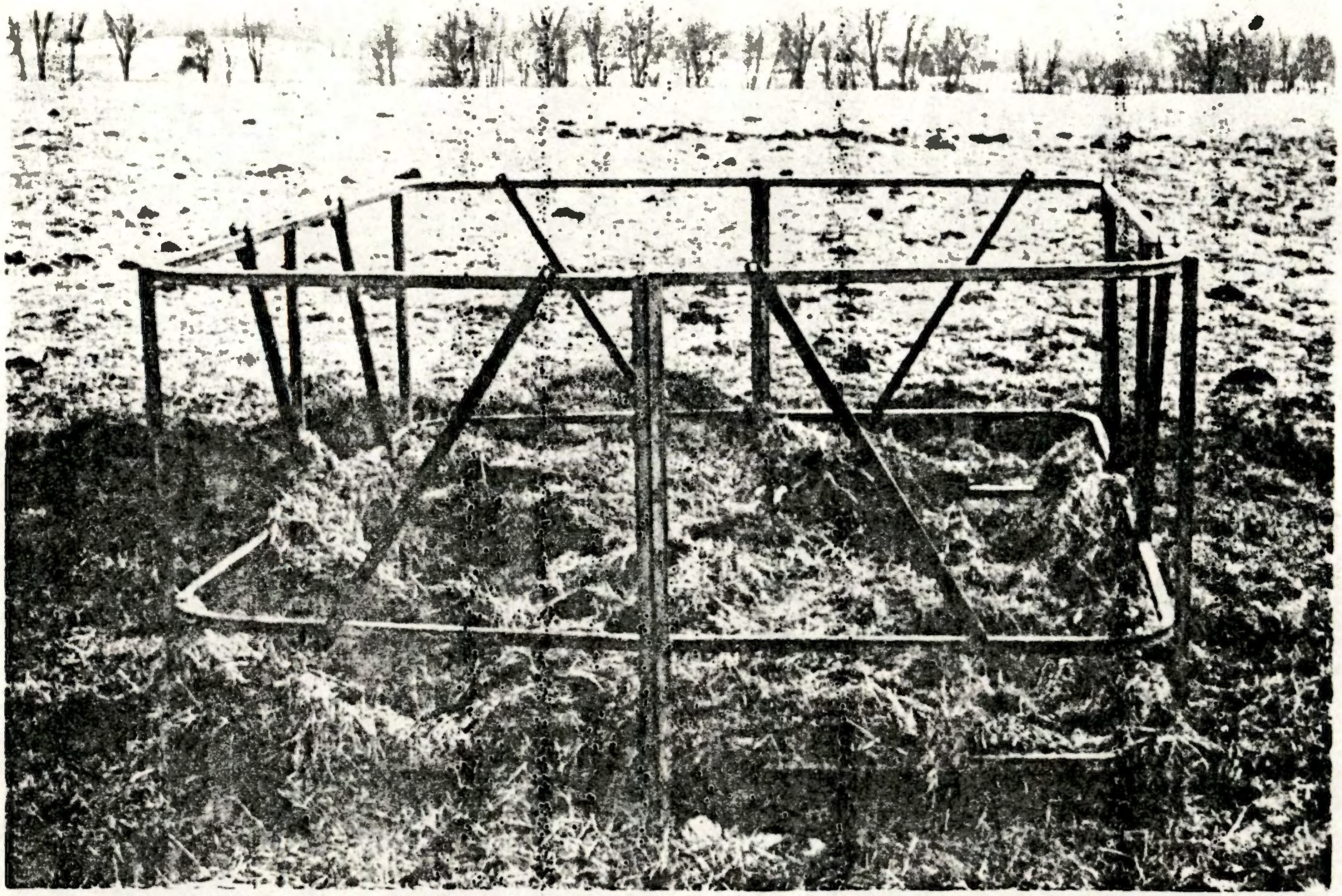

Figure 3. Typical feeding panel for large round bales used at Middle Tennessee Experiment Station.

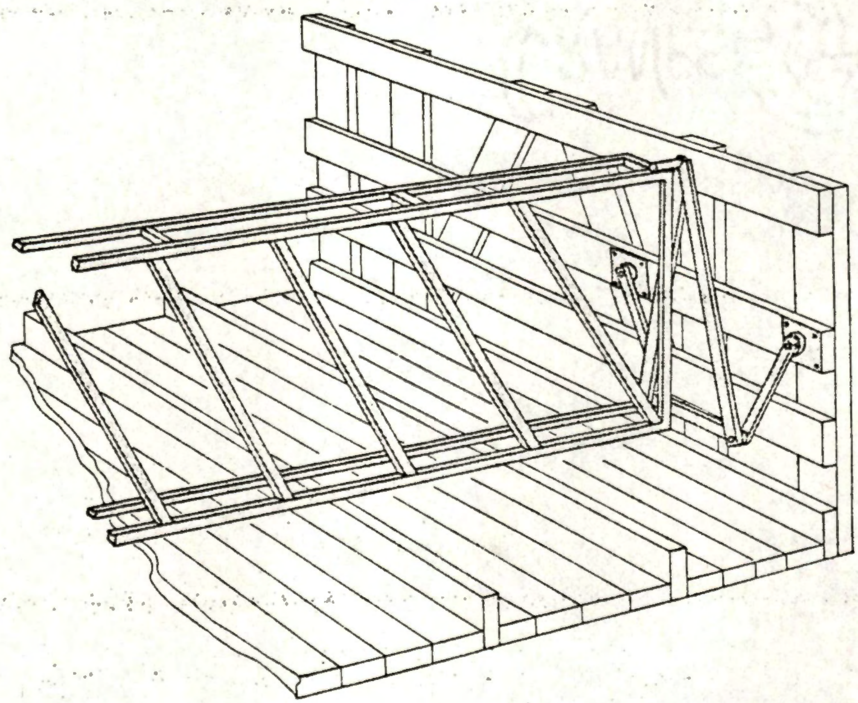

Figure 4. Straight-line linkage head gate system.

spaced 1 ft. apart to allow only the head and neck up to the brisket of the animal to reach for the hay. To prevent the head gate from coming in contact with the roll of hay, two extension bars - one at the top and one at the bottom - were used with the gate to keep it about 23 cm (nine inches) away from the hay. The gate was fastened to the suspension linkage at the top with only two pins; this allowed easy removal of the gate to put in a new hay package during feeding.

The head gate suspension linkage was a modified Roberts' 4-bar straight-line linkage (Figure 5) designed by Dr. Bledsoe and fabricated at the University of Tennessee Agricultural Engineering Research Laboratory. The linkage was made from 2.54 cm x 5.08 cm (one inch x two in.) rectangular steel tubing (Figure 6). Two linkage units, one at each end, permited the head gate to move a distance of about 0.9 meter (three feet) in a straight-line motion. As the cattle feed on the hay and push on the gate, the gate moves to expose more of the hay for consumption.

The main body of the linkage is a metal isosceles triangle with two identical extension arms joined to the base of the triangular piece (Figure 6). Each linkage was bolted to the center lumber piece of the bunk end through two 1.27 x 1.27 x 0.05 cm (6 x 6 x ¼ in.) steel plates spaced about 0.9 meter (three feet) apart along the end of the bunk. Two stop pins were used with each linkage to control the extent the gate could be moved in both directions. The head gate was fastened to the linkage with only two solid round steel pins. The plate pin, joint pin and the gate pin were made from 3.49 cm (1.375 in.) O. D. solid round steel cut to specified length. The linkage had pinned joints with sufficient clearance to prevent binding.

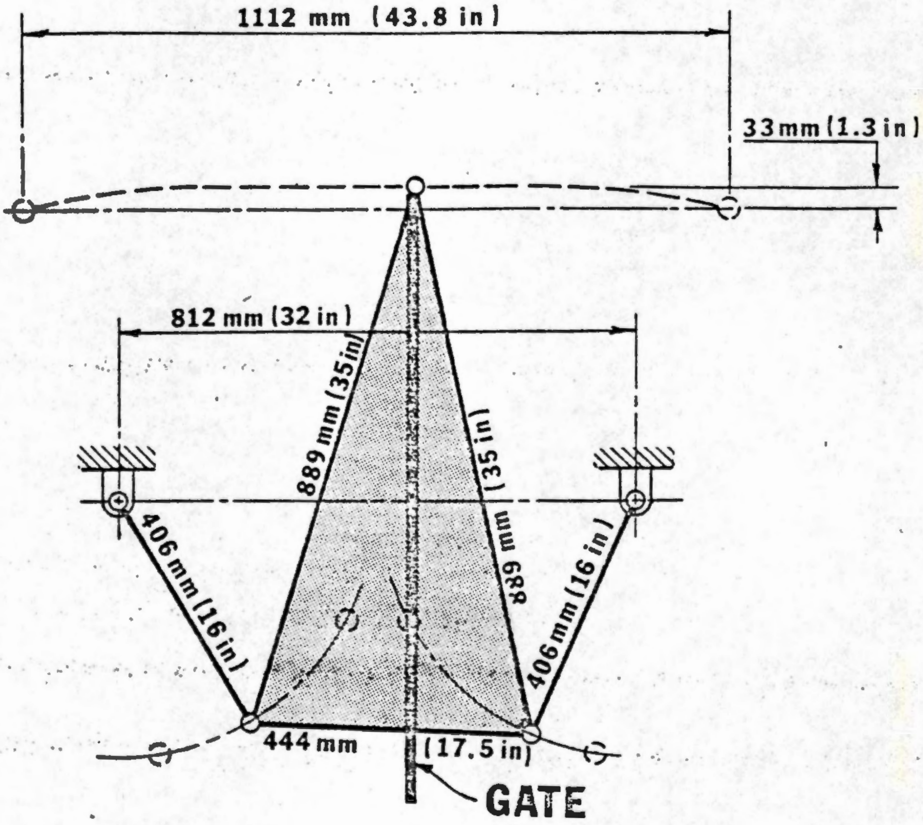

Figure 5. Schematic diagram of modified Roberts' straight-line linkage used for gate suspension.

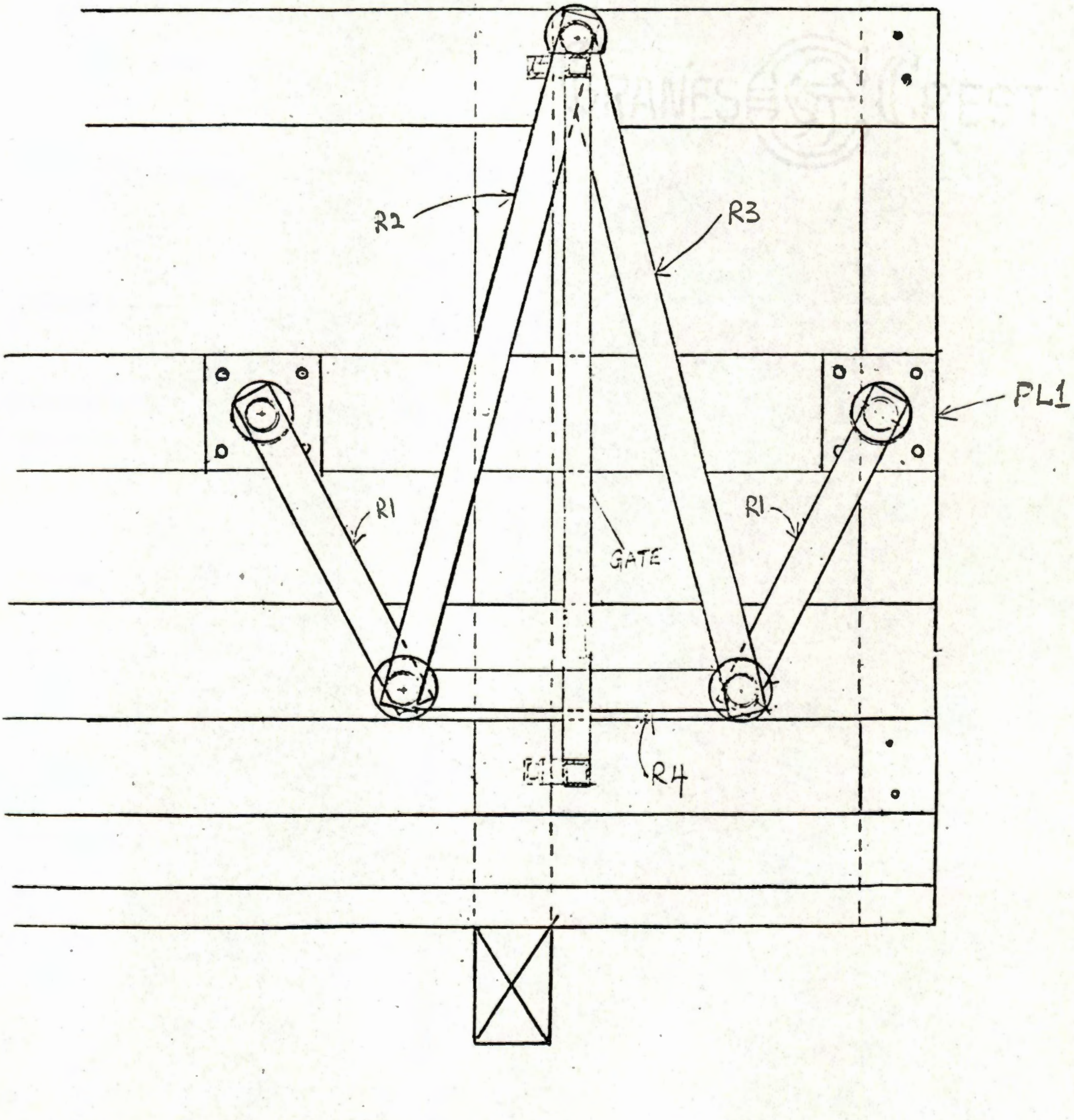

Figure 6. Head gate suspension linkage.

### C. HANDLING AND STORAGE OF HAY PACKAGES

Midland bermudagrass hay was baled at the Middle Tennessee Experiment Station, Spring Hill, in October, 1978, and stored four months before feeding trials began in the winter of 1979. A Pennsylvania coring tool, powered by an electric drill, was used to take core samples of the hay package (Figure 7). Three random core samples were taken from each bale and placed in a plastic bag along with a tag indicating the date and the bale identification number. The samples were placed in an ice chest and brought to Knoxville for laboratory determination of dry matter percentage. Bales were stacked and retrieved with a spear-type bale mover attached to a tractor-mounted front-end-loader.

The weighing station was located in a convenient point between the field and the two storage areas (Figure 8). Each bale produced was weighed before storing. The scale was a merchant-type scale connected to a wooden platform. The spear-type bale mover was used to pick up each bale and place it on the scale platform. The weight of the bale was read to the nearest pound. Half of the bales were stored four-high inside a tobacco barn on lumber to separate the bales from contact with the ground (Figures 9 and 10). The other half of the large round bales were placed single file along the fence line in a well drained area covered with bermudagrass sod (Figure 11). All packages stored outside were spaced at least one foot apart to allow for water run-off and air circulation to facilitate drying.

Figure 7. Core sample of the bale being taken with a Pennsylvania coring tool at Middle Tennessee Experiment Station.

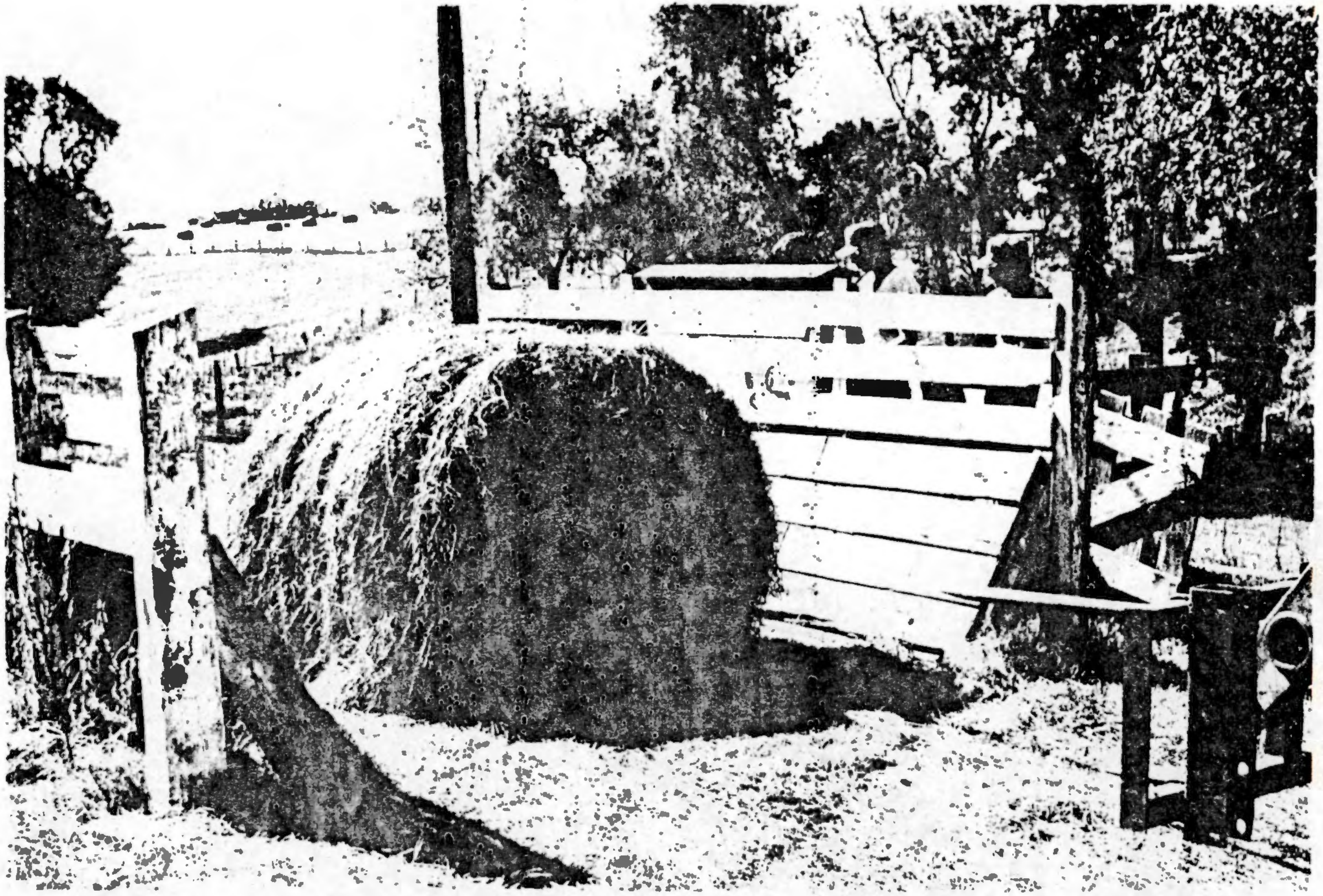

Figure 8. Platform scale used for weighing large round bales.

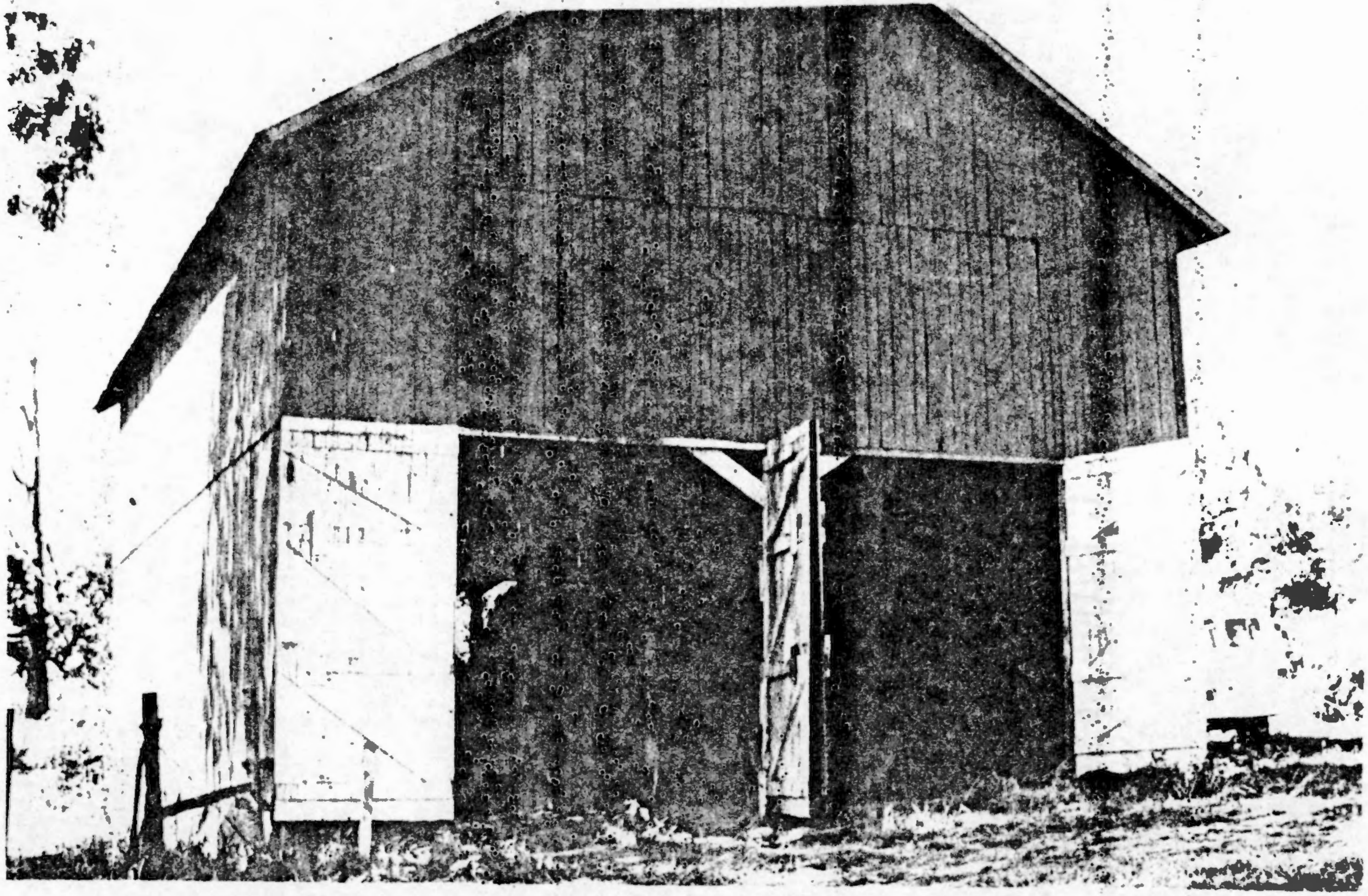

Figure 9. Tobacco barn used for storing large round bales at Middle Tennessee Experiment Station.

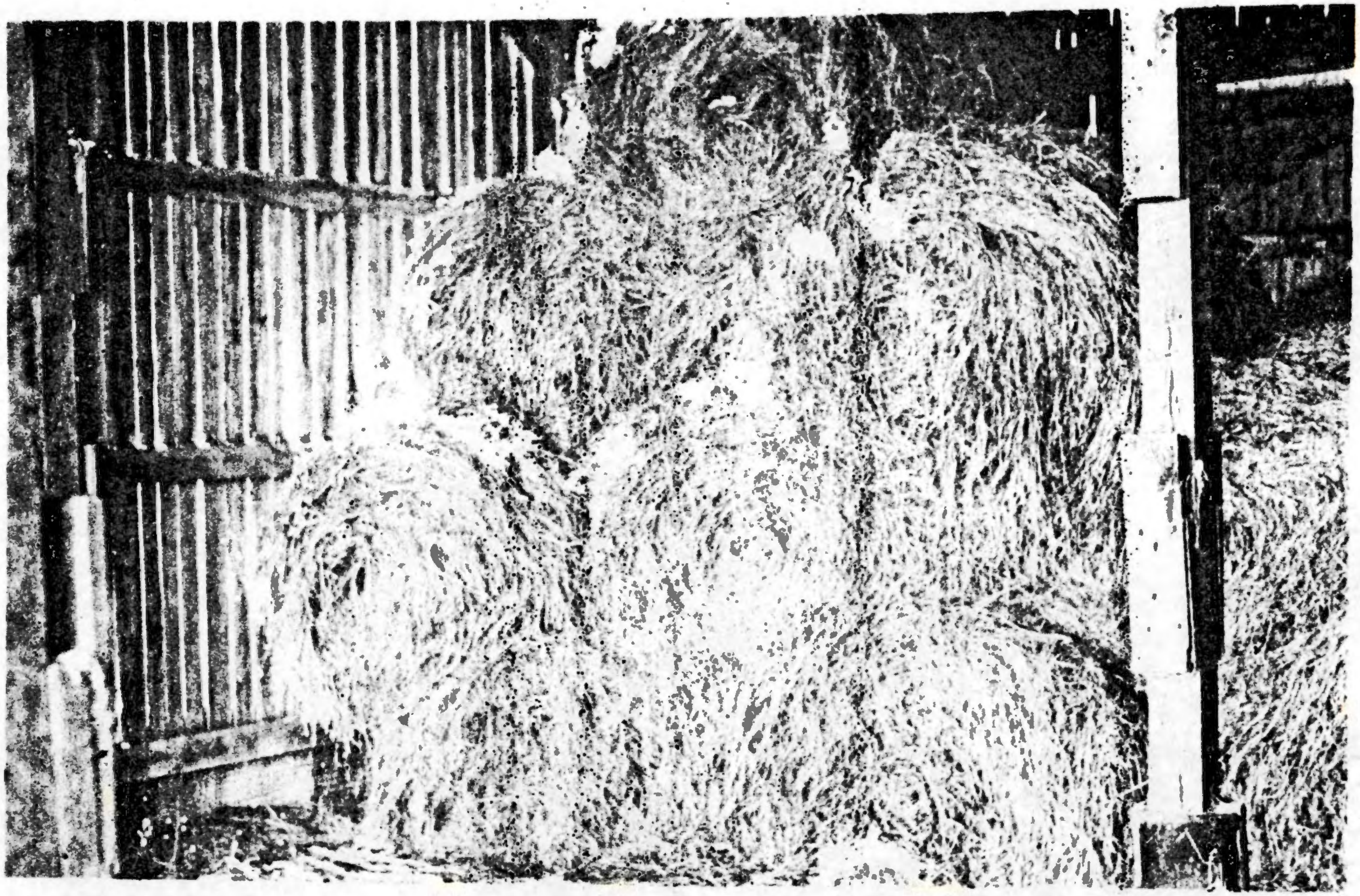

Figure 10. Large round bales stacked four-high inside tobacco barn.

Figure 11. Large round bales stored outside along a well-drained area of the fence surrounding the hay field.

## D. FEEDING LARGE HAY PACKAGES

Core samples were taken from both inside and outside stored hay bales just before the feeding trials started. The samples were taken randomly in the same manner as at the beginning of the storage period. By January 20th, 1979, all materials and preparations were ready for the feeding trials to begin at Middle Tennessee Experiment Station, Spring Hill. The winter feeding trials started on January 28th and extended over a period of 42 days. Each hay package was weighed just before being fed.

The hay bales were fed in roofed bunks, in unroofed bunks and in feeding panels placed on sod. Although Rider and Boyer (24) recommended a short distance between storage and feeding locations, at Middle Tennessee Experiment Station each bale was moved an average distance of one mile (from the field to weighing station, then to storage site, back to weighing station before feeding, and finally to the feeding area). To facilitate easy transportation of the large round bales, a trailer wagon was used to move three large round bales per trip (Figure 12). The movable head-gate was removed from the roofed bunk to allow a hay package to be placed in the bunk with a spear-type bale mover (Figure 13). For unroofed bunks and the feeding panels, new hay packages were deposited over the sides (Figure 14).

## E. EXPERIMENTAL DESIGN

A split-plot (nested) design was chosen to assess the effect of feeding equipment type on hay feeding losses while simultaneously

Figure 12. Large round bales loaded on a trailer to transport three bales per trip.

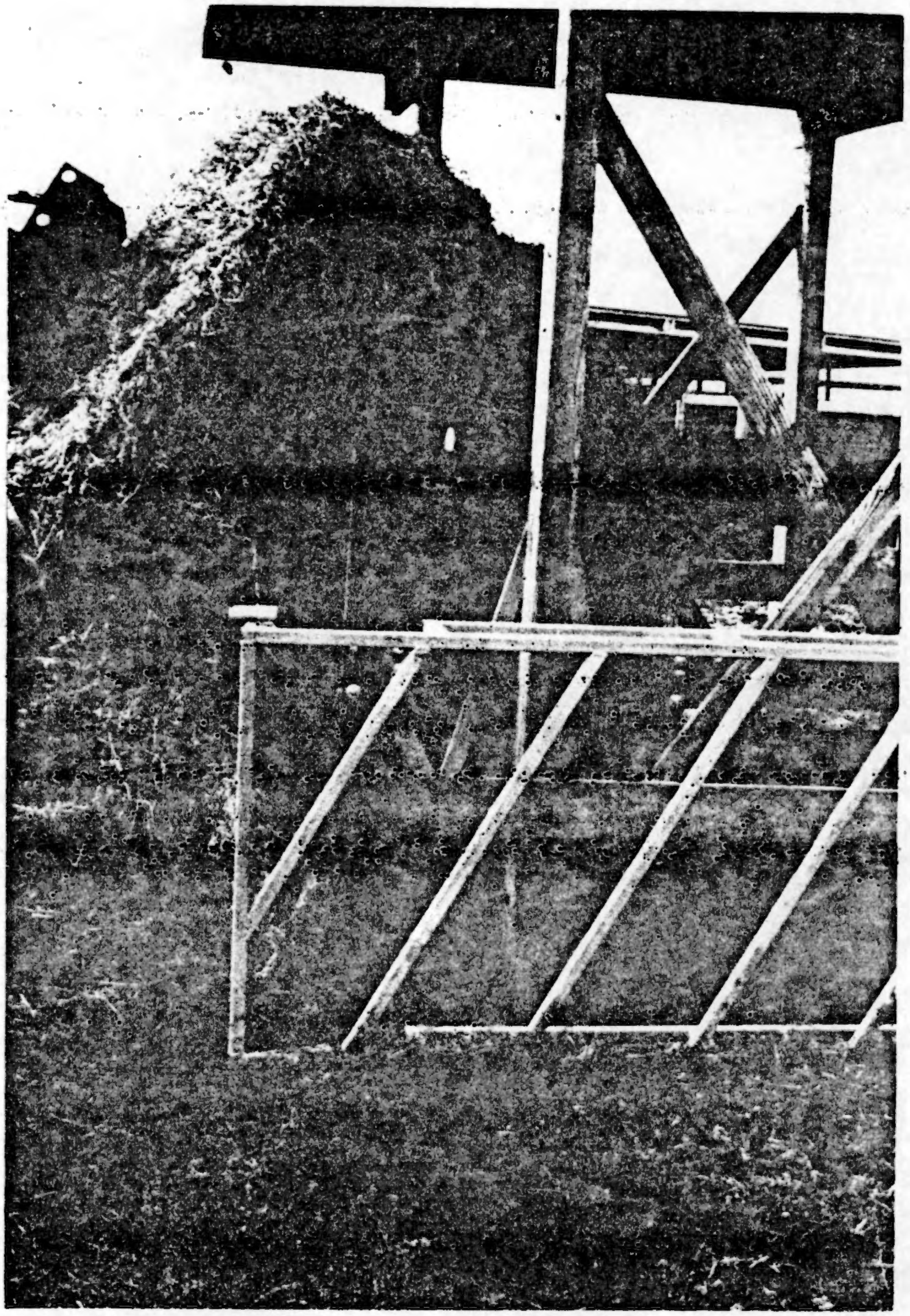

Figure 13. Roofed bunk head gate removed to load hay package into the bunk.

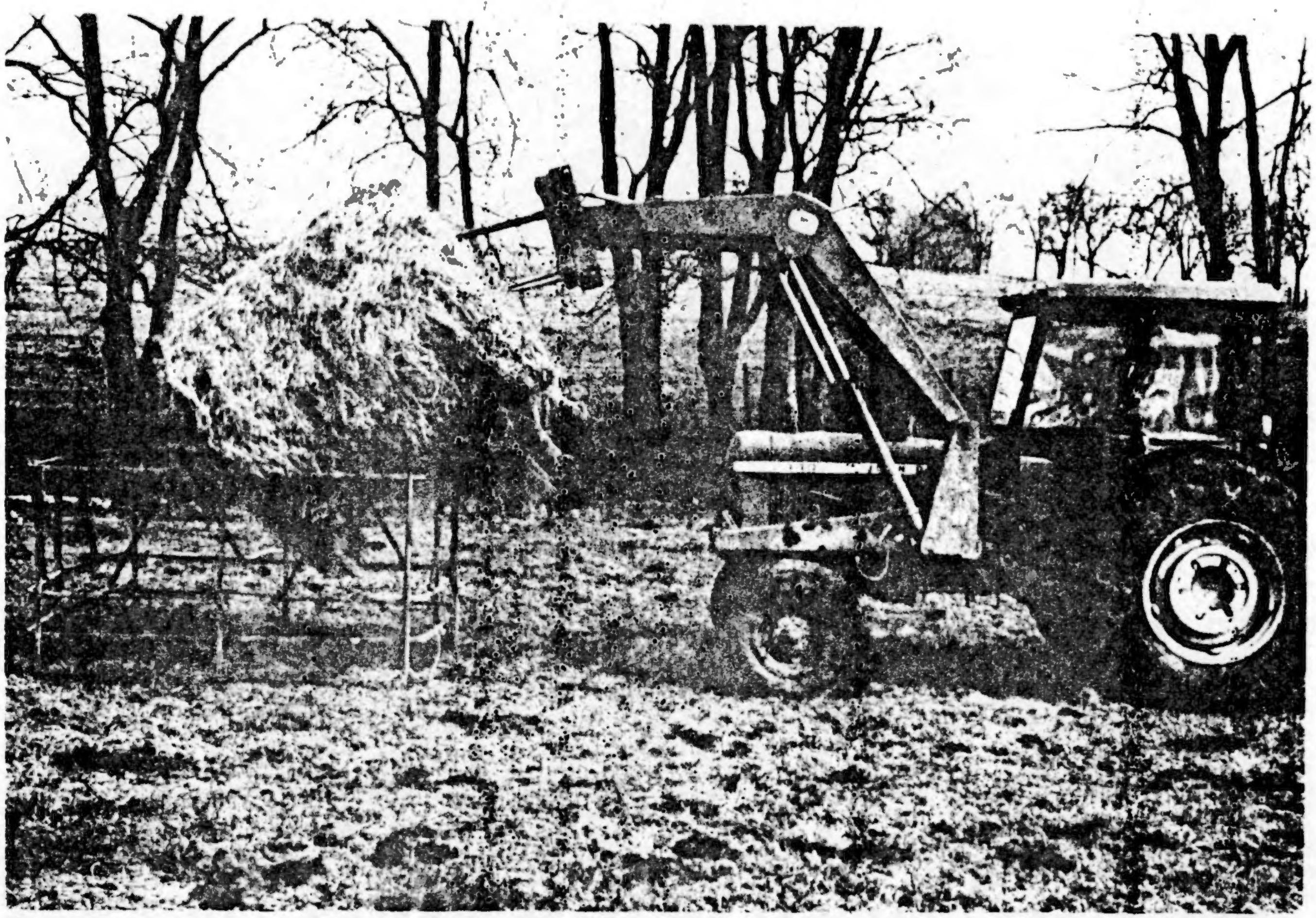

Figure 14. Loading the feeding panel at Middle Tennessee Experiment Station.

evaluating the effect of hay storage method (inside or outside) on animal gain. A schematic representation of the experiment layout is shown in Figure 15.

### F. IMPLEMENTATION OF THE EXPERIMENTAL PLAN

Four pens with sizes of 0.6 ha (1.5 ac), 1.0 ha (2.5 ac), 2.5 ha (6.1 ac) and 3.6 ha (9.0 ac) were prepared. The three types of feeders - roofed, unroofed and panel were placed in each pen to give the animal opportunity to feed freely from the feeder of his choice. The feeders were positioned about three meters (10 feet) apart in a straight line with the feed gates parallel to the line. Outside stored hay was used in all the feeders in pens one and three, while inside stored hay were used in pens two and four throughout the feeding trial period. These arrangements gave two replications each for evaluating animal performance (weight gain) on inside and outside stored hay. At the start of the experiment, forty yearling black angus steers, average initial weight of 268 Kg (590 pounds) were randomly divided into the four pens with 10 steers per pen. It was noticed after about five days that 10 animals in one week could not consume all the three packages available to them. Therefore, another forty yearling steers within the same weight range were randomly divided among the pens. This made the number of animals used for the feeding trial a total of 80 - 20 animals per pen. Each animal was weighed twice within 48 hours before being assigned to a pen. The average weight was recorded as the initial weight of the animal. The cattle were allowed to feed on the hay until they refused to eat any more from the feeders. The cattle pushed the headgate inward with their

| | Outside Stored Hay | | | Inside Stored Hay | | |
|---|---|---|---|---|---|---|
| | Pen 1 (20 animals) | | | Pen 2 (20 animals) | | |
| REP I | Feeder | Feeder | Feeder | Feeder | Feeder | Feeder |
| | A | B | C | A | B | C |
| | Pen 3 (20 animals) | | | Pen 4 (20 animals) | | |
| REP II | Feeder | Feeder | Feeder | Feeder | Feeder | Feeder |
| | A | B | C | A | B | C |

Figure 15. Schematic representation of experimental design.

withers to reach for hay as they ate (Figure 16). It was assumed that the cattle had consumed all of the edible hay when they left the feeders and began walking the fences looking for feed.

The trampling loss sample for each bale fed was taken every other day using a two square foot frame made of 5.0 cm (2 in.) x 10.2 cm (4 in.) lumber (Figure 17). The frame was placed randomly on the ground in front of the feed gate, and all the hay tramped was collected free of mud and weighed. Four random samples were collected from each gate and the area of the trampling space in front of the bunk gates. In the case of the panel, the trampling area was measured around the panel. The dry matter content of the tramped sample was determined by oven drying at 64° C for forty-eight to seventy-two hours. All the refused hay from each feeder was collected and weighed. The refused hay was placed on a canvas and was hung on a spring scale supported by a tripod (Figure 18).

Each feeder was evaluated on the basis of amount of hay wasted during the feeding period. Altogether, a total of thirty inside-stored and thirty outside-stored round bales were fed to the cattle. In addition to hay consumed, cattle were also fed 0.91 Kg (two pounds) crushed corn and about 0.68 Kg (1.5 pound) liquid supplement per head each day.

## G. STATISTICAL ANALYSIS

The SAS (Statistical Analysis System) computer program package was used for the statistical calculations. The SAS program computed the analysis of variance tables and means for the amount of hay refused,

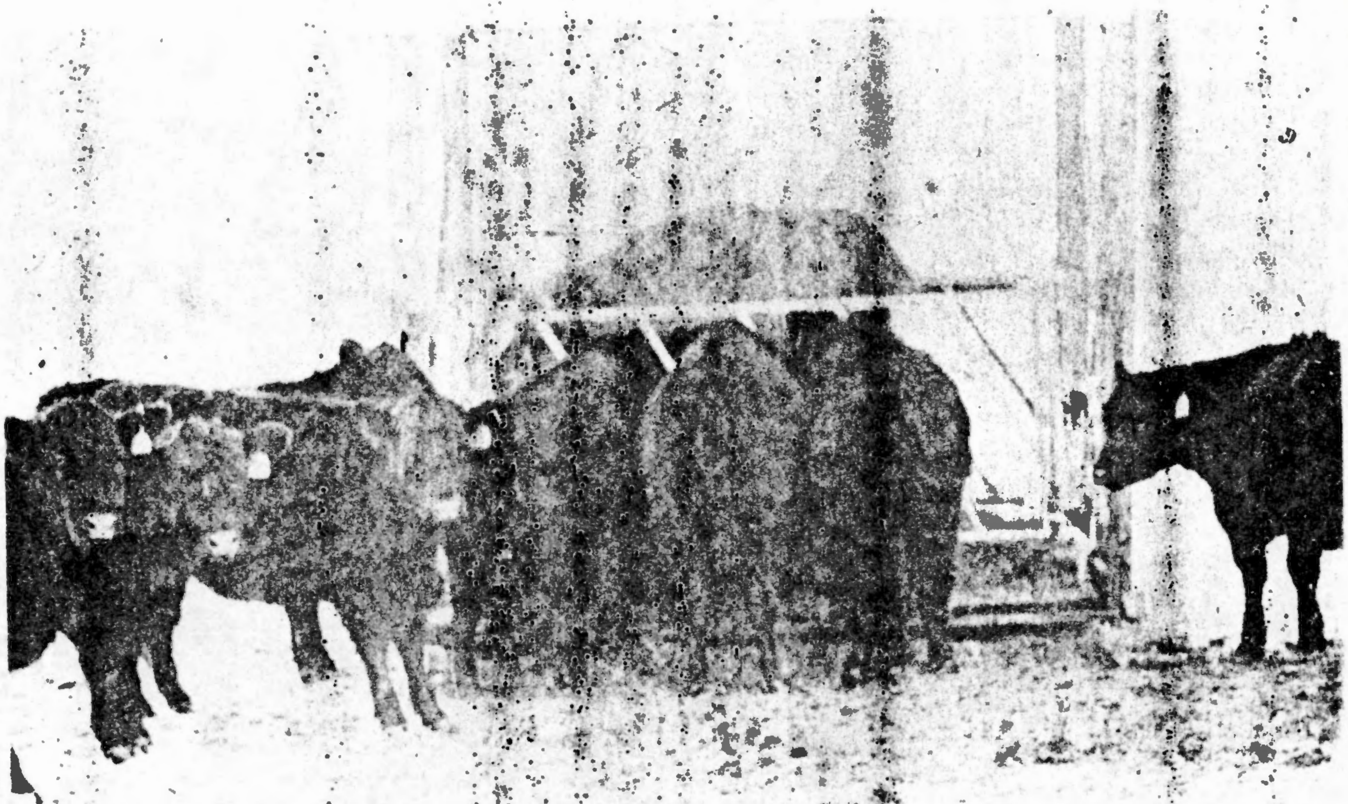

Figure 16. Animals pushing the headgate with their withers as they feed on the hay.

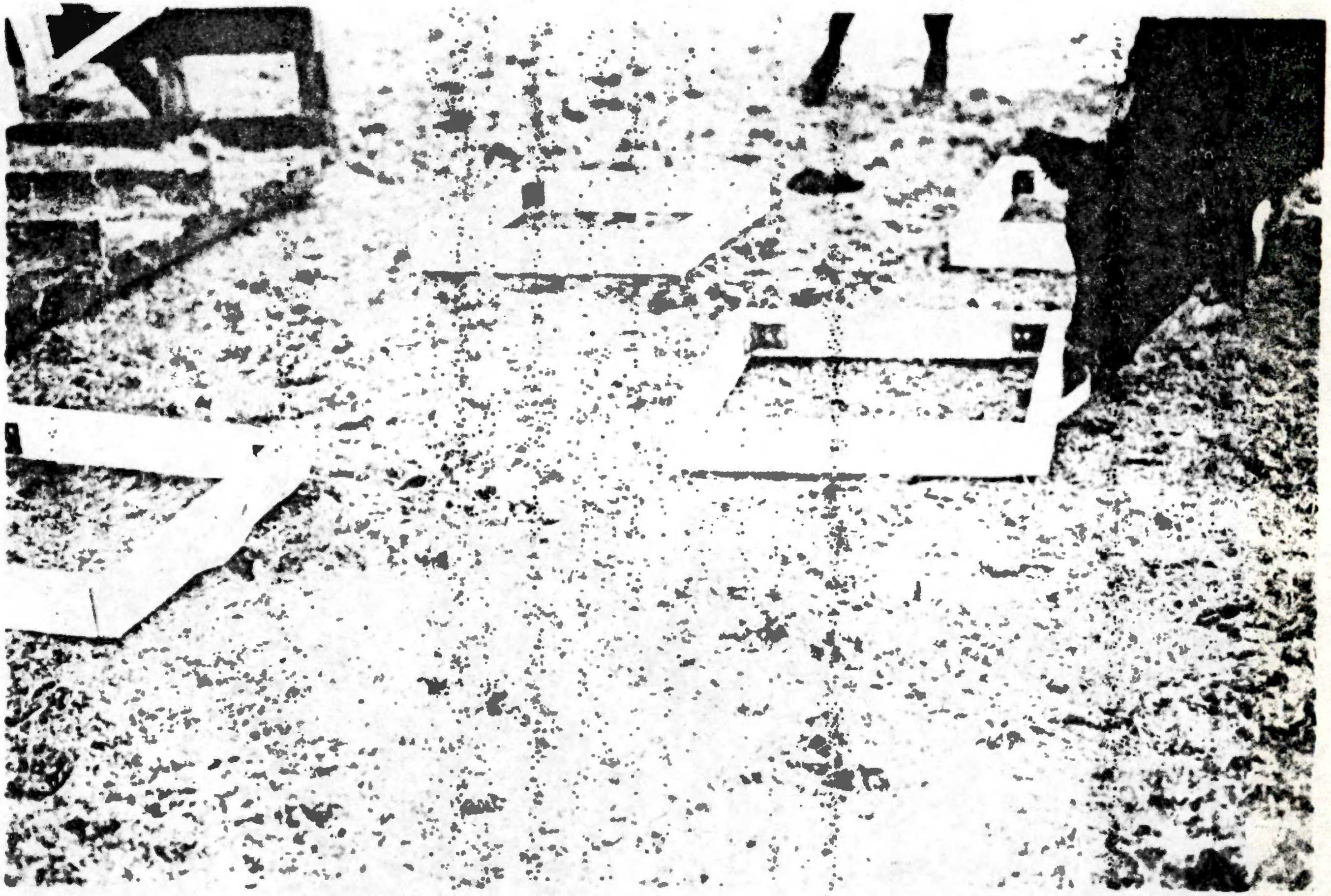

Figure 17. Two square foot frame used to collect the trampling sample of hay.

Figure 18. Refused hay sample being weighed with spring scale supported from tripod.

tramped and the total loss for each of the feeding systems used during the feeding trials. The SAS program package was also used with Duncan's Multiple Range Test to determine any significant difference in animal performance (weight gain) on outside- and inside-stored hay.

# CHAPTER IV

# RESULTS AND DISCUSSION

## A. EFFECT OF EACH FEEDING SYSTEM ON THE AMOUNT OF HAY WASTED

Data collected during the feeding trial are presented in Appendix A. Results of the statistical analysis of the data are summarized in Tables 1 and 2. As noted in Tables 1 and 2, bunk type had a significant effect (at 5 percent level of probability) on the amount of hay refused and tramped into the mud during the feeding of the large round bales.

The least square means for refused hay (wet basis) were 31.3 kg (60 pound), 9.8 percent of hay available in the bales, for the roofed bunk; 41.7 kg (92 pound), 13.5 percent, for the unroofed bunk; and 74.8 kg (165 pound), 24.8 percent, for the panel. While trampling losses were about the same amount for roofed and unroofed bunks - 4.2 kg (9.2 pound), 1.3 percent, and 4.3 kg (9.6 pound), 1.4 percent, respectively, the trampling losses for the panel amounted to more than twice as much as for the roofed or unroofed bunks - 9.6 kg (21.2 pound), 3.1 percent (Figure 19). The total hay wasted for the roofed, unroofed and the panel was 35.4 kg (78 pound), 11 percent; 45.8 kg (101 pound), 15 percent; and 84.4 kg (186 pound), 28 percent, respectively. The panel feeder was significantly different from the roofed and the unroofed feeders at ($\alpha = 0.05$).

In comparing the percentage refused loss of the available dry matter at feeding, the roofed feeders had a refusal loss of 5.6 percent

## Table 1

### Analysis of Variance for Hay Loss (Wet Basis) During The Feeding Trials

| | | Mean Squares | | | | | |
|---|---|---|---|---|---|---|---|
| Sources of Variation | df | Refused | F-Value | Tramped | F-Value | Total Loss | F-Value |
| Storage | 1 | 32666.66 | 9.43$^*$ | 1275.13 | 786.67$^*$ | 46883.33 | 13.34$^*$ |
| Pen (Storage) | 2 | 11027.63 | 3.18 | 38.88 | 23.99$^*$ | 9872.04 | 2.81 |
| Bunk Type | 2 | 50116.02 | 14.47$^*$ | 919.22 | 567.10$^*$ | 64373.34 | 18.32$^*$ |
| Storage x Bunk | 2 | 350.62 | 0.10 | 92.74 | 57.21$^*$ | 192.30 | 0.05 |
| Pen x Bunk (Storage) | 4 | 1756.28 | 0.51 | 1.35 | 0.83 | 1753.09 | 0.05 |
| Error | 48 | 3462.59 | | 1.62 | | 3513.27 | |

$^*$Significant at $\alpha = 0.05$.

## Table 2

Analysis of Variance for Hay Loss (Dry Basis) During the Feeding Trials

| | | Mean Squares | | | | | |
|---|---|---|---|---|---|---|---|
| Source of Variation | df | Refused | F-Value | Tramped | F-Value | Total Loss | F-Value |
| Storage | 1 | 2140.36 | 2.73 | 683.44 | 95.57* | 404.87 | 0.53 |
| Pen (Storage) | 2 | 1545.74 | 1.97 | 116.69 | 16.32* | 1013.49 | 1.33 |
| Bunk Type | 2 | 8172.34 | 10.44* | 1061.80 | 148.47* | 14988.53 | 19.70* |
| Storage x Bunk | 2 | 465.84 | 0.60 | 91.46 | 12.79* | 203.36 | 0.27 |
| Pen x Bunk (Storage) | 4 | 254.31 | 0.32 | 29.52 | 4.13 | 211.79 | 0.28 |
| Error | 48 | 782.83 | | 7.15 | | 760.67 | |

*Significant at $\alpha$ = 0.05.

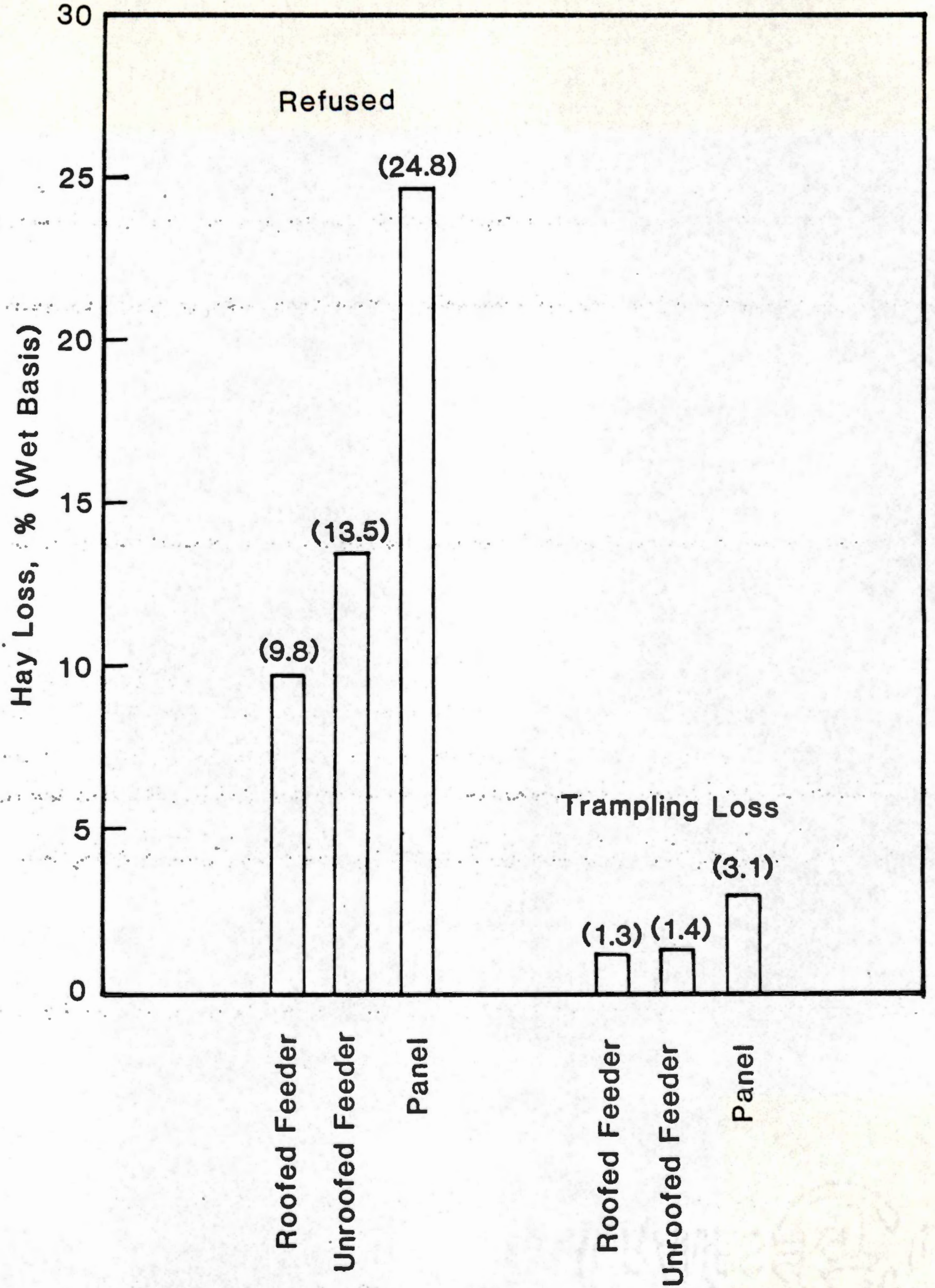

Figure 19. Percentage of hay refused and trampled (wet basis).

(dry matter), the unroofed feeder has a loss of 7.7 percent, and the panel had a loss of 13.3 percent. The trampling losses were 1.4 percent (dry matter) for the roofed, 1.5 percent for the unroofed and 3.9 percent for the panel (Figure 20). Combining the refused and tramped losses the total losses for each kind of feeder - roofed, unroofed and panel - were 7.1 percent, 9.2 percent and 17.3 percent dry matter losses, respectively. Losses from each feeder are presented in Figure 21.

All results indicate the panel had the highest amount of waste, followed by the unroofed feeder while the least amount of waste came from the roofed bunk. The large refused loss from the panel and the unroofed feeders can be attributed to precipitation and weather conditions directly affecting the hay during the feeding period. In the case of the panel placed on sod, the hay was not protected by any means from the precipitation and the wet and muddy condition of the feeding area, hence hay offered to animals in the panel was always very wet and unpalatable. Whereas in the case of roofed bunk, the top cover kept moisture from entering the bale, hence the hay offered to the cattle from the roofed bunks stayed fairly dry. Duncan's Multiple Range Test shows that hay wasted from the panel was significantly different from the hay wasted by either the roofed or the unroofed feeders.

## B. INFLUENCE OF HEAD GATE ON LOSSES

The two types of head gates used in this study were fixed wooden head gate and movable steel head gate. It was observed that the cattle fed equally well from both head gates. Animals tended to trample more hay into the mud when they ate from the wooden head gate than when they ate from the movable metal head gate. The animals pulled hay directly

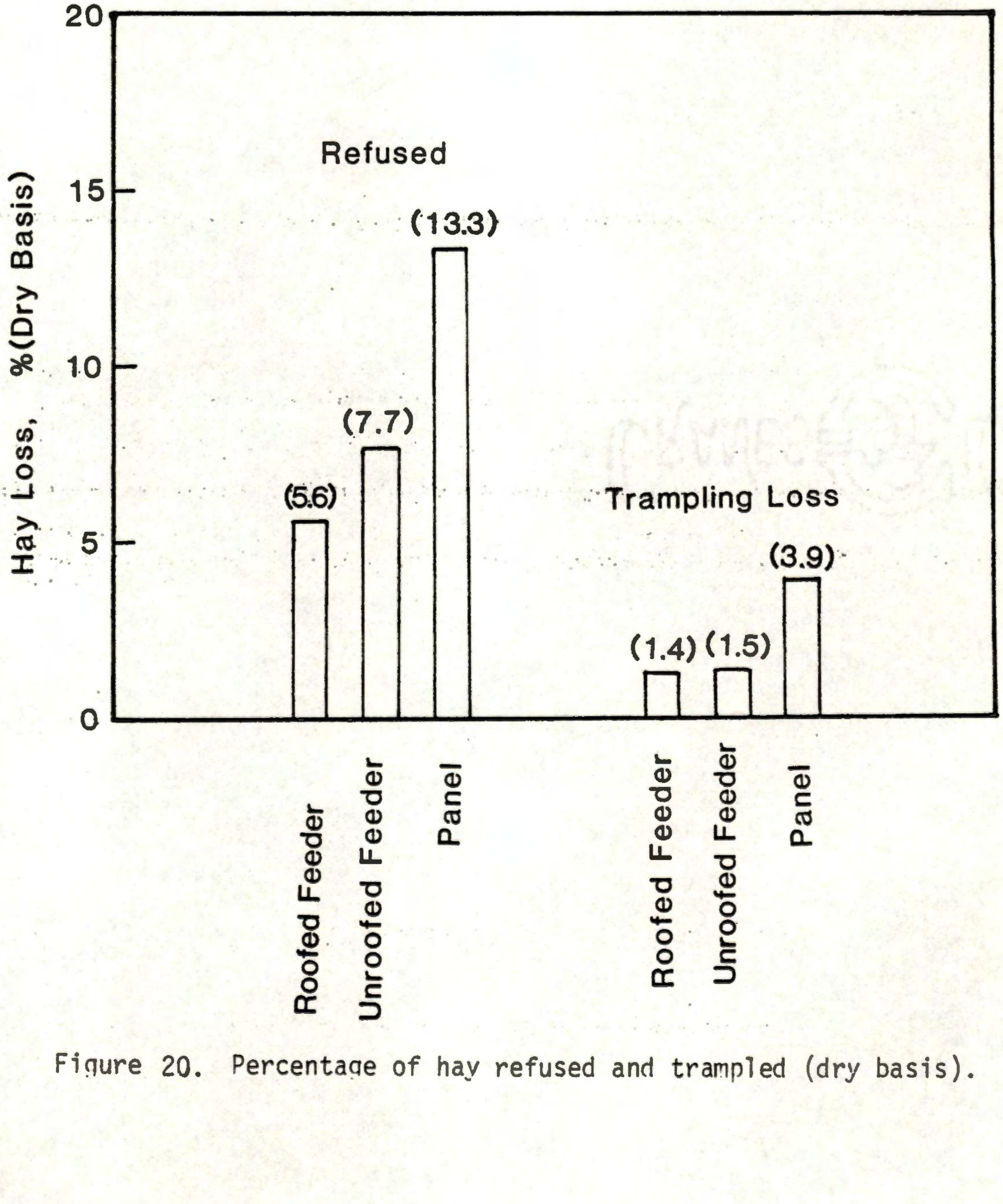

Figure 20. Percentage of hay refused and trampled (dry basis).

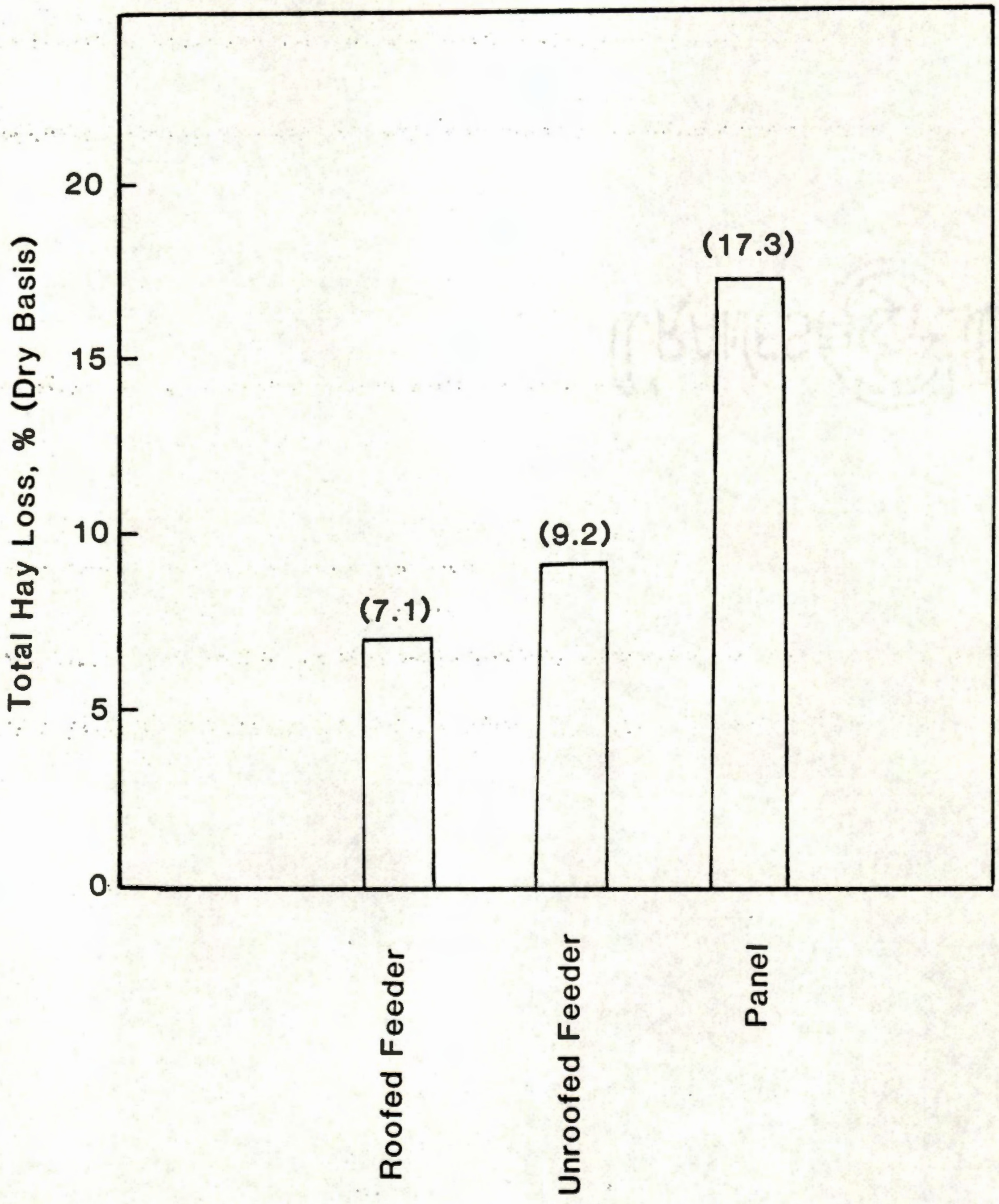

Figure 21. Percentage of total dry matter hay loss during feeding trial.

from the wooden head gate onto the ground as they fed; whereas from the metal gate, the forelegs of the cattle were placed on the bunk floor while they stretched their head through the gate to reach for the hay. Any hay pulled by the animals would be dropped on the bunk floor as the animal backed up from the head gate then continued to feed on the hay outside the head gate.

Previous study (4) showed that slanted bars on the head gate required the animals to bend their heads slightly to one side as they backed from the hay. This requirement reduced the frequency of animals backing from the bunk which helped reduce trampling losses. Although the head gate was designed to move in a straight line motion with the help of the linkage system, it was observed that when animals first started feeding on the hay, all four of their legs were on the ground, and they ate the hay from the lower portion of the bale. As they pushed the head gate against the hay, they put the forelegs on the bunk floor and ate from the top portion of the round bale. After about two days of feeding, the roll bale collapsed on the bottom extension bar that kept the head gate away from the hay. This situation created some problem and prevented the head gate from moving in a vertical plane as the animals pushed with their withers; instead, the lower part of the head gate was stopped by the hay, and the top portion of the head gate moved inward to give the position of the head gate as shown in Figure 22.

The bottom extension bar caused a problem on the second day of the feeding trial at Middle Tennessee Experiment Station. At this time the animals were familiarizing themselves with feeding from the bunks, and one animal suffered a broken leg when it was trapped between the head gate lower extension bar and the bunk.

Figure 22. Position of the animal forelegs and moveable head-gate at feeding.

## C. STORAGE METHOD EFFECT ON LOSSES

Previous studies have shown that animals perform better (weight gain) on inside-stored hay than on outside-stored hay (24, 3).

Observations during these feeding trials revealed that animals ate both the outside- and inside-stored hay equally well, but a larger amount (wet basis) was wasted from the outside stored hay. The statistical analysis of data collected showed a significant difference ( = 0.05) between the tramped hay losses (wet basis) from outside- and inside-stored hay. There was a significant difference between the outside- and inside-stored hay in the amount of hay refused (wet basis) by the cattle (Table 1, page 40). The mean amount of hay refused per bale fed during the 42 day feeding trial was 59.8 kg (132 pound), 17.3 percent, for outside-stored hay; and 38.5 kg (85 pound), 14.7 percent, for inside-stored hay. The mean tramped losses were 8.1 kg (17.9 pound), 2.4 percent, for the outside-stored hay; and 3.9 kg (8.7 pound), 1.5 percent, for the inside-stored hay. The combined or the total losses were 67.9 kg (149.7 pound), 19.7 percent, for the outside-stored hay; and 42.5 kg (93.8 pound), 16.2 percent, for the inside-stored hay.

The outside-stored hay package maintained its shape and was easily maneuvered with the bale mover. On the other hand, the inside-stored hay bales were loose and fluffy, and a considerable amount of hay was lost during the transportation of these bales from the storage area to the feeding location. On a dry matter basis, the total amount of losses recorded was higher for the inside-stored hay, but this difference was not statistically significant at 5 percent level of significance (Table 2, page 41). For the outside-stored hay, 10.5 percent of the total available dry matter was lost during feeding; whereas 11.8 percent dry matter was lost during feeding the inside-stored hay. The total amount of outside-stored hay fed was 10276.60 kg (22,660 pound) wet basis, which was 6638.9 kg (14,638.85 pound) dry matter available at feeding. For the inside-stored hay, 7834.5 kg (17,275 pound) wet basis was fed, which was 6511.6 kg (14,358.04 pound) dry matter available at feeding from inside-stored hay. The inside-stored hay packages contained 83.1 percent dry matter at feeding; the outside-stored hay packages contained 64.6 percent dry matter at feeding.

## D. ANIMAL PREFERENCE FOR BUNK TYPE AND PERFORMANCE (WEIGHT GAIN) ON INSIDE- AND OUTSIDE-STORED HAY

Daily visual estimations were made as to what percentage of the package loaded in the feeder had been consumed by animals. This estimation was used as a measure of animal preference for type of feeder.

It appeared that animals preferred feeding from the panels rather than from either the roofed or unroofed bunks. Observations made over all hay packages fed revealed that animals consumed about 50 percent of hay from the panels during the first twenty-four hours after loading the feeders and then abandoned the hay in the panels to feed from either the roofed or unroofed bunks. The preference for panels can be simply explained by the fact that hay in the panel could be easily reached by cattle. This easy access enabled the animal to pull out and tramp a large amount of hay into the mud. They also used the hay around the panel for bedding. Occasionally an animal was found inside the panel lying on the hay. Figures 23 and 24 show the typical rate of consumption of hay from the feeding systems.

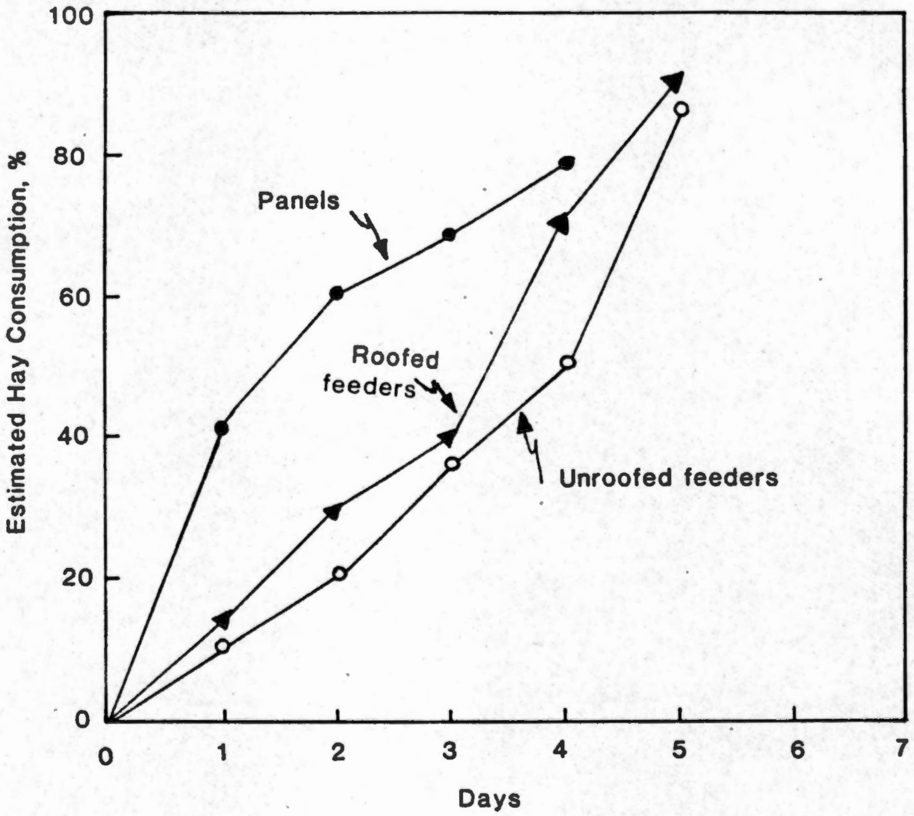

Figure 23. Typical daily estimated rate of consumption for the outside stored hay.

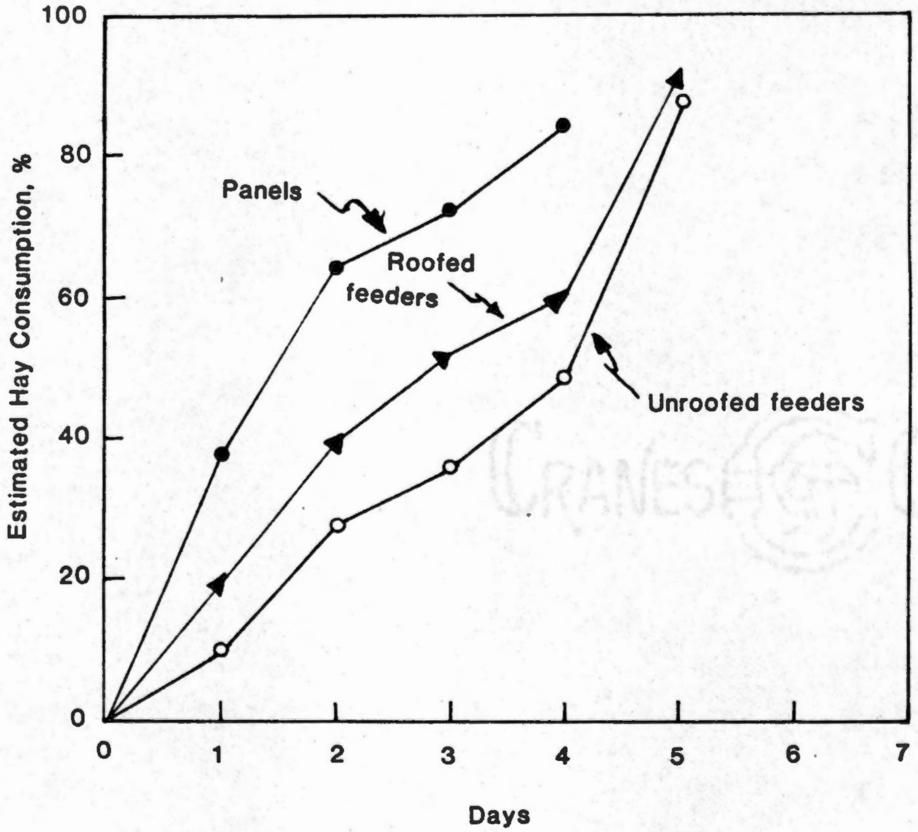

Figure 24. Typical daily estimated rate of consumption for inside stored hay.

It was also noted that animals fed on inside-stored hay performed better (weight gained) than the animals fed on outside-stored hay. Average daily weight gain by animals is presented in Appendix B. Statistical analysis of this data is summarized in Tables 3 and 4. Animals fed inside-stored hay gained 0.44 kg/day (0.98 pound), while those fed outside-stored hay gained 0.36 kg/day (0.80 pound). This animal performance was not statistically significant at the 5 percent level of significance.

### Table 3

Analysis of Variance for Animal Performance (Average Daily Gain) during the 1978 Feeding Trials

| Sources of | | Mean Squares | |
|---|---|---|---|
| Variation | df | ADG | F-Value |
| Storage | 1 | 1.7854 | 11.86* |
| Pen (Storage) | 2 | 0.1715 | 1.14 |
| Error | 36 | 0.1506 | |

---

*Significant at $\alpha = 0.05$.

### Table 4

Analysis of Variance for Animal Performance (Average Daily Gain) during the 1979 Feeding Trials

| Sources of | | Mean Squares | |
|---|---|---|---|
| Variation | df | ADG | F-Value |
| Storage | 1 | 0.4753 | 2.22 |
| Pen (Storage) | 2 | 0.2436 | 1.14 |
| Error | 76 | 0.2142 | |

---

*Significant at $\alpha = 0.05$.

# CHAPTER V

# ECONOMIC COMPARISON OF THE FEED BUNKS

Large acreages of forage crops are grown throughout the United States. The most valuable of these forages is alfalfa. Each producer would like to maximize his return by feeding the maximum amount of nutrients possible. Therefore, good management decisions should be employed for planting, harvesting, storing and feeding crops to farm animals.

A cost comparison of the traditional baling system and the automatic bale wagon system has been made by Wendell Bowers (5). He estimated the feeding cost of both systems to be equivalent.

Results of various experiments over the nation indicated that considerable amounts of hay can be saved if restricted access to the hay is provided to animals (12, 17 and 22). Several reports have concluded that the cost for harvesting and feeding hay, using mechanized handling of both big package and conventional bales, was lower for the big package systems. This is mainly due to the lower labor requirement. It was estimated that the cost per 45.4 kg (100 pound) gain of steers was higher for the big round bales when feeding panels were not used, but costs per 45.4 kg (100 pound) gain were lower for the round bales when feed loss was reduced by using panels (13).

Results of experiments to determine the value of hay saved required to justify the use of a feeding system in feeding large hay packages were not available. Therefore, results from this study were used to calculate such economic guidelines. The cost of each bunk was based on retail prices of materials obtained locally. The labor cost to build a bunk was estimated to be equivalent to the material cost for the bunk.

Tables 5 and 6 show the cost of various components making up the roofed and unroofed bunks. The panel bunk cost $120 retail value. Cost analyses were computed on an assumed eight year useful life for the bunk. The amount of hay saved during the 42 day feeding trial was extrapolated to 100 days for a typical winter feeding period in the southeastern region, and this value was used to calculate the cost benefit from use of feeding equipment.

Equipment costs were divided into two categories, fixed costs and variable costs. Fixed costs are those that accrue whether the equipment is used or not, in other words - ownership costs. This cost is independent of use, while variable costs are the costs associated with operating the equipment; these increase proportionally with the amount of operational use given the equipment.

The following parameters are included in:

fixed cost - a. Depreciation
  b. Interest
  c. Taxes
  d. Insurance
  e. Housing

variable costs - a. Repair and maintenance
  b. Tractor power
  c. Fuel and oil
  d. Labor
  e. Miscellaneous

## Table 5

### Purchase List of Materials for the Roofed Bunk Used at Middle Tennessee Experiment Station

| Item | No. Reqd. | Description | For Part[1] | BD. Ft. | Length |
|---|---|---|---|---|---|
| **Bunk:** | | | | | |
| 1 | 2 | 2"x6"x10' | (1) | 20.00 | |
| 2 | 27 | 2"x6"x8' | (2)(3)(6) | 216.00 | |
| 3 | 3 | 2"x6"x12' | (10)(13) | 36.00 | |
| 4 | 5 | 2"x4"x10' | (4)(9) | 33.33 | |
| 5 | 4 | 4"x4"x8' | (5) | 42.66 | |
| 6 | 2 | 2"x4"x8' | (15) | 10.66 | |
| 7 | 4 | 2"x4"x12' | (7)(14)(16) | 32.00 | |
| | | | Total | 390.66 | |

390.66 bd. ft. @ $0.4656/bd ft = $181.89

| Item | No. Reqd. | Description | For Part[1] | BD. Ft. | Length |
|---|---|---|---|---|---|
| **Wooden Gate:** | | | | | |
| 1 | 3 | 2"x4"x8' | (19) | 16.00 | |
| 2 | 2 | 2"x4"x12' | (20)(21)(24)<br>(25) | 16.00 | |
| 3 | 1 | 2"x4"x10' | (26) | 6.00 | |
| | | | Total | 38.66 | |

38.66 bd ft @ $0.4656/bd ft. = $18.00

| Item | No. Reqd. | Description | For Part[1] | BD. Ft. | Length |
|---|---|---|---|---|---|
| **Steel Tubing Head Gate:** | | | | | |
| | | 1.25 sq. steel tubing | (1) | | 173.40" |
| | | " | (2) | | 71.00" |
| | | " | (3) | | 58.55" |
| | | " | (4) | | 166.85" |
| | | " | (5) | | 54.00" |
| | | " | (6) | | 20.25" |
| | | | | Total | 544.04" |

45.336 ft @ $41.01/100 ft = $18.59

| | | | | | |
|---|---|---|---|---|---|
| 1.625 OD Round Tubing | | | (S2) | | 8.0" |

2/3 ft @ $25.10/100 lbs. (7.05 lbs/ft)

$$\frac{7.05\ \cancel{lb}}{1\ \cancel{ft}} \times \frac{2}{3}\ \cancel{ft} \times \frac{\$25.10}{100\ \cancel{lb}} = \$1.18$$

Table 5 (cont'd)

| Item | No. Reqd. | Description | For Part$^2$ | BD Ft. | Length |
|---|---|---|---|---|---|
| Linkages: | | | | | |
| | | 1"x2"x14 ga rect. stl tubing | (R4) | | 31.9" |
| | | " | (R2) | | 74.90" |
| | | " | (R3) | | 71.88" |
| | | " | (R1) | | 74.00" |
| | | | | Total | 252.68" |
| 21.06 ft @ \$51.20/100 ft. = \$10.78 | | | | | |
| Pins: | | | | | |
| | | 13/8" OD. Solid Round St. | (P1) | | 9.50" |
| | | " | (P2) | | 18.00" |
| | | " | (P3) | | 12.50" |
| | | | | Total | 40.00" |
| 3.33 ft @ \$20.27/100 lb. (5.05 lb/ft) | | | | | |
| $\frac{5.05\ \cancel{lb}}{1\ \cancel{ft}} \times 3.33\ \cancel{ft} \times \frac{\$20.27}{100\ \cancel{lb}} = \$3.41$ | | | | | |
| Steel Plate: | | | | | |
| | | 6" width x 1/4" thick mill plate stl. | (PL1) | | 24.0" |
| 2 ft @ \$30.31/100 lbs (10.2 lbs/ft)<br>12" width | | | | | |
| $\frac{10.2\ \cancel{lb}}{\cancel{ft}} \times \frac{2\ \cancel{ft}}{2} \times \frac{\$30.31}{100\ \cancel{lb}} = \$3.09$ | | | | | |
| Sleeve & Spacer: | | | | | |
| | | 1¼" std Black Pipe (for Sleeve) | (B1) | | 17.5" |
| | | " (for Spacer) | (S1) | | 5.0" |
| | | | | Total | 22.5" |
| 1.875 ft @ \$64.88/100 ft = \$1.22 | | | | | |
| Plain Washer: | | | | | |
| | | 3¼" OD x 0.18" Thick | (W1) | | |
| 16 required @ \$42.35/100 = \$6.78 | | | | | |

Table 5 (cont'd)

| Item | No. Reqd. | Description | For Part | BD Ft. | Length |
|---|---|---|---|---|---|
| Bolts: | | | | | |
| | 16 | ½" Dia x 5" Long @ $48.80/100 = $7.80 | | | |
| | 16 | ½" Dia x 3" Long @ $33.24/100 = $5.32 | | | |
| | 50 | ¼" Dia x 6" Long @ $46.50/100 = $23.25 | | | |
| | 10 | 1/8" Clip Pin x 2" Long @ $3.80/100 = $0.38 = $36.75 | | | |
| Angle Reinforcing: | | | | | |
| | | 3½"x3½"x¼" Thick Stl Angle | | | 48.0" |

4 ft @ $20.13/100 lbs (5.80 lb/ft)

$$\frac{5.80\ \cancel{lb}}{1\ \cancel{ft}} \times 4\ \cancel{ft} \times \frac{\$20.13}{100\ \cancel{lb}} = \$4.67$$

Roofing:
1¼" x 26" width x 8'-0" #29 Ga. Corr. Iron Sheet

12 Sheets @ $5.80/sheet = $69.60

| Ridge Cap Angle: | |
|---|---|
| 12'-0" @ $3.80/10"x10'-0" = $4.56 | 12'-0" |

Roofed Bunk Material Cost:

| Material | Cost |
|---|---|
| Bunk | $181.89 |
| Wooden Gate | 18.00 |
| Steel Tubing Head Gate | 18.59 |
| OD Round Tubing | 1.18 |
| Linkage | 10.78 |
| Pins | 3.41 |
| Steel Plate | 3.09 |
| Sleeve & Spacer | 1.22 |
| Plain Washer | 6.78 |
| Bolts | 36.75 |
| Angle Reinforcing | 4.67 |
| Roofing | 69.60 |
| Ridge Cap Angle | 4.56 |
| | $360.52 |
| Labor: Assumed Equal Material Cost | 360.52 |
| | $721.04 |

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[1] Figures 25, 26 and 27 show feeder parts.
[2] Figure 28 shows linkage parts.

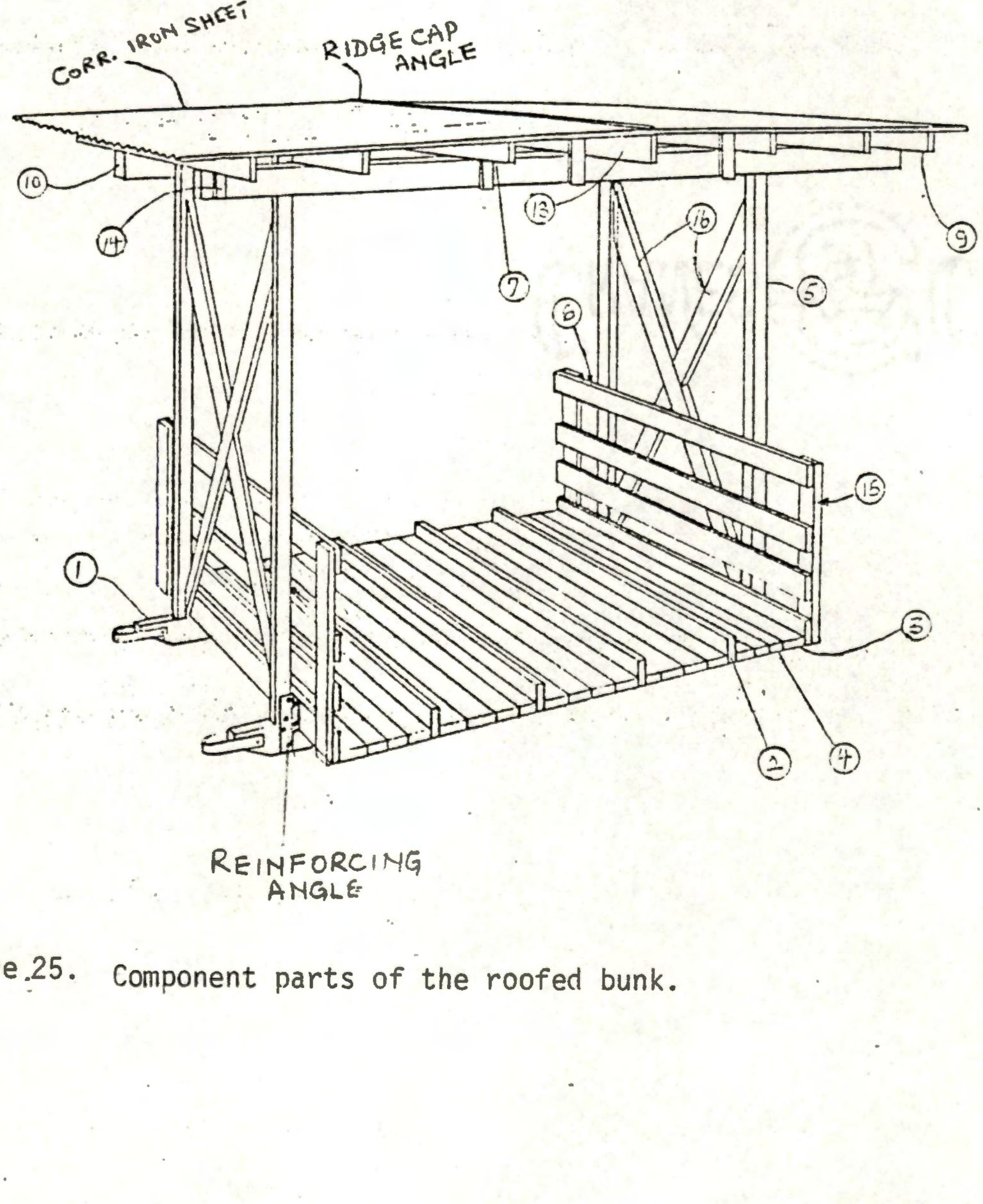

Figure 25. Component parts of the roofed bunk.

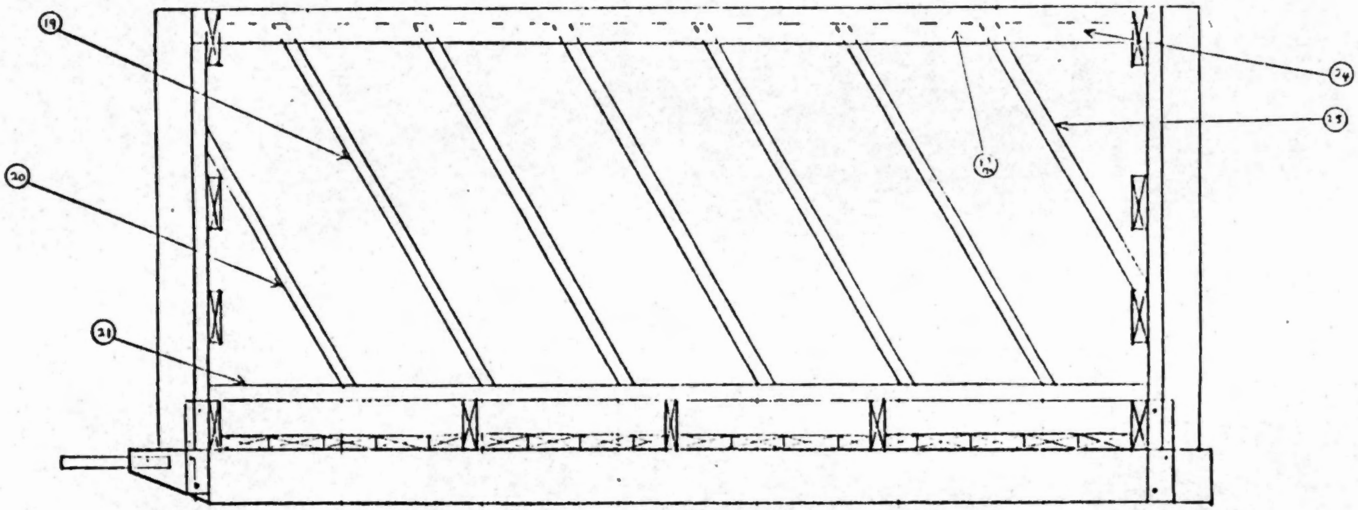

Figure 26. Component parts of the fixed wooden head-gate.

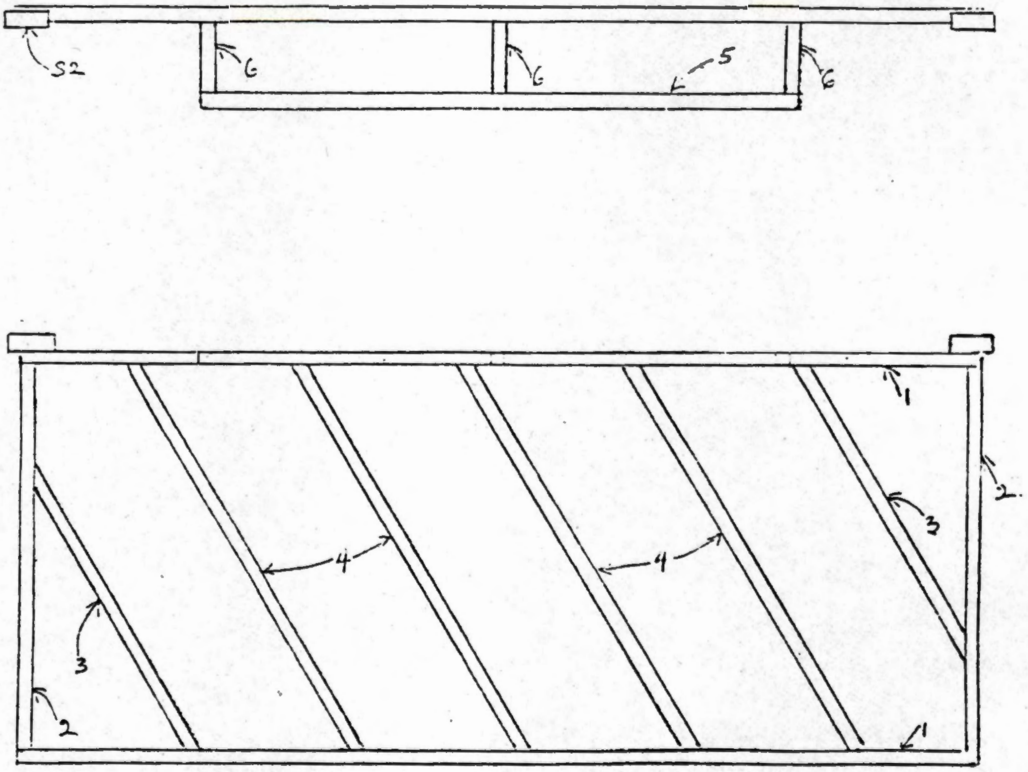

Figure 27. Component parts of movable metal head-gate.

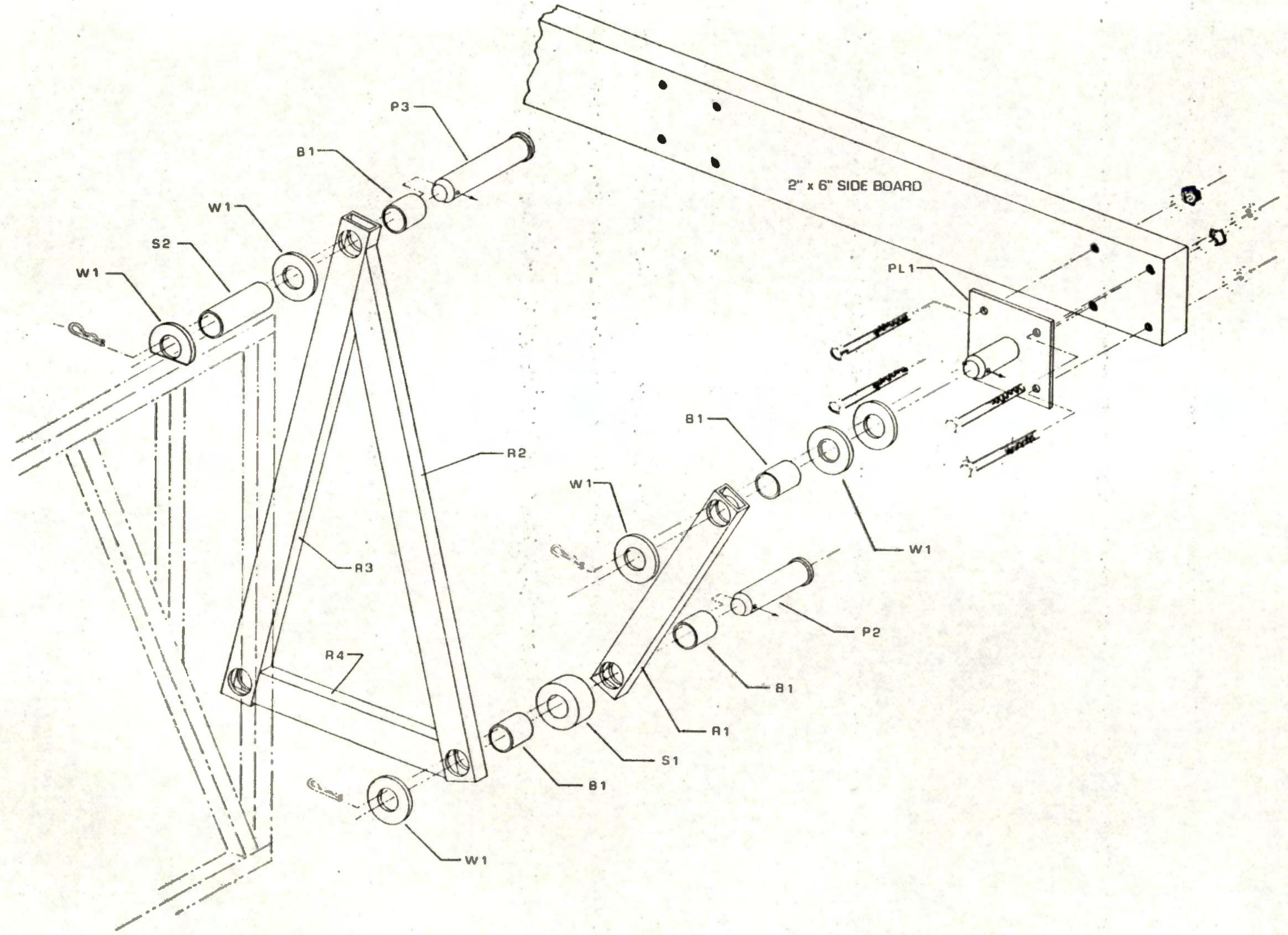

Figure 28. Component parts of the gate linkage suspension.

## Table 6

Purchase List of Materials for the Unroofed Bunk Used at Middle Tennessee Experiment Station

| Item | No. Reqd. | Description | For Part[3] | BD Ft. | Length |
|---|---|---|---|---|---|
| Bunk: | | | | | |
| 1 | 2 | 2"x6"x10' | (1) | 20.00 | |
| 2 | 27 | 2"x6"x8' | (2)(3)(6) | 216.00 | |
| 3 | 1 | 2"x4"x8' | (4) | 5.33 | |
| 4 | 2 | 4"x4"x8' | (5) | 21.33 | |
| 5 | 2 | 2"x4"x10' | (7) | 13.33 | |
| 6 | 2 | 2"x4"x8' | (11) | 10.66 | |
| | | | Total | 286.66" | |
| 286.66 bd ft. @ $0.4656 per bd ft = $133.47 | | | | | |
| Wooden Gate: | | | | | |
| 1 | 3 | 2"x4"x8' | (19) | 16.00 | |
| 2 | 2 | 2"x4"x12' | (20)(21)(24)<br>(25) | 16.00 | |
| 3 | 1 | 2"x4"x10' | (26) | 6.66 | |
| | | | Total | 38.66 | |
| 38.66 bd ft @ $0.4656/bd ft = $18.00 | | | | | |
| Steel Tubing Head Gate: | | | | | |
| | | 1.24 sq. steel tubing | (1) | | 173.40" |
| | | " | (2) | | 71.00" |
| | | " | (3) | | 58.55" |
| | | " | (4) | | 166.84" |
| | | " | (5) | | 54.00" |
| | | " | (6) | | 20.25" |
| | | | | Total | 544.04" |
| 45.336 ft @ $41.01/100 ft = $18.59 | | | | | |
| 1.625 OD Round Tubing: | | | (S2) | | 8.0" |
| 2/3ft @ $25.10/100 lbs. (7.05 lbs/ft) | | | | | |

$$\frac{7.05\ \cancel{lb}}{1\ \cancel{ft}} \times \frac{2}{3}\ \cancel{ft} \times \frac{\$25.10}{100\ \cancel{lb}} = \$1.18$$

Table 6 (cont'd)

| Item | No. Reqd. | Description | For Part | BD Ft. | Length |
|---|---|---|---|---|---|
| Linkages: | | | | | |
| | | 1"x2"x14 ga rect. stl tubing | (R4) | | 31.9" |
| | | " | (R2) | | 74.90" |
| | | " | (R3) | | 71.88" |
| | | " | (R1) | | 74.00" |
| | | | | Total | 252.68" |

21.06 ft @ $51.20/100 ft = $10.78

| | | | | | |
|---|---|---|---|---|---|
| Pins: | | | | | |
| | | 13/8" OD Solid Round Steel | (P1) | | 9.50" |
| | | " | (P2) | | 18.00" |
| | | " | (P3) | | 12.50" |
| | | | | Total | 40.00" |

3.33 ft @ $20.27/100 lb. (5.05 lb/ft)

$$\frac{5.05\ \cancel{lb}}{1\ \cancel{ft}} \times 3.33\ \cancel{ft} \times \frac{\$20.27}{100\ \cancel{lb}} = \$3.41$$

| | | | | | |
|---|---|---|---|---|---|
| Steel Plate: | | | | | |
| | | 6" width x 1/4" thick mill plate stl. | (PL1) | | 24.0" |

2 ft @ $30.31/100 lbs (10.2 lbs/ft)
12" width

$$\frac{10.2\ \cancel{lb}}{\cancel{ft}} \times \frac{2\ \cancel{ft}}{2} \times \frac{\$30.31}{100\ \cancel{lb}} = \$3.09$$

| | | | | | |
|---|---|---|---|---|---|
| Sleeve & Spacer: | | | | | |
| | | 1¼" std. Black Pipe (For sleeve) | (B1) | | 17.5" |
| | | " (For spacer) | (S1) | | 5.0" |
| | | | | Total | 22.5" |

1.875 ft @ $64.88/100 ft = $1.22

| | | | | | |
|---|---|---|---|---|---|
| Plain Washer: | | | | | |
| | | 3¼" OD x 0.18" Thick | (W1) | | |

16 required @$42.35/100 = $6.78

Table 6 (cont'd)

| Item | No. Reqd. | Description | For Part | BD Ft. | Length |
|---|---|---|---|---|---|
| Bolts: | | | | | |
| | 16 | ½"Dia x 5" Long @ $48.80/100 = $7.80 | | | |
| | 16 | ½"Dia x 3" Long @ $33.24/100 = 5.32 | | | |
| | 50 | ¼"Dia x 6" Long @ $46.50/100 = 23.25 | | | |
| | 10 | 1/8" Clip Pin x 2" Long @ $3.80/100 = $0.38 = $36.75 | | | |
| Angle Reinforcing: | | | | | |
| | | 3½"x3½"x¼" Thick Stl Angle | | | 48.0" |

4 ft @ $20.13/100 lbs (5.80 lb/ft)

$$\frac{5.80\ \cancel{lb}}{1\ \cancel{ft}} \times 4\ \cancel{ft} \times \frac{\$20.13}{100\ \cancel{lb}} = \$4.67$$

Unroofed Bunk Material Cost:

| Material | Cost |
|---|---|
| Bunk | $133.47 |
| Wooden Gate | 18.00 |
| Steel Tubing Head Gate | 18.59 |
| OD Round Tubing | 1.18 |
| Linkage | 10.78 |
| Pins | 3.41 |
| Steel Plate | 3.09 |
| Sleeve & Spacer | 1.22 |
| Plain Washer | 6.78 |
| Bolts | 36.75 |
| Angle Reinforcing | 4.67 |
| Labor: Assumed Equal Material Cost | $237.94 |
| Labor: Assumed Equal Material Cost | 237.94 |
| | $475.88 |

---

[3] Figure 29 shows unroofed bunk parts.

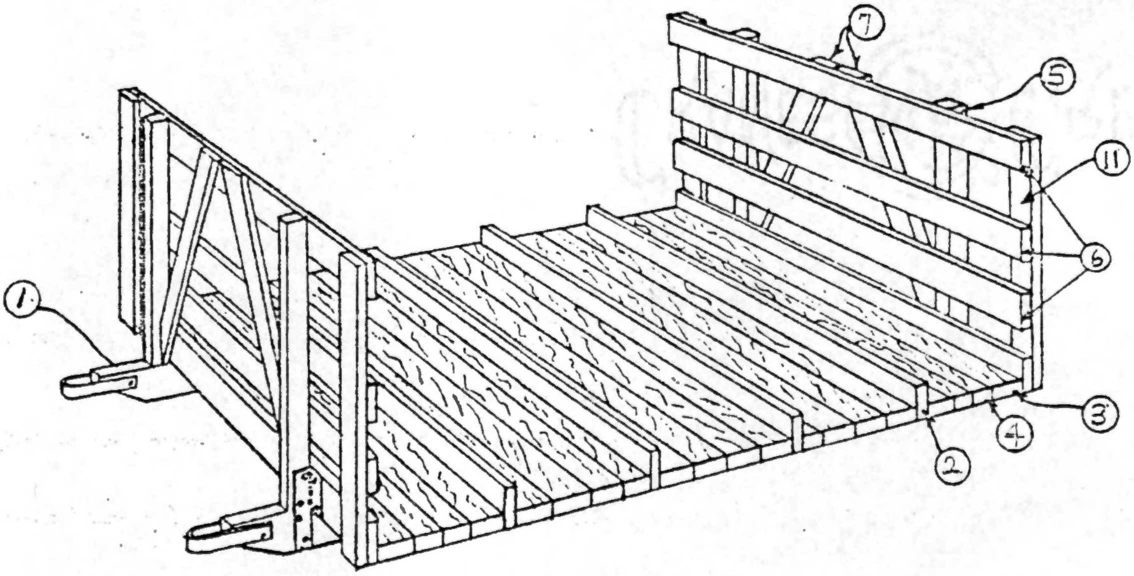

Figure 29. Component parts of the unroofed bunk.

Donnell Hunt (14) defined the economic life of equipment as the length of time from purchase of equipment to that point where it is more economical to replace with new equipment than to continue with the old. The average annual cost of operating the feeders was based on various assumptions and the cost determination method defined by Hunt (14).

Average Annual Cost = fixed costs + variable costs

1. Fixed Costs

a. Depreciation - Straight-line method. The annual depreciation charge by $D = \frac{(P-S)}{L}$

where;

D = Depreciation

P = Purchase Price

S = Salvage Price

L = Economic Life

Assume Salvage = 0% P

Life = 8 years

$$D = \frac{P - 0.0P}{8}$$

$$D = \frac{P}{8}$$

$$D = \underline{\underline{0.125\ P/yr}}$$

b. Interest - Annual avg. cost of interest over the life of equipment

$$\text{Int.} = \left(\frac{P+S}{2}\right) i \quad \text{where } i = 8\% \text{ (suggested by Hunt)}$$

$$= P\left(\frac{1}{2}\right) 0.08$$

$$\text{Int.} = \underline{\underline{0.04\ P/yr}}$$

### 2. Variable Costs

a. Repair and Maintenance - This was the only aspect of the variable costs that can be associated with the hay feeding equipment, and it was estimated to be approximately 1% P (purchase price) per year.

$$\therefore \text{ Average Annual Cost} = \text{fixed cost} + \text{variable cost}$$

$$= 17\%\ P + 1\%\ P$$

$$= \underline{\underline{18\%\ P}}$$

## Value of Hay Losses

The total amount of hay loss during the 42 day feeding trial was 7306.8 lbs. wet weight which contained 3228.6 lbs. dry matter.

$$\text{Moisture } \% = \frac{\text{Wet Wt} - \text{Dry Wt}}{\text{Wet Wt}} \times 100$$

$$= \frac{7306.8 - 3228.6}{7306.8} \times 100$$

$$= 55.8\% \text{ moisture}$$

In other words, 7306.8 lbs. of hay at 55.8 percent moisture was the total hay loss. To determine the amount of hay loss at 30 percent moisture content containing 3228.6 pounds of dry matter, proceed as follows:

$$\text{Wet Wt} - 3228.6 = 0.3 \text{ Wet wt.}$$

$$0.7 \text{ Wet Wt} = 3228.6$$

$$\text{Wet Wt} = \frac{3228.6}{0.7} = 4612.28 \text{ lbs.}$$

$$\therefore \quad 7306.8 \text{ lbs. at } 55.8\% \text{ moisture} = 4612.28 \text{ lb at } 30\% \text{ moisture}$$

$$\text{Ratio } \frac{4612.28}{7306.8} = 0.63$$

Loss per feeder:

at 55.8% moisture

Roofed - 1564.10 lbs

Unroofed - 2024.10 lbs

Panel - 3718.60 lbs

7306.8 lbs.

at 30% moisture

Roofed - 987.30 lbs.

Unroofed -1277.68 lbs.

Panel -2347.30 lbs

4612.28

Typically animals are fed for 100 days in the southeast during the winter period.

feeding for 42 days loss: Roofed = 987.30 lbs.

Unroofed = 1277.68 lbs.

Panel = 2347.30 lbs.

∴ 100 days feeding loss:

Roofed $\frac{987.30}{42} \times \frac{100}{1} =$ 2350.71 lb/100 days/year

Unroofed $\frac{1277.68}{42} \times \frac{100}{1} =$ 3042.10 lb/yr

Panel $\frac{2347.30}{42} \times \frac{100}{1} =$ 5588.81 lb/yr

Cost of hay loss per year:

1 ton (2000 lb) of hay cost $46 (28)

∴ 2350.71 lb will cost $54.07 - roofed

3042.10 lb will cost $69.97 - unroofed

5588.81 lb will cost $128.54 - panel

From previous analysis, the purchase price (P) of Roofed feeder = $721.04, Avg. Annual Cost = 18% P = $129.78: Unroofed feeder = $475.88, Avg. Annual cost = 18% P = $85.66: Panel = $120, Avg. Annual Cost = 18% P = $21.60. Annual cost of hay saved (benefit):

Roofed feeder vs. Unroofed ($69.97 - $54.07) = $15.90/year
Roofed feeder vs. Panel ($128.54 - $54.07) = $74.47/year
Unroofed feeder vs. Panel ($128.54 - $69.97) = $58.57/year

Annual operating cost difference (Cost):

Roofed vs. unroofed ($129.78 - $85.66) = $44.12
Roofed vs. Panel ($129.78 - $21.60) = $108.18
Unroofed vs. Panel ($85.66 - $21.60) = $64.06

Cost-benefit ratio:

$$\text{Roofed vs. unroofed} = \frac{\text{Annual cost of hay saved difference}}{\text{Annual operating cost difference}}$$

$$= \frac{\$15.90}{\$44.12}$$

$$= \underline{\underline{0.36}}$$

$$\text{Roofed vs. Panel} = \frac{\$74.47}{\$108.18}$$

$$= \underline{\underline{0.69}}$$

$$\text{Unroofed vs. Panel} = \frac{\$58.57}{\$64.06}$$

$$= \underline{\underline{0.91}}$$

Based on the above results of the cost and benefit analysis, it would not be economical to operate the roofed feeder instead of the unroofed or the panel because the extra annual operating cost associated with the roofed feeder would not justify the annual value of hay saved. In the same manner, it would not be economical to use the unroofed feeder in place of the panel because the extra annual operating cost associated with the unroofed feeder would not justify the annual value of hay saved.

It might not be economical to use either the roofed or the unroofed feeders to feed grass hay, but where high - quality hay - for example alfalfa hay - is being fed, the value of hay saved by the feeders would justify the use of each bunk.

# CHAPTER VI

# SUMMARY AND CONCLUSIONS

## A. SUMMARY

One objective of this study was to compare three outdoor feeding structures with respect to amount of hay loss when feeding large bales to beef animals. Another objective of this study was to evaluate the difference in animal performance (weight gain) when fed outside or inside stored hay. Hay losses during feeding were categorized into two groups: 1) trampling losses, and 2) refused losses. Each animal was weighed twice within a 48 hour period before and after the experiment and the mean weight was determined. These animals, 80 in number, were randomly divided into four groups of 20 animals per group. Two groups of the animals were fed inside stored hay while the other two groups were fed outside-stored hay. Each of the three feeding systems was provided for each group of animals. This situation allowed the animals to feed free choice from among the feeding systems.

Core samples were taken from randomly selected bales at the beginning of the storage period; core samples were taken again and each bale weighed before the bales were fed. A total of 60 round bales of hay - 30 stored outside and 30 stored inside were fed to the animals during the 42 day feeding trial.

Visual observations were made daily on the amount of hay consumed from each feeding system. It appeared that animals preferred feeding from panel over feeding from either the roofed or the unroofed bunk. This could be explained by the fact that the animal had easier access to hay in the panel than to hay in the bunks.

The amount of the hay wasted due to refused and trampling losses was significantly greater for the panel than for either the roofed or the unroofed bunks. More hay was wasted from the outside stored hay than from the inside stored hay. Animals fed on inside stored hay had a significantly higher average daily weight gain than animals fed on the outside stored hay.

The moveable head-gate worked satisfactorily in reducing the amount of hay wasted. Certain design problems need correcting such that the head-gate will move in a straight-line motion. A disadvantage associated with the roofed bunk was the problem of removing and replacing the head-gate each time the bunk was to be loaded with hay. The unroofed bunk had an advantage over the roofed bunk in this respect because the unroofed bunk could be loaded with hay with the head-gate in place.

Based on economic comparisons of the feeding systems, the cost of hay saved by the roofed or the unroofed bunks did not justify the use of the roofed or the unroofed bunks to feed grass hay to beef animals, but where high-quality hay is involved, it may be economical to feed legume hay in the bunks to dairy animals.

## B. CONCLUSIONS

1. The roofed feed bunks and the unroofed bunks were significantly different from the panels with respect to the amount of hay (wet basis and dry basis) refused and tramped during the feeding experiment.

2. No significant difference existed between the roofed feed bunks and the unroofed feed bunks with respect to the amount of hay (wet basis and dry basis) refused and tramped, although total amounts of waste were greater for the unroofed bunks than for the roofed bunks.

3. A significant difference existed in the amount of hay (wet basis and dry basis) refused and tramped between the outside and inside stored hay.

4. Based on this study, the roofed and the unroofed feeding equipments were more efficient than the panel feeder.

5. There was no significant difference in total loss (dry matter) between the outside- and inside-stored hay.

6. Cattle fed on inside-stored hay had greater average daily gain than cattle fed on outside-stored hay. The average daily gain difference was significant in the 1978 trial but not in the 1979 trial.

7. Cattle fed inside-stored hay consumed 3.8 kg (8.5 lbs.) dry matter daily per 0.5 kg (1 lb.) average daily gain; cattle fed outside-stored hay consumed 4.9 kg (11 lbs.) dry matter daily per 0.5 kg (1 lb.) average daily gain.

8. Cattle preferred to eat from the panel, but more hay was wasted from the panels than from the bunks.

9. Economically, the roofed and the unroofed feeders were unjustified for feeding bermudagrass hay.

## C. RECOMMENDATIONS FOR FURTHER STUDY

Several observations made during the feeding trials at Middle Tennessee Experiment Station showed that the head-gate worked fairly well in substantially reducing the amount of hay loss.

Further design revision is needed to make the head-gate lighter in weight.

The possibility of using a hinge to open the head-gate to one side while loading the roofed bunk should be explored.

More work should be done with legume hays to determine the economic feasibility of using the roofed or the unroofed bunks in feeding this type hay.

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# BIBLIOGRAPHY

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APPENDICES

# APPENDIX A

## APPENDIX A. DATA COLLECTED DURING THE FEEDING TRIALS

| OBS | STORAGE | CALLID | BUNK | WTBALING | WTFEEDG | REFUSED | TRAMP | TLOSS | PEN | PCREFUS | PCTRAMP | PCTLOSS | DMFEEDG | DMREFUS | DMTRAMP | DMTLOSS | PDMREFUS | PDMTRAMP | PDMTLOSS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 132 | 1 | 690 | 810 | 171 | 14.1 | 185.1 | 1 | 21.1111 | 1.74074 | 22.8519 | 577.04 | 27.53 | 9.6 | 37.13 | 4.7709 | 1.66366 | 6.4346 |
| 2 | 1 | 131 | 2 | 690 | 810 | 249 | 15.3 | 264.3 | 1 | 30.7407 | 1.88389 | 32.6296 | 446.31 | 55.03 | 10.6 | 65.63 | 12.3300 | 2.37503 | 14.7050 |
| 3 | 1 | 130 | 3 | 670 | 810 | 217 | 32.3 | 249.3 | 1 | 26.7901 | 3.98765 | 30.7778 | 560.52 | 86.10 | 25.5 | 111.60 | 15.3607 | 4.54935 | 19.9101 |
| 4 | 1 | 124 | 1 | 660 | 710 | 133 | 11.7 | 149.7 | 3 | 19.4366 | 1.64789 | 21.0845 | 396.18 | 29.80 | 8.0 | 37.80 | 7.5216 | 2.01928 | 9.5411 |
| 5 | 1 | 123 | 2 | 670 | 790 | 157 | 11.9 | 168.9 | 3 | 19.8734 | 1.50633 | 21.3797 | 550.63 | 33.76 | 8.4 | 42.16 | 6.1312 | 1.52553 | 7.6567 |
| 6 | 1 | 125 | 3 | 660 | 773 | 316 | 31.6 | 347.6 | 3 | 41.0390 | 4.10390 | 45.1429 | 566.72 | 76.79 | 23.1 | 99.89 | 13.5499 | 4.07609 | 17.6260 |
| 7 | 1 | 74 | 1 | 700 | 820 | 174 | 14.9 | 198.9 | 1 | 21.2195 | 1.81707 | 23.0366 | 456.74 | 50.11 | 10.4 | 60.51 | 10.9712 | 2.27701 | 13.2482 |
| 8 | 1 | 121 | 2 | 640 | 740 | 193 | 15.9 | 208.9 | 1 | 26.0811 | 2.14865 | 28.2297 | 466.94 | 80.87 | 12.1 | 92.97 | 17.3191 | 2.59134 | 19.9105 |
| 9 | 1 | 122 | 3 | 670 | 795 | 209 | 29.8 | 238.8 | 1 | 26.2893 | 3.74843 | 30.0377 | 542.20 | 53.08 | 32.3 | 85.38 | 9.7897 | 5.95721 | 15.7470 |
| 10 | 1 | 126 | 1 | 640 | 710 | 104 | 10.9 | 114.9 | 3 | 14.6479 | 1.53521 | 16.1831 | 391.21 | 52.52 | 7.1 | 59.62 | 13.4250 | 1.81488 | 15.2399 |
| 11 | 1 | 64 | 2 | 690 | 710 | 131 | 12.3 | 143.3 | 3 | 18.4507 | 1.73239 | 20.1831 | 470.02 | 39.70 | 8.7 | 48.40 | 8.4464 | 1.85099 | 10.2974 |
| 12 | 1 | 73 | 3 | 690 | 740 | 235 | 26.3 | 261.3 | 3 | 31.7568 | 3.55405 | 35.3108 | 446.26 | 93.53 | 18.8 | 112.33 | 20.9556 | 4.21279 | 25.1714 |
| 13 | 1 | 61 | 1 | 750 | 780 | 48 | 13.5 | 61.5 | 1 | 6.1538 | 1.73077 | 7.8846 | 542.10 | 12.90 | 9.5 | 22.40 | 2.3796 | 1.75244 | 4.1321 |
| 14 | 1 | 62 | 2 | 720 | 765 | 62 | 14.3 | 76.3 | 1 | 8.1046 | 1.86928 | 9.9739 | 548.51 | 13.60 | 10.1 | 23.70 | 2.4794 | 1.84135 | 4.3208 |
| 15 | 1 | 63 | 3 | 720 | 780 | 85 | 30.5 | 115.5 | 1 | 10.8974 | 3.91026 | 14.8077 | 565.50 | 33.03 | 29.0 | 62.03 | 5.8408 | 5.12821 | 10.9691 |
| 16 | 1 | 59 | 1 | 740 | 730 | 95 | 10.4 | 105.4 | 3 | 13.0137 | 1.42466 | 14.4384 | 480.34 | 32.10 | 7.2 | 39.30 | 6.6828 | 1.49894 | 8.1817 |
| 17 | 1 | 57 | 2 | 670 | 750 | 70 | 11.9 | 81.9 | 3 | 9.3333 | 1.58667 | 10.9200 | 425.25 | 24.30 | 8.3 | 32.60 | 5.7143 | 1.95179 | 7.6661 |
| 18 | 1 | 56 | 3 | 690 | 750 | 174 | 27.0 | 201.0 | 3 | 23.2000 | 3.60000 | 26.8000 | 473.25 | 55.55 | 24.8 | 80.35 | 11.7360 | 5.24036 | 16.9783 |
| 19 | 1 | 48 | 1 | 710 | 690 | 10 | 14.5 | 24.5 | 1 | 1.4493 | 2.10145 | 3.5507 | 420.70 | 1.40 | 10.1 | 11.50 | 0.3328 | 2.40076 | 2.7335 |
| 20 | 1 | 41 | 2 | 800 | 840 | 27 | 13.7 | 40.7 | 1 | 3.2143 | 1.63095 | 4.8452 | 519.81 | 6.40 | 9.7 | 16.10 | 1.2312 | 1.86607 | 3.0973 |
| 21 | 1 | 47 | 3 | 770 | 730 | 143 | 29.5 | 172.5 | 1 | 19.5890 | 4.04110 | 23.6301 | 499.01 | 26.27 | 42.3 | 68.57 | 5.2644 | 8.47678 | 13.7412 |
| 22 | 1 | 46 | 1 | 770 | 800 | 47 | 10.9 | 57.9 | 3 | 5.8750 | 1.36250 | 7.2375 | 501.23 | 10.50 | 7.7 | 18.20 | 2.0948 | 1.53622 | 3.6311 |
| 23 | 1 | 60 | 2 | 750 | 780 | 53 | 12.0 | 65.0 | 3 | 6.7949 | 1.53846 | 8.3333 | 500.91 | 12.70 | 8.4 | 21.10 | 2.5354 | 1.67695 | 4.2123 |
| 24 | 1 | 45 | 3 | 670 | 690 | 187 | 25.6 | 212.6 | 3 | 27.1014 | 3.71014 | 30.8116 | 473.34 | 38.50 | 18.1 | 56.60 | 8.1337 | 3.82389 | 11.9576 |
| 25 | 1 | 27 | 1 | 930 | 680 | 27 | 13.0 | 40.0 | 1 | 3.9706 | 1.91176 | 5.8824 | 416.84 | 12.10 | 9.9 | 22.00 | 2.9028 | 2.37501 | 5.2776 |
| 26 | 1 | 26 | 2 | 710 | 700 | 19 | 13.4 | 32.4 | 1 | 2.7143 | 1.91429 | 4.6286 | 504.70 | 5.70 | 10.3 | 16.00 | 1.1294 | 2.04082 | 3.1702 |
| 27 | 1 | 25 | 3 | 760 | 635 | 81 | 26.3 | 107.3 | 1 | 12.7559 | 4.14173 | 16.8976 | 426.09 | 32.20 | 23.5 | 55.70 | 7.5571 | 5.51527 | 13.0724 |
| 28 | 1 | 42 | 1 | 770 | 840 | 157 | 10.3 | 167.3 | 3 | 13.6905 | 1.22619 | 19.9167 | 527.44 | 26.20 | 7.8 | 34.00 | 5.0034 | 1.50742 | 6.5708 |
| 29 | 1 | 43 | 2 | 690 | 720 | 171 | 11.4 | 142.4 | 3 | 23.7500 | 1.58333 | 25.3333 | 451.44 | 24.50 | 8.6 | 33.10 | 5.4271 | 1.90502 | 7.3321 |
| 30 | 1 | 44 | 3 | 770 | 785 | 203 | 23.8 | 226.8 | 3 | 25.8599 | 3.03185 | 28.8917 | 501.62 | 52.80 | 16.9 | 69.70 | 10.5259 | 3.36908 | 13.8950 |

## APPENDIX A. DATA COLLECTED DURING THE FEEDING TRIALS

| OBS | STORAGE | BALLID | BUNK | WTBALING | WTFEEDG | REFUSED | TRAMP | TLOSS | PEN | PCREFUS | PCTRAMP | PCTLOSS | DMFEEDG | DMREFUS | DMTRAMP | DMTLOSS | PDMREFUS | PDMTRAMP | PDMTLOSS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 2 | 34 | 1 | 760 | 615 | 16 | 7.5 | 23.5 | 2 | 2.6016 | 1.21951 | 3.8211 | 488.31 | 7.02 | 6.6 | 13.62 | 1.4376 | 1.35160 | 2.7892 |
| 32 | 2 | 37 | 2 | 710 | 615 | 39 | 6.8 | 45.8 | 2 | 6.3415 | 1.10569 | 7.4472 | 498.37 | 20.51 | 5.6 | 26.11 | 4.1154 | 1.12366 | 5.2391 |
| 33 | 2 | 33 | 3 | 740 | 590 | 80 | 16.7 | 96.7 | 2 | 13.5593 | 2.83051 | 16.3898 | 496.19 | 45.28 | 17.0 | 62.28 | 9.1255 | 3.42611 | 12.5516 |
| 34 | 2 | 39 | 1 | 680 | 565 | 90 | 4.7 | 94.7 | 4 | 15.9292 | 0.83186 | 16.7611 | 475.17 | 59.40 | 3.6 | 63.00 | 12.5008 | 0.75762 | 13.2584 |
| 35 | 2 | 35 | 2 | 760 | 610 | 130 | 5.3 | 135.3 | 4 | 21.3115 | 0.86885 | 22.1803 | 452.62 | 54.08 | 4.2 | 58.28 | 11.9482 | 0.92793 | 12.8761 |
| 36 | 2 | 36 | 3 | 760 | 600 | 160 | 14.6 | 174.6 | 4 | 26.6667 | 2.43333 | 29.1000 | 490.20 | 73.28 | 13.3 | 86.58 | 14.9490 | 2.71313 | 17.6622 |
| 37 | 2 | 40 | 1 | 680 | 630 | 46 | 7.6 | 53.6 | 2 | 7.3016 | 1.20635 | 8.5079 | 513.45 | 38.82 | 6.0 | 44.82 | 7.5606 | 1.16857 | 8.7292 |
| 38 | 2 | 38 | 2 | 680 | 560 | 68 | 7.1 | 75.1 | 2 | 12.1429 | 1.26786 | 13.4107 | 465.36 | 50.59 | 5.7 | 56.29 | 10.8712 | 1.22486 | 12.0960 |
| 39 | 2 | 52 | 3 | 680 | 575 | 156 | 13.8 | 169.8 | 2 | 27.1304 | 2.40000 | 29.5304 | 474.95 | 101.40 | 11.8 | 113.20 | 21.3496 | 2.48447 | 23.8341 |
| 40 | 2 | 47 | 1 | 600 | 550 | 32 | 4.5 | 36.5 | 4 | 5.8182 | 0.81818 | 6.6364 | 432.85 | 27.10 | 3.5 | 30.60 | 6.2598 | 0.80859 | 7.0694 |
| 41 | 2 | 55 | 2 | 650 | 550 | 38 | 4.2 | 42.2 | 4 | 6.9091 | 0.76364 | 7.6727 | 440.55 | 29.87 | 3.4 | 33.27 | 6.7802 | 0.77176 | 7.5519 |
| 42 | 2 | 54 | 3 | 710 | 590 | 96 | 14.6 | 110.6 | 4 | 16.2712 | 2.47458 | 18.7458 | 467.87 | 69.60 | 11.1 | 80.70 | 14.8759 | 2.37245 | 17.2484 |
| 43 | 2 | 18 | 1 | 730 | 570 | 53 | 7.1 | 60.1 | 2 | 9.2982 | 1.24561 | 10.5439 | 495.90 | 26.80 | 5.6 | 32.40 | 5.4043 | 1.12926 | 6.5336 |
| 44 | 2 | 65 | 2 | 700 | 590 | 101 | 6.7 | 107.1 | 2 | 17.1186 | 1.13559 | 18.1525 | 500.32 | 79.30 | 5.5 | 84.80 | 15.8499 | 1.09930 | 16.9492 |
| 45 | 2 | 50 | 3 | 710 | 590 | 164 | 14.2 | 178.2 | 2 | 27.7966 | 2.40678 | 30.2034 | 479.08 | 119.54 | 11.8 | 131.34 | 24.9520 | 2.46305 | 27.4150 |
| 46 | 2 | 69 | 1 | 690 | 585 | 133 | 5.3 | 138.3 | 4 | 22.7350 | 0.90598 | 23.6410 | 491.40 | 97.10 | 4.2 | 101.30 | 19.7599 | 0.85470 | 20.6146 |
| 47 | 2 | 53 | 2 | 630 | 525 | 189 | 5.1 | 194.1 | 4 | 36.0000 | 0.97143 | 36.9714 | 447.30 | 129.80 | 4.0 | 133.80 | 29.0186 | 0.89425 | 29.9128 |
| 48 | 2 | 66 | 3 | 690 | 585 | 182 | 13.1 | 195.1 | 4 | 31.1111 | 2.23932 | 33.3504 | 489.06 | 80.11 | 11.5 | 91.61 | 16.3804 | 2.35145 | 18.7319 |
| 49 | 2 | 51 | 1 | 700 | 590 | 0 | 7.6 | 7.6 | 2 | 0.0000 | 1.28814 | 1.2881 | 508.11 | 0.00 | 6.0 | 6.00 | 0.0000 | 1.18085 | 1.1808 |
| 50 | 2 | 19 | 2 | 830 | 500 | 0 | 7.7 | 7.7 | 2 | 0.0000 | 1.54000 | 1.5400 | 472.37 | 0.00 | 6.2 | 6.20 | 0.0000 | 1.31253 | 1.3125 |
| 51 | 2 | 99 | 3 | 670 | 490 | 100 | 13.8 | 113.8 | 2 | 20.4082 | 2.81633 | 23.2245 | 470.15 | 24.88 | 19.6 | 44.48 | 5.2919 | 4.16883 | 9.4608 |
| 52 | 2 | 21 | 1 | 670 | 540 | 0 | 5.3 | 5.3 | 4 | 0.0000 | 0.98148 | 0.9815 | 459.98 | 0.00 | 4.3 | 4.30 | 0.0000 | 0.93482 | 0.9348 |
| 53 | 2 | 21 | 2 | 810 | 580 | 38 | 6.2 | 44.2 | 4 | 6.5517 | 1.06897 | 7.6207 | 488.24 | 18.10 | 4.1 | 22.20 | 3.7072 | 0.83975 | 4.5469 |
| 54 | 2 | 24 | 3 | 790 | 570 | 203 | 14.2 | 217.2 | 4 | 35.6140 | 2.49123 | 38.1053 | 492.30 | 96.80 | 11.5 | 108.30 | 19.6628 | 2.33597 | 21.9988 |
| 55 | 2 | 56 | 1 | 640 | 550 | 0 | 5.8 | 5.8 | 2 | 0.0000 | 1.05455 | 1.0545 | 452.10 | 0.00 | 4.7 | 4.70 | 0.0000 | 1.03959 | 1.0396 |
| 56 | 2 | 6 | 2 | 830 | 590 | 13 | 7.0 | 20.0 | 2 | 2.2034 | 1.18644 | 3.3898 | 464.92 | 8.20 | 5.6 | 13.80 | 1.7637 | 1.20451 | 2.9683 |
| 57 | 2 | 20 | 3 | 780 | 620 | 129 | 12.8 | 141.8 | 2 | 20.8065 | 2.06452 | 22.8710 | 507.78 | 64.05 | 19.9 | 83.95 | 12.6137 | 3.91902 | 16.5328 |
| 58 | 2 | 7 | 1 | 750 | 565 | 39 | 4.5 | 43.5 | 4 | 6.9027 | 0.79646 | 7.6991 | 468.95 | 16.60 | 3.6 | 20.20 | 3.5398 | 0.76767 | 4.3075 |
| 59 | 2 | 1 | 2 | 820 | 630 | 83 | 5.5 | 88.5 | 4 | 13.1746 | 0.87302 | 14.0476 | 523.53 | 37.10 | 4.3 | 41.40 | 7.0865 | 0.82135 | 7.9079 |
| 60 | 2 | 22 | 3 | 750 | 555 | 175 | 13.1 | 189.1 | 4 | 31.5315 | 2.36036 | 33.8919 | 450.66 | 82.60 | 10.1 | 92.70 | 18.3287 | 2.24116 | 20.5698 |

# APPENDIX B

## APPENDIX A. INITIAL PERFORMANCE ON OUTSIDE-INSIDE STORED HAY

| OBS | ID | INITIALWT | FINALWT | STORAGE | PEN | YEAR | GAIN | ADG |
|---|---|---|---|---|---|---|---|---|
| 1 | 160 | 802 | 842 | 1 | 1 | 78 | 40 | 0.56338 |
| 2 | 121 | 749 | 728 | 1 | 1 | 78 | -21 | -0.29577 |
| 3 | 171 | 748 | 800 | 1 | 1 | 78 | 52 | 0.73239 |
| 4 | 150 | 732 | 794 | 1 | 1 | 78 | 62 | 0.87324 |
| 5 | 107 | 702 | 776 | 1 | 1 | 78 | 74 | 1.04225 |
| 6 | 170 | 722 | 764 | 1 | 1 | 78 | 42 | 0.59155 |
| 7 | 172 | 713 | 756 | 1 | 1 | 78 | 43 | 0.60563 |
| 8 | 153 | 685 | 638 | 1 | 1 | 78 | -47 | -0.66197 |
| 9 | 157 | 685 | 712 | 1 | 1 | 78 | 27 | 0.38028 |
| 10 | 139 | 668 | 770 | 1 | 1 | 78 | 102 | 1.43662 |
| 11 | 128 | 739 | 870 | 2 | 2 | 78 | 81 | 1.14085 |
| 12 | 179 | 758 | 844 | 2 | 2 | 78 | 86 | 1.21127 |
| 13 | 155 | 747 | 804 | 2 | 2 | 78 | 57 | 0.80282 |
| 14 | 149 | 729 | 808 | 2 | 2 | 78 | 79 | 1.11268 |
| 15 | 109 | 702 | 752 | 2 | 2 | 78 | 50 | 0.70423 |
| 16 | 167 | 725 | 824 | 2 | 2 | 78 | 99 | 1.39437 |
| 17 | 169 | 681 | 736 | 2 | 2 | 78 | 55 | 0.77465 |
| 18 | 143 | 680 | 802 | 2 | 2 | 78 | 122 | 1.71831 |
| 19 | 110 | 681 | 770 | 2 | 2 | 78 | 89 | 1.25352 |
| 20 | 101 | 663 | 736 | 2 | 2 | 78 | 73 | 1.02817 |
| 21 | 136 | 779 | 812 | 2 | 4 | 78 | 33 | 0.46479 |
| 22 | 140 | 774 | 860 | 2 | 4 | 78 | 86 | 1.21127 |
| 23 | 164 | 743 | 790 | 2 | 4 | 78 | 47 | 0.66197 |
| 24 | 117 | 726 | 794 | 2 | 4 | 78 | 68 | 0.95775 |
| 25 | 122 | 722 | 784 | 2 | 4 | 78 | 62 | 0.87324 |
| 26 | 163 | 705 | 744 | 2 | 4 | 78 | 39 | 0.54930 |
| 27 | 166 | 678 | 762 | 2 | 4 | 78 | 84 | 1.18310 |
| 28 | 142 | 704 | 746 | 2 | 4 | 78 | 42 | 0.59155 |
| 29 | 114 | 693 | 756 | 2 | 4 | 78 | 63 | 0.88732 |
| 30 | 108 | 670 | 760 | 2 | 4 | 78 | 90 | 1.26761 |
| 31 | 112 | 785 | 840 | 1 | 3 | 78 | 55 | 0.77465 |
| 32 | 159 | 780 | 814 | 1 | 3 | 78 | 34 | 0.47887 |
| 33 | 123 | 748 | 786 | 1 | 3 | 78 | 38 | 0.53521 |
| 34 | 146 | 729 | 780 | 1 | 3 | 78 | 51 | 0.71831 |
| 35 | 129 | 697 | 764 | 1 | 3 | 78 | 67 | 0.94366 |
| 36 | 145 | 718 | 744 | 1 | 3 | 78 | 26 | 0.36620 |
| 37 | 131 | 695 | 726 | 1 | 3 | 78 | 31 | 0.43662 |
| 38 | 133 | 692 | 750 | 1 | 3 | 78 | 58 | 0.81690 |
| 39 | 115 | 686 | 736 | 1 | 3 | 78 | 50 | 0.70423 |
| 40 | 125 | 691 | 712 | 1 | 3 | 78 | 21 | 0.29577 |
| 41 | 37 | 652 | 686 | 1 | 1 | 79 | 34 | 0.80952 |
| 42 | 43 | 590 | 622 | 1 | 1 | 79 | 32 | 0.76190 |
| 43 | 63 | 620 | 674 | 1 | 1 | 79 | 54 | 1.28571 |
| 44 | 78 | 620 | 666 | 1 | 1 | 79 | 46 | 1.09524 |
| 45 | 105 | 603 | 646 | 1 | 1 | 79 | 43 | 1.02381 |
| 46 | 113 | 609 | 683 | 1 | 1 | 79 | 74 | 1.76190 |
| 47 | 129 | 607 | 670 | 1 | 1 | 79 | 63 | 1.50000 |
| 48 | 148 | 603 | 649 | 1 | 1 | 79 | 46 | 1.09524 |
| 49 | 189 | 591 | 614 | 1 | 1 | 79 | 23 | 0.54762 |
| 50 | 192 | 574 | 620 | 1 | 1 | 79 | 46 | 1.09524 |
| 51 | 44 | 564 | 615 | 1 | 1 | 79 | 51 | 1.21429 |
| 52 | 55 | 580 | 616 | 1 | 1 | 79 | 36 | 0.85714 |
| 53 | 57 | 603 | 635 | 1 | 1 | 79 | 32 | 0.76190 |
| 54 | 84 | 588 | 569 | 1 | 1 | 79 | -19 | -0.45238 |
| 55 | 123 | 576 | 604 | 1 | 1 | 79 | 28 | 0.66667 |
| 56 | 128 | 607 | 649 | 1 | 1 | 79 | 42 | 1.00000 |
| 57 | 137 | 571 | 626 | 1 | 1 | 79 | 55 | 1.30952 |
| 58 | 149 | 590 | 622 | 1 | 1 | 79 | 32 | 0.76190 |
| 59 | 190 | 631 | 662 | 1 | 1 | 79 | 31 | 0.73810 |
| 60 | 195 | 580 | 600 | 1 | 1 | 79 | 20 | 0.47619 |
| 61 | 67 | 612 | 686 | 2 | 2 | 79 | 74 | 1.76190 |

APPENDIX 8. ANIMAL PERFORMANCE ON OUTSIDE-INSIDE STORED HAY

| OBS | ID | INITIALWT | FINALWT | STORAGE | PEN | YEAR | GAIN | ADG |
|---|---|---|---|---|---|---|---|---|
| 62 | 71 | 589 | 647 | 2 | 2 | 79 | 58 | 1.38095 |
| 63 | 75 | 594 | 676 | 2 | 2 | 79 | 82 | 1.95238 |
| 64 | 79 | 600 | 652 | 2 | 2 | 79 | 52 | 1.23810 |
| 65 | 81 | 604 | 658 | 2 | 2 | 79 | 54 | 1.28571 |
| 66 | 107 | 645 | 684 | 2 | 2 | 79 | 39 | 0.92857 |
| 67 | 108 | 603 | 653 | 2 | 2 | 79 | 50 | 1.19048 |
| 68 | 119 | 590 | 651 | 2 | 2 | 79 | 61 | 1.45238 |
| 69 | 131 | 605 | 621 | 2 | 2 | 79 | 16 | 0.38095 |
| 70 | 168 | 612 | 638 | 2 | 2 | 79 | 26 | 0.61905 |
| 71 | 34 | 593 | 624 | 2 | 2 | 79 | 31 | 0.73810 |
| 72 | 60 | 550 | 595 | 2 | 2 | 79 | 45 | 1.07143 |
| 73 | 102 | 574 | 602 | 2 | 2 | 79 | 28 | 0.66667 |
| 74 | 115 | 571 | 545 | 2 | 2 | 79 | -26 | -0.61905 |
| 75 | 120 | 560 | 645 | 2 | 2 | 79 | 85 | 2.02381 |
| 76 | 157 | 606 | 635 | 2 | 2 | 79 | 29 | 0.69048 |
| 77 | 178 | 580 | 633 | 2 | 2 | 79 | 53 | 1.26190 |
| 78 | 182 | 555 | 592 | 2 | 2 | 79 | 37 | 0.88095 |
| 79 | 183 | 586 | 637 | 2 | 2 | 79 | 51 | 1.21429 |
| 80 | 198 | 589 | 630 | 2 | 2 | 79 | 41 | 0.97619 |
| 81 | 42 | 624 | 682 | 1 | 3 | 79 | 58 | 1.38095 |
| 82 | 64 | 599 | 645 | 1 | 3 | 79 | 46 | 1.09524 |
| 83 | 80 | 614 | 664 | 1 | 3 | 79 | 50 | 1.19048 |
| 84 | 86 | 597 | 640 | 1 | 3 | 79 | 43 | 1.02381 |
| 85 | 87 | 609 | 641 | 1 | 3 | 79 | 32 | 0.76190 |
| 86 | 116 | 588 | 631 | 1 | 3 | 79 | 43 | 1.02381 |
| 87 | 160 | 621 | 657 | 1 | 3 | 79 | 36 | 0.85714 |
| 88 | 170 | 642 | 692 | 1 | 3 | 79 | 50 | 1.19048 |
| 89 | 171 | 595 | 612 | 1 | 3 | 79 | 17 | 0.40476 |
| 90 | 173 | 593 | 632 | 1 | 3 | 79 | 39 | 0.92857 |
| 91 | 31 | 573 | 595 | 1 | 3 | 79 | 22 | 0.52381 |
| 92 | 91 | 592 | 614 | 1 | 3 | 79 | 22 | 0.52381 |
| 93 | 100 | 583 | 622 | 1 | 3 | 79 | 39 | 0.92857 |
| 94 | 103 | 621 | 655 | 1 | 3 | 79 | 34 | 0.80952 |
| 95 | 139 | 578 | 574 | 1 | 3 | 79 | -4 | -0.09524 |
| 96 | 140 | 580 | 607 | 1 | 3 | 79 | 27 | 0.64286 |
| 97 | 147 | 588 | 612 | 1 | 3 | 79 | 24 | 0.57143 |
| 98 | 153 | 575 | 592 | 1 | 3 | 79 | 17 | 0.40476 |
| 99 | 194 | 599 | 615 | 1 | 3 | 79 | 16 | 0.38095 |
| 100 | 196 | 548 | 563 | 1 | 3 | 79 | 15 | 0.35714 |
| 101 | 33 | 600 | 654 | 2 | 4 | 79 | 54 | 1.28571 |
| 102 | 58 | 619 | 672 | 2 | 4 | 79 | 53 | 1.26190 |
| 103 | 95 | 601 | 635 | 2 | 4 | 79 | 34 | 0.80952 |
| 104 | 99 | 637 | 673 | 2 | 4 | 79 | 36 | 0.85714 |
| 105 | 150 | 593 | 672 | 2 | 4 | 79 | 79 | 1.88095 |
| 106 | 162 | 608 | 668 | 2 | 4 | 79 | 60 | 1.42857 |
| 107 | 166 | 615 | 642 | 2 | 4 | 79 | 27 | 0.64286 |
| 108 | 186 | 594 | 626 | 2 | 4 | 79 | 32 | 0.76190 |
| 109 | 187 | 609 | 651 | 2 | 4 | 79 | 42 | 1.00000 |
| 110 | 193 | 602 | 642 | 2 | 4 | 79 | 40 | 0.95238 |
| 111 | 29 | 549 | 580 | 2 | 4 | 79 | 31 | 0.73810 |
| 112 | 38 | 551 | 565 | 2 | 4 | 79 | 14 | 0.33333 |
| 113 | 56 | 580 | 621 | 2 | 4 | 79 | 41 | 0.97619 |
| 114 | 89 | 596 | 615 | 2 | 4 | 79 | 19 | 0.45238 |
| 115 | 98 | 613 | 650 | 2 | 4 | 79 | 37 | 0.88095 |
| 116 | 104 | 584 | 646 | 2 | 4 | 79 | 62 | 1.47619 |
| 117 | 109 | 575 | 599 | 2 | 4 | 79 | 24 | 0.57143 |
| 118 | 134 | 598 | 629 | 2 | 4 | 79 | 31 | 0.73810 |
| 119 | 143 | 543 | 589 | 2 | 4 | 79 | 46 | 1.09524 |
| 120 | 146 | 582 | 588 | 2 | 4 | 79 | 6 | 0.14286 |

# VITA

Babatunde Akanni Adeyemo was born in Lagos, Nigeria on December 6, 1949. He attended elementary school in Lagos, Nigeria and graduated from Muslim College Ijebu-ode in December 1968.

He enrolled at Western Michigan University in September 1975 and later transferred to the University of Tennessee, Knoxville, where he received the Bachelor of Science degree in August, 1978.

He began his graduate work in September 1978. He received the Master of Science degree in Agricultural Mechanization in the Department of Agricultural Engineering in March 1980. He is a member of the University of Tennessee Student Branch of the American Society of Agricultural Engineers.

He is happily married to the former Miss Sheri Oladunni Oshikoya and they are blessed with a son, Babatunde, Jr.