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To the Graduate Council:

I am submitting herewith a thesis written by Najeeb Tawfik Kazzal entitled "Selectivity and Contamination Influences Upon Levels of Chemical Composition and Digestibility of Samples Obtained from Esophageal-Fistulated Steers Grazing Two Types of Pasture." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

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SELECTIVITY AND CONTAMINATION INFLUENCES UPON LEVELS OF CHEMICAL
COMPOSITION AND DIGESTIBILITY OF SAMPLES OBTAINED FROM
ESOPHAGEAL-FISTULATED STEERS GRAZING
TWO TYPES OF PASTURE

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ABSTRACT

During the summer of 1969 (May 30 to September 19), five grazing trials were conducted at 4-weekly intervals, to study the effect of selective grazing on the chemical composition and in vitro dry matter digestibility of forage samples. In addition, the effects of saliva contamination, partial mastication, and sample preparation of fistula samples (squeezed and non-squeezed) also were investigated at 4-weekly intervals by means of pen-feeding studies.

Five esophageal-fistulated Hereford steers and two types of pastures, tall fescue and orchardgrass, were used in this study. To estimate the effect of saliva contamination and partial mastication, hand-clipped forage samples from each pasture plot were each divided into two portions. One portion was fed to an esophageal-fistulated steer and then collected (clipped-fistula sample) through the fistula. The other part (clipped-control sample) was not subjected to further treatment.

The differences between the chemical components and in vitro dry matter digestibility (DDM) of clipped-fistula and clipped-control samples were used to show the effect of the esophageal fistula. The results from both types of pasture showed that clipped-fistula samples contained more ash, crude protein, acid detergent fiber (ADF), acid insoluble lignin (AIL) and less of the nitrogen free extract + ether extract fraction than clipped-control samples. The differences were statistically significant ($P < .05$) except with respect to crude protein. The in vitro DDM was higher in the clipped-fistula samples than in the clipped control;

however, the difference between the two sample types was statistically significant ($P < .05$) only in tall fescue samples, not in orchardgrass samples.

The results of this study indicate that non-squeezed samples represent the true situation of contamination and mastication better than squeezed samples. Therefore, the following results were obtained from the non-squeezed samples only. To estimate the degree of selective grazing, a comparison was made between grazed-fistula samples (selected forages) and clipped-fistula samples (available forages) in chemical components and in vitro DDM. Crude protein was significantly higher ($P < .05$), and ADF and NFE + EE were lower in the selected fescue forages. In orchardgrass samples, animals selected forages higher in crude protein and lower in NFE + EE than were available forages.

From this study we assume, therefore, that beef cattle are capable to select forages which are higher in crude protein and lower in NFE + EE than are the average of the available forages in the pasture. This study shows also that hand-clipping is an inadequate method of measuring the nutritive value of pasture forages.

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CHAPTER I

INTRODUCTION

In the southeastern region of the United States, forages are a large part of the total feed of beef cattle slaughtered as yearlings. Permanent pastures provide a considerable portion of these forages. In Tennessee, tall fescue, orchardgrass, and Ladino clover are among the principal plant species in permanent pastures.

Staff members of The University of Tennessee Animal Husbandry-Veterinary Science Department have conducted many grazing trials to determine the nutritive value of these pastures for grazing beef cattle. In most of these trials, hand-clipped samples were used to represent the diet of the grazing animals. However, since animals graze selectively, improved methods might yield better estimates of the actual diet of the animals.

Many indirect methods have been developed to determine the diet of the grazing animals, such as the "before-and-after" grazing method and "hand plucking" plants or parts of plants observed to be grazed by the animal. None of these methods can duplicate the actual diet of the grazing animal, and many investigators have felt that the only reliable and direct method of evaluating the diet of grazing animal is to use the animal itself to sample the pastures. Such methods became available with the development of the esophageal fistula technique (Torrell, 1954) and rumen fistula technique (Lesperance, 1960a).

A considerable amount of attention has been paid in recent years to the use of esophageal-fistulated animals. The use of these animals is the first major advance in evaluating forages actually grazed, and the degree of selectivity might be determined by comparing characteristics of the forage available in the pasture and of the forage grazed by esophageal-fistulated animals. However, salivary contamination, partial mastication, possible regurgitation, and sample preparation have been suggested as factors affecting the chemical composition of fistula samples.

A number of investigators have compared grazed and hand-clipped forage samples to estimate the degree of selectivity. Most of them did not take into account the effect of salivary contaminations and the other afore-mentioned factors. However, by including another type of sample (clipped-fistula) it is possible to separate the effects of "selectivity" and "contamination."

The purpose of this study was to determine the degree of selective grazing exhibited by beef steers by comparing the chemical composition and digestibility of forages available in the pastures at a certain time with the chemical composition and digestibility of the forage selected by the animals after adjusting for effects of the fistula. It was important also to determine the magnitude of effects of salivation, partial mastication, possible regurgitation, and sample preparation on the chemical composition and in vitro dry matter digestibility of the consumed forages.

CHAPTER II

REVIEW OF LITERATURE

I. SELECTIVE GRAZING OF PASTURE FORAGES

Importance of Selective Grazing

It has long been known that grazing animals do not consume all available forage in a pasture or range to the same extent; i.e., they graze selectively. Selective grazing, except on very leafy awards, is likely to be considerable, and some method of studying "forage grazed" as opposed to "forage available" is essential (Raymond et al., 1952). The extend of this selectivity has been studied by various methods. Until recently, the "before-and-after" grazing method or the hand-clipping method was used in determining the nature, quality, and quantity of forage consumed by the grazing animal. However, most of the indirect methods are subject to human error and are very time consuming (Cook et al., 1958; Lesperance et al., 1960a).

With the phenomenon of selective grazing in mind, many investigators in recent years have felt that the only reliable way to conduct pasture studies is by using the animal itself. A report by the Joint Committee of the American Society of Agronomy, the American Dairy Science Association, the American Society of Animal Production, and the American Society of Range Management (Anonymous, 1952) recommended that only the animal should be used for the determination of forage quality.

Occurrence of Selective Grazing

The occurrence of grazing selectivity has been observed by many investigators (Hardison et al., 1954; Heady and Torell, 1959; Weir et al., 1959; Weir and Torell, 1959; Blaser et al., 1960; Lesperance et al., 1960a; and Van Dyne and Torell, 1964; High, 1966; Berdon et al., 1967; Wang, 1968; Barth et al., 1969b; Kiesling et al., 1969).

Davis (1925) and Jones (1937) suggested that the degree of selectivity is related to the amount of palatable forage available. Hardison et al. (1954) reported the first quantitative results which showed the extent to which selective grazing occurs. They observed that the degree of selectivity was decreased by restricting grazing to a small area containing small quantities of forage, while providing large quantities of forage increased the extent of selection. They suggested that certain characteristics of forage, such as the kinds of plants present, stage of growth, proportions of leaves and stems, and accessibility of plant part, may have influenced to some degree the results obtained. Lofgreen and Meyer (1956) reported that selective grazing may be more pronounced with mature than with immature forage. High (1966) and Barth et al. (1969b) showed that selectivity was greater during the early part of the grazing season when more forage was available in the pasture.

Methods of Measuring Selective Grazing

Several direct and indirect methods have been used to measure the diet which the animal actually consumes. Recently, Cook (1964) discussed three methods which have been used with some success in obtaining forage

samples representative of ingested material under pasture and range conditions. These methods are: (1) hand plucking, (2) harvesting before and after grazing, and (3) sampling from fistulated animals.

Hand plucking of forages has been most extensively used. This can be accomplished by observing which plants or portions of plants the animal grazes and by sampling comparable ungrazed material (Cook, 1964). However, this method does not give an accurate picture of the forage actually consumed by the animals (Rusoff and Foote, 1961; Cook, 1964; Harris et al., 1967).

Collection of forage samples by the "before-and-after" or cage method has also been used. This method of determining the animal's diet consists of measuring the dry weight and chemical composition of the available forage before and after grazing. This method is described by Cook (1964) as follows: Several plots in the pasture are protected from grazing by portable cages so that ungrazed material can be harvested at the end of the experiment. The forage enclosed in the cage is the source of the before-grazing samples. Uncaged forages from similar areas are likewise harvested at the end of the experiment to obtain the after-grazing samples. The differences in chemical composition between the before-grazing sample and the after-grazing sample provide estimates of the chemical content of the forage selected by the animal. The disadvantage of this method is that little or no growth of plants will take place during these short periods (Cook, 1964, and Harris, 1968).

The rumen-evacuation method has been successfully used to obtain samples which represent what the animal consumes. To sample the grazing animal's diet by this technique, an animal with a permanent rumen

fistula is necessary. The procedure, described by Lesperance et al. (1960a), is as follows: the animal is restrained and the rumen cap removed. Then, all the contents of both the rumen and reticulum are removed and placed in a suitable container. The sides of the rumen are cleaned by downward strokes with the hand. This step is essential to lessen contamination of the subsequently collected forage sample. Harris et al. (1967) advised quickly rinsing the rumen and then removing the water with a small pump before permitting the animal to graze. The animal is then allowed to graze for 30 to 45 minutes. The forage sample is removed from the rumen and reticulum, and the previously removed rumen contents are returned to the rumen. This method of measuring selective grazing has some advantages in that it does give a total collection (lesperance et al., 1960), a rumen fistula is easier to establish and maintain than an esophageal fistula (Van Dyne and Torell, 1964), and it is better than the esophageal fistula for sampling some coarse dry grasses (Harris, 1968). However, the rumen-evacuation method has disadvantages, in that it is very laborious and may cause death of the animal (Cook, 1964).

An alternate method of using the grazing animal itself is the esophageal-fistula method. This becomes possible with the development of the esophageal-fistula technique by Torell (1954) in a two-year old wether. When the animal is not used for sampling, the fistula is closed by inserting stainless steel pins on either side of the fistula and lacing the ends of the pins together. This closes the fistula and allows normal passage of food. This technique has been modified by inserting a plastic or metal cannula with a cap into the esophagus

(Cook et al., 1958). Recent improvements in operative technique and closing device of the esophageal fistula have been made in California by Van Dyne and Torell (1964). This method for collecting forage is described as follows. A fistula is made in the skin and wall of the esophagus, and no cannula is used. As the animal grazes, a portion of the food drops through the fistula and may then be collected in a canvas bag fastened around the neck. When the animal is not being used for collections, the fistula is closed by a rubber plug.

Attempts to establish esophageal fistulas have not always been successful. Earlier investigators have faced difficulties in performing the surgery and maintaining the fistulated animals. Saint (1929) gave five reasons why surgery of the esophagus is difficult. These are: (1) the esophagus lacks a serosa, (2) in order to expose the esophagus in surgery, it is necessary to open the mediastinal structures and fascial planes, (3) there is a very low blood supply to the esophagus, (4) the esophagus cannot be restricted from movement, and (5) there is an absence of the greater omentum. Improved operative techniques have been outlined also by Bohman et al. (1967).

Many animals die during or shortly after the operation. Torell (1954) reported success in only one out of four sheep. After that, he established a fistula in a heifer, but she died of a digestive disorder before use. For establishing fistulas, Lesperance (1956) used four steers; but none of these animals survived a year, and some of them survived only a few weeks. Very similar results were obtained by Cook (1958), McManus (1962), and Nelson (1962).

Since then, esophageal-fistulated animals have been used widely in pasture studies by many investigators; e.g., in Utah by Cook et al. (1958), Cook and Stoddart (1961), and Cook et al. (1965); in California by Bath et al. (1956), Weir et al. (1959) and Van Dyne and Torell (1964); in Nebraska by Hoehne et al. (1965); in Tennessee by High (1966), Wang (1968) and Barth et al. (1969a); in Wyoming by Blackstone et al. (1965), Jefferies and Rice (1969); in Alabama by Guthrie et al. (1968); in New Mexico by Kiesling et al. (1969); in Australia by Grimes et al. (1965), Arnold et al. (1966); and in Uganda by Torell et al. (1967).

II. PROBLEMS IN THE DETERMINATION OF SELECTIVE GRAZING

The use of the esophageal-fistulated animals for collecting grazed samples has become very important in the field of pasture evaluation. However, certain corrections need to be applied to the samples in order to eliminate the effect of saliva contamination (Bath et al., 1956; Van Dyne and Torell, 1964) and for partial mastication and rumination (Hoehne et al., 1967 and Barth et al., 1969a). Grimes et al. (1965) pointed out that there are three main factors which have an effect on the composition of the fistula samples: (1) percentage recovery per fistula, (2) chemical changes during mastication, and (3) chemical changes during drying.

Amount of Recovery

The sample collected through the fistula must represent what the animal has swallowed (Arnold et al., 1964). They reported that this will be true if recovery of the ingested forage is complete. In the same

report, they suggested that the recovery rates under pen conditions may be lower than in the pasture because grazing sheep normally ingested material that is shorter than that fed in pens. Percentage dry matter recovery from ingested feed samples seemed to be related to the fistula size, although recovery rates varied greatly within sheep. They also suggested that in sheep, fistulas should be at least 10 cm² in area in order to obtain consistently high recoveries. Recovery rates appeared to be lower for long mature grass than for young succulent clover, but there were insufficient data to test this point. Lesperance et al. (1960a) reported that the low crude fiber content found in the fistula samples may have been because the more fibrous portion of the ingesta bypasses the fistula. The data of Lambourne (1965) indicated that the percentage of dry matter recovery was related to feed digestibility. Alder (1969) found that this seemed to be related to the size of the fistula. More than 90 percent recovery was reported by Bath et al. (1956), using a single esophageal fistulated sheep fed on chopped alfalfa hay. They recommended that collection times should not exceed 30 minutes. Similarly, McManus (1961) reported that the high percentage of recovery is desirable in order to have a large enough sample for analysis. He suggested also that 35 percent of recovery is sufficient for chemical analysis either for concentrate or roughages. Percentage recovery more than 50 was recorded by Grimes et al. (1965). Other investigators obtained more than 90 percent (Bath et al., 1956; Cook, 1964; Alder, 1969; and Kiesling et al., (1969). While results of Blackstone et al. (1965) and Campbell et al. (1968) were variable, the latter showed that

organic matter recoveries ranged from 84 to 94 percent for concentrate-type rations and from 26 to 81 percent for roughages.

Influence of Saliva Contamination

Salivary contamination during collection has been shown to effect the chemical composition of esophageal-fistula samples. The work by Bath et al. (1956) indicated that comparatively few chemical changes take place in the forage while in the mouth before passing the esophageal fistula. They found that the ash content appeared to be somewhat higher in the esophageal-fistula samples than in control samples because of salivary contamination of the fistula samples. Other workers also have found that ash was increased while the results with respect to other constituents were variable (Edlefsen et al., 1960; Lesperance et al., 1960b; McManus, 1961; Arnold et al., 1964; Cundy and Rice, 1968; Barth et al., 1969a; Kiesling et al., 1969).

Since the protein content of esophageal-fistula samples is often used to indicate a higher quality forage selected by grazing animals, as compared to hand clipped samples, salivary addition of nitrogen should be considered, according to Blackstone et al., 1965. They fed native grass hay and fresh green grass to four esophageal-fistulated wethers. The results showed that the amount of nitrogen added to grass hay was 0.45 percent and that 0.19 percent was added to fresh grass. Radde (1967) stated that the saliva increased the nitrogen levels in the forage samples collected through esophageal fistula significantly as compared to hand-clipped samples from the same source. Nitrogen contamination of esophageal-fistula samples was noticed also by Cook (1964). However,

Bath et al. (1956) and Lesperance et al. (1960a) did not show nitrogen contamination during esophageal collections from cattle.

Using yearling steers, Hoehne et al. (1967) reported that salivary contamination increased the ash, phosphorus, and chloride content and decreased the calcium content of fistula samples, as compared to fed samples. While Lombard and Van Schalkwyk (1963) and Langlands (1966) found that the calcium contents of the feed and fistula samples were similar but that the phosphorus content of the fistula samples was increased. They indicated also that the fistula samples contained, on the average, 27 percent less potassium and 547 percent more sodium than the feed consumed.

The saliva contamination of samples obtained through esophageal-fistulated animals would tend to limit their usefulness (Radde, 1967). However, many investigators suggested that it may be better to express nutrient composition on an ash-free or organic matter basis (McManus, 1961; Nelson, 1962; Van Dyne and Torell, 1964; Grimes et al., 1965).

Influence of Partial Mastication and Rumination

Partial mastication seems to have an effect on the chemical composition of the ingested forage. Grimes et al. (1965) studied especially the water soluble carbohydrates in seven samples collected from pen-fed sheep. They pointed out that animals on the same diet masticated the forage to a different extent, which resulted in variable proportions of the water-soluble fractions appearing in the liquor.

The problem of contamination of esophageal-fistula samples with regurgitated rumen material was found to be serious only when more than

two hours elapsed during the collection (Cook et al., 1963). A collection time of not more than one hour was suggested by McManus (1962). Also, High (1966) and Wang (1968) reported that no contamination due to regurgitation occurred during sample periods of 30 to 45 minutes.

Influence of Sample Preparation

The chemical composition of samples obtained from esophageal fistulas is affected by the method of sample preparation which leads to an inaccurate estimate of the degree of selectivity (Lesperance et al., 1960b; Lesperance and Bohman, 1964; Van Soest, 1965; Langlands, 1966; Hoehne et al., 1967; Radde, 1967).

There are three main factors affecting the apparent chemical composition of the samples during preparation. These factors are: (1) type of collection bag, (2) squeezing of the sample after collection, and (3) drying temperature. In their review of the development and use of esophageal fistulas, Van Dyne and Torell (1964) suggested that the use of screen-bottom collection bags would reduce salivary contamination by allowing the excess saliva to drain from the collected forage samples. They felt also that a waterproof collection bag has the further disadvantage of becoming quite heavy, which may affect the grazing performance of the animal. Using both screen bottom and closed bottom collection bags with five wethers, Radde (1967) fed three green grasses, one dried grass, and one alfalfa hay. He found that there was no effect of type of collection bag on ash increase, but water-soluble carbohydrates were significantly reduced when screen bottom bags were used. The amount of reduction in water-soluble carbohydrates varied significantly among

forages and was highly and positively correlated with volume of saliva dripping through the screen from the collected samples. He suggested that the calculations of the percentage of water soluble carbohydrates in the ingested forages would be more precise if based on the total collection of forage residues plus drip saliva, as opposed to calculations based on levels of water-soluble carbohydrates in the offered and refused forages.

Several studies have been conducted to determine the effect of drying temperature on the chemical composition of forage samples in general. Van Soest (1965) found that percentages of acid detergent fiber (ADF) and of acid insoluble lignin (AIL) will increase at drying temperatures above 50°C. However, Jones (1962) reported a 25 percent loss of soluble carbohydrates of grasses due to drying at 100°C overnight and a maximum loss of 6 percent when drying for four hours at 80°C. Using forage samples, Lesperance and Bohman (1964) pointed out that vacuum drying at 25°C minimized these changes while freeze-drying apparently eliminated them. Burns et al. (1964) also used the freeze-drying method and observed that the soluble carbohydrates in a green plant sample were almost twice as much as similar samples oven-dried at 77°C. Smith et al. (1967), using two drying methods, reported that all the chemical measures except protein in hand-clipped and fistula samples were significantly associated with method of drying. These changes were greater in fistula samples than in clipped samples. Crude fiber, ADF, and AIL were higher in all oven-dried samples than in freeze-dried samples while nitrogen-free extract was lower. More recently, Barth et al. (1969a) compared the effects of 45 and 65°C dry temperatures on control

and fistula samples. They found that in control forage samples, drying temperature had no effect on percentage of ash, crude protein, or in vitro digestible dry matter (DDM), and observed little increase in ADF and AIL when samples were dried at 65°C. Drying at 65°C had no significant effect on the determination of crude protein, ADF, AIL, and in vitro DDM except for ash which was slightly decreased at this temperature in fistula samples.

Regarding the squeezing of samples after collection, it is evident that squeezed fistula subsamples contain less moisture than control samples. Grimes et al. (1965) reported that the non-squeezed portion of the sample had 10 percent more moisture than the squeezed portion. The non-squeezed subsamples also required more time to dry (Hoehne et al. 1967). They indicated also no difference between squeezed and non-squeezed fistula samples in the amount of water soluble carbohydrates and crude protein, while the squeezed samples had a lower mineral content than non-squeezed samples.

Although ruminant saliva does not contain enzymes, the increased moisture of the fistula samples may permit plant enzymes to break down or alter certain chemical constituents of these samples.

III. EFFECT OF SELECTIVITY ON CHEMICAL COMPOSITION OF FORAGES

Several researchers have indicated that animals select the green and leafy portions of plants when these are available. Hardison et al. (1954) estimated the degree of selectivity by allowing one group of steers to graze forage while pen-feeding another group samples from the

same source. They found that the diet selected by grazing steers was higher in crude protein than the whole forage available for consumption.

Working with grazing sheep, Weir and Torell (1959) studied selective grazing by comparing the chemical composition of a variety of forage samples obtained by hand clipping and by esophageal-fistulated sheep. They showed that the selected forage contained 4 percent more protein than clipped samples using previously ungrazed pasture range. Similar results for protein content have been reported by Meyer et al. (1957), Pieper et al. (1959), Bryant et al. (1961), High (1966), Bredon et al. (1967), Wang (1968), Barth et al. (1969a), Kiesling et al. (1969), and Jeferies and Rice (1969). The latter indicated that grazed samples were higher in crude protein content than clipped samples at the beginning of the grazing season, while they observed no differences between grazed and clipped samples at the end of the season. Using esophageal-fistulated sheep grazing orchardgrass, ryegrass and tall fescue with and without clover pastures, Grimes et al. (1966) observed that the differences between clipped and grazed samples from all grass pastures were small throughout the experiment. However, in grass-clover pastures, they found that the sheep selected forage higher in crude protein.

Some research workers have reported a lower percentage of crude fiber in esophageal-fistula samples than in the hand-clipped samples (Hardison et al., 1954; Weir et al., 1959; Weir and Torell, 1959; Bredon et al., 1967; and Kiesling et al., (1969). However, Bath et al. (1956) and Campbell et al. (1968) found no significant differences in crude fiber.

Some investigators have shown that ADF and AIL were lower in grazed-fistula samples than in control samples (Achacosa, 1963 and Guthrie et al., 1968). However, Lesperance et al. (1960b), Kenneth (1965), High (1966), Conner et al. (1967), and Kiesling et al. (1969) observed that ADF and Ail contents were considerable higher in grazed-fistula samples than in clipped samples, while Wang (1968) and Campbell et al. (1968) found no change in ADF of fistula samples as compared to the control or clipped samples.

This phenomenon of fistula samples containing higher percentages of ADF and AIL has been observed also when a comparison of forages fed and those collected through esophageal fistula have been made and selection was prevented (Lesperance and Bohman, 1964; Blackstone et al., 1965; Hoehne, 1966; Cundy and Rice, 1968; and Barth et al., 1969a). Therefore, changes in chemical composition may have been due to salivary contamination and sample preparation rather than to the effect of selective grazing.

Dealing with the nitrogen-free extract (NFE), Lesperance et al. (1960a) and Campbell et al. (1968) found that fistula samples were lower in NFE than control samples, except for alfalfa hay. They indicated that the change in the NFE might have been due to leaching of soluble carbohydrates. Similar results have been obtained by Lombard and Van Schalkwyk (1963) in South Africa. They showed significant decreases of NFE in both hay and green forage samples obtained from esophageal-fistulated steers as compared to the control samples.

Hardison et al. (1954) estimated that clipped forage was only 94 percent as digestible as that selected by cattle grazing the sward.

Lofgreen and Meyer (1956) observed a small but consistent increase in total digestible nutrients (TDN) due to selective grazing. Van Dyne and Weir (1964) reported that nylon-bag cellulose and dry matter digestibility values of the mixed forage collected through esophageal fistulas were higher than those of hand-clipped samples. High (1966) also indicated that esophageal-fistulated steers grazed selectively as measured by differences in cellulose digestibility between hand-clipped and grazed samples. Jefferies and Rice (1969) observed higher dry matter digestibility in fistula samples than in clipped samples, especially during the early part of the grazing season.

In Summary, esophageal-fistulated animals have been suggested as a means of determining the actual diet of grazing animals. Using these animals, many researchers have compared the chemical composition of grazed samples (representing forage eaten) and clipped samples (representing available forage) in an attempt to estimate the degree of selective grazing (Weir and Torell, 1959; Lesperance et al., 1960a; Ridley et al., 1963; Cook, 1964; High, 1966; Bohman and Lesperance, 1967; Bredon et al., 1967; Wang, 1968). However, in estimating true selectivity, it is necessary to adjust grazed samples for saliva contamination, mastication and sample preparation (Bath et al., 1956; Marshall et al., 1967; Hoehne et al., 1967; Barth et al., 1969a). Many of the afore-mentioned investigators have not separated the effects of saliva contamination and other influences to arrive at true selectivity. To measure true selectivity, comparisons have to be made between samples treated in the same manner, such as clipped samples obtained via an esophageal fistula and grazed samples obtained via an esophageal fistula.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. EXPERIMENTAL PASTURES

The pastures studied were four three-acre plots of tall fescue (Festuca arundinacea), three three-acre plots of orchardgrass (Dactylis glomerata), and one three-acre plot of Ladino clover (Trifolium repens). These pastures were located at The University of Tennessee's Blount Farm. The tall fescue pastures were initially established in the fall of 1954, while the orchardgrass and ladino clover pastures were established in the fall of 1968. All the pastures were subjectively evaluated at two-week intervals during the entire experimental period. The evaluation involved the percentage composition of the various plant species, the average height of grasses and legumes, stage of growth, condition of the pasture, color, carrying capacity, thickness of sod, footing, and grade of pastures.

While this study was conducted, each pasture was grazed by three weanling beef steers. The initial weight of the steers ranged from 180 to 210 kg., and they graded good and medium. The steers were maintained on their respective pastures without additional feeding from May 1 until pastures were depleted in the autumn.

II. EXPERIMENTAL ANIMALS

Five esophageal-fistulated steers were used in this study. They ranged from three to five years in age. The fistulas had been established when they were yearlings using the fistulation technique and fistula closing devices similar to those of Van Dyne and Torell (1964). The post-operation care of the steers was according to High (1966). Throughout the test period, the steers were kept on a separate pasture adjacent to the test pastures except during the collection days, when they grazed the test pastures or consumed the "clipped fistula" samples. Water, salt, and minerals were available free choice.

One rumen-fistulated steer was used as donor for rumen liquor. This steer was maintained together with the five esophageal-fistulated steers on a mixed pasture of tall fescue, orchardgrass, and Ladino clover.

III. EXPERIMENTAL DESIGN

Following is a description of the three types of forage samples collected:

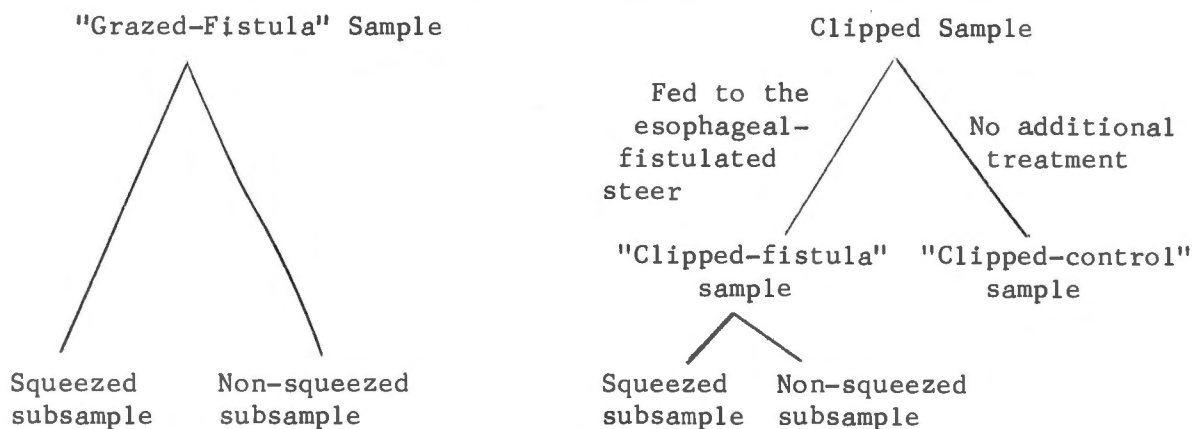
Clipped-control samples--those forage samples which were clipped by hand from the test pastures. They were analyzed for their chemical components and in vitro digestibility without further treatment and represent the average composition of forages available in the pastures.

Clipped-fistula samples--the other portion of the hand-clipped samples which were fed to esophageal-fistulated steers in the corrals and obtained through the fistulas. Differences in chemical composition

and in vitro digestibility between these samples and the clipped-control samples represent the effects of saliva contamination, partial mastication and possible regurgitation and selective recovery.

Grazed-fistula samples--this refers to the forage samples obtained by the esophageal-fistulated steers when grazing the test pastures. Differences in chemical composition and in vitro digestibility between these samples and clipped-fistula samples represent true selectivity because both types of samples have been equally subjected to saliva contamination, partial mastication, and possible regurgitation and selective recovery.

Types of Forage Samples



Collections of forage samples were started on May 30, 1969, and continued at four-week intervals until September 19, 1969. Four esophageal-fistulated steers were used to collect both grazed and clipped fistula samples. The grazed samples were obtained on the first day of each collection period, while the clipped-control and clipped-fistula samples were obtained on the second day of the collection period. The following

scheme illustrates the collection procedure used for obtaining the grazed and clipped-fistula samples at each collection period:

Day 1. Collection of Grazed Samples

	<u>Tall-fescue</u>				<u>Orchardgrass</u>			<u>Ladino-clover</u>
Pasture number	1	4	5	7	3	6	8	2
Steer number	1	2	3	2	4	1	4	3

Day 2. Collection of Clipped-Fistula Samples

	<u>Tall-fescue</u>				<u>Orchardgrass</u>			<u>Ladino-clover</u>
Pasture number	1	4	5	7	3	6	8	2
Steer number	1	2	3	2	4	1	4	3

IV. COLLECTION OF FORAGE SAMPLES

Clipped-Control and Clipped-Fistula Samples

The night before the collection day, the esophageal-fistulated steers were brought from the pasture and placed in a corral beside the test pastures, with access to water but not feed. The following morning, approximately at 7:00 a.m., the fistula plugs were removed and steers were fitted with canvas collection bags which had a fine-mesh screen wire bottom. The screen bottom allowed excess saliva to drain from the sample.

While the steers were in the corral, hand-clipped samples were taken from the test pastures as shown in the scheme. Each of these samples was well mixed and divided into two portions. One portion which is referred to as the clipped-control sample was weighed and kept for chemical analyse and in vitro dry matter digestibility determination.

The remainder of the sample from each pasture, hereafter referred to as the clipped-fistula sample, was weighed and fed to each particular steer (as indicated in the scheme, day 2). The collection bags were removed from the steers' neck after they had eaten the samples. Then the steers were ready to consume the second four forages. They were then fitted with the fistula plugs and returned to the pasture to continue normal grazing.

Grazed-Fistula Samples

Each of the four esophageal-fistulated steers was put on the allotted experimental pasture, as shown in the scheme (day 1), and grazed along with the three non-fistulated steers on each lot. The fistulated steers were allowed about 15 to 20 minutes in the pasture before being returned to the corral where the collection bags were removed. After about 10 minutes, these steers were ready to sample the second set of four pasture lots. They were then returned to the corral, the collection bags removed, and the fistula plugs replaced. The steers were then moved to their particular pasture to graze normally.

V. PREPARATION OF FORAGE SAMPLES

Each grazed- and clipped-fistula sample was transferred from the collection bag into a suitable metal container, mixed by hand, and divided into two approximately equal portions. One-half was squeezed by hand through four layers of cheesecloth until no more saliva could be removed. This squeezed subsample then was placed in a polyethylene bag. The other half of the sample was not squeezed but allowed to drain

through the same cheesecloth which was used for squeezing the first portion of the sample.

All the forage samples were then taken immediately to the laboratory where they were transferred to aluminum pans, weighed and dried at 45°C. in a forced-air drying oven for approximately three days. After drying and air equilibration they were weighed again in order to calculate the percentage of dry matter recovery. The forage samples then were ground in a Wiley mill using a medium mesh screen of 2-mm. diameter and stored in air tight containers for subsequent chemical analyses and in vitro dry matter digestibility determinations.

VI. LABORATORY ANALYSES AND CALCULATIONS

Chemical Analyses

The forage samples were analyzed for dry matter, ash, and crude protein by the A.O.A.C. (1965) method, acid detergent fiber (ADF) and acid insoluble lignin (AIL) by the Van Soest (1963) method and nitrogen-free extract (NFE) + ether extract (EE) values were calculated as follows: percent (NFE + EE) = 100 - percent crude protein - percent ADF. Percentage of ash was expressed on a dry-matter basis whereas crude protein, NFE + EE, ADF and AIL were expressed on an organic-matter basis. The percentage of dry matter recovery, which is the ratio between the amount of feed collected through the esophageal fistula and the feed swallowed, was calculated as follows:

Percent dry matter recovery =

$$\frac{\text{grams collected through fistula} \times \text{percent dry matter}}{\text{grams ingested} \times \text{percent dry matter}} \times 100.$$

Dry Matter Digestibility

In vitro dry matter digestibility was determined by the method of Tilley and Terry (1963). One rumen-fistulated Hereford steer was used to obtain the rumen liquor during the grazing period. This steer grazed a mixed pasture containing tall fescue, orchardgrass, and Ladino clover. The in vitro digestion trials consisted of three runs and duplicate samples within each run.

Statistical Analyses

Separate analyses of variance were made for tall fescue and orchardgrass samples using the following linear additive mathematical model:

$$Y_{ijk} = u + p_i + t_j + (pt)_{ij} + e_{ijk}.$$

Where:

Y_{ijk} = The percentage of ash, crude protein, acid detergent fiber, acid insoluble lignin, nitrogen-free extract + ether extract and in vitro dry matter digestibility for the k^{th} observation of the j^{th} type of sample in the i^{th} collection period.

Where:

u = the theoretical population mean.

P_i = the effect of i^{th} period where $i = 1, 2, 3, 4, 5$, as follows:

- | | |
|------------|-----------------|
| 1. May 31 | 4. August 22 |
| 2. June 27 | 5. September 19 |
| 3. July 25 | |

t_j = t effect of j^{th} type of sample where $j = 1, 2, 3, 4, 5$, as follows:

1. Clipped-control
2. Clipped-fistula, squeezed
3. Clipped-fistula, non-squeezed
4. Grazed-fistula, squeezed
5. Grazed-fistula, non-squeezed

$(pt)_{ij}$ = The effect of the interaction between period and type of sample for the j^{th} type of sample and the i^{th} period.

Estimation of missing data was accomplished using methods outlined by Steel and Torrie (1960). Differences in all possible comparisons were tested for significance by Duncan's (1955) multiple-range test.

CHAPTER IV

RESULTS AND DISCUSSION

I. FORAGE SAMPLING

Grazing Trials

A description of the botanical composition of the pastures at each sampling date is reported in Table 1. Each steer was used to collect samples from two pasture plots in each collection period. Generally, acceptable samples were obtained from all the steers for chemical and in vitro dry matter digestibility determinations.

Several times during the grazing experiment, plugs were found missing from some steers. In most cases, this did not influence the experiment. However, in one instance, a steer lost his plug and thereafter appeared very sick and unthrifty for a period of three weeks. Therefore, another esophageal-fistulated steer was used for that collection period.

Pen-Feeding Trials

In most cases, the esophageal-fistulated steers consumed the clipped forages offered to them in the metal buckets without much difficulty. In some cases, it was necessary to force-feed the steers; i.e., the samples were picked up by the investigators and placed in the mouth of the animal. No effect of this force-feeding on clipped-fistula sample composition and digestibility was evident. In three instances, steers could not be induced to consume the forage samples.

TABLE 1
BOTANICAL COMPOSITION OF PASTURES AT
EACH SAMPLING PERIOD^{a, b}

Date	Fescue pastures				Orchardgrass pastures			
			Other		Orchard-		Other	
	<u>Fescue</u>	<u>Legume</u>	<u>grasses</u>	<u>Weeds</u>	<u>grass</u>	<u>Legume</u>	<u>grasses</u>	<u>Weeds</u>
	%	%	%	%	%	%	%	%
May 31	96.2		.5	3.3	73.3		6.7	20.0
June 27	94.0	3.0	.5	2.5	71.7	.7	15.0	12.6
July 25	90.3	4.0	.3	2.7	65.3	2.7	21.0	11.0
August 22	87.0	3.0	6.5	3.5	63.3	2.7	22.3	11.7
Sept. 19	87.8	1.0	7.0	4.2	59.3	8.0	17.7	15.0

^aMeans of four and three pastures of fescue and orchardgrass, respectively. Botanical composition of each pasture is shown in Appendix, Table 7.

^bBased on visual estimation.

II. DRY MATTER RECOVERY

The dry matter recoveries of the forage samples obtained from esophageal fistulas are shown in Table 2. These recoveries varied from 33 to 92 percent with a mean of 68 percent. The average percentage recovery in fescue samples was 67 and in orchardgrass samples was 69. Recovery percentages do not seem to be influenced by type of plant species or collection period. In similar pen-feeding studies with fresh grass samples, Campbell et al. (1968) observed average recoveries of only 30 percent. However, stainless steel canulas were used in that study which would cause lower recoveries due to a smaller opening. Using sheep in pen-feeding studies, Radde (1967) reported recoveries averaging 21 percent and ranging from 5 to 92 percent. He suggested that in grazing studies, recoveries are probably higher than in pen-feeding studies because the forage in the pen-feeding studies is usually longer and tends to bypass the fistula more readily.

As shown in Table 2, on one occasion recovery was very much higher than 100 percent. This was due to regurgitation of rumen contents which caused contamination of the collected forage sample. Radde (1967) observed this on many occasions.

III. EFFECT OF ESOPHAGEAL FISTULA

Many chemical compositions and in vitro dry matter digestibility of the forage offered (clipped-control samples) and the fistula samples (clipped-fistula, squeezed and non-squeezed samples) by periods are shown in Table 3. Individual data are presented in the Appendix, Table 7.

TABLE 2
 DRY MATTER RECOVERY OF FORAGE SAMPLES OBTAINED
 THROUGH ESOPHAGEAL FISTULAS^a

Collection period	Forage type						
	Tall fescue				Orchardgrass		
	Lot 1	Lot 4	Lot 5	Lot 7	Lot 3	Lot 6	Lot 8
	Percent						
2	78	87	35	82	51	68	63
3	80	50 ^b	72	33	41	85	51
4	63	82	64	36	91	71	80
5	69	63	75	78	72	76	68

^aRecovery was not determined in the first collection period.

^bSample was contaminated with rumen material.

TABLE 3
CHEMICAL COMPOSITION AND IN VITRO DRY MATTER DIGESTIBILITY
OF THE FORAGE SAMPLES BY PERIODS^a

Item	Collection Period					Mean
	1	2	3	4	5	
	May 31	June 27	July 25	Aug. 22	Sept. 19	
TALL FESCUE						
Ash, ^b %						
Clipped-control	7.8	7.2	7.4	7.6	7.6	7.5
Clipped-fistula						
Squeezed	8.8	8.6	9.2	12.8	12.2	10.3
Non-squeezed	11.9	10.7	11.4	13.4	12.8	12.1
Grazed-fistula						
Squeezed	10.8	11.8	12.9	12.8	13.5	12.3
Non-squeezed	12.6	12.4	12.9	12.9	13.2	12.8
Crude protein ^c (N X 6.25), %						
Clipped-control	9.9	12.3	13.6	16.3	13.6	13.1
Clipped-fistula						
Squeezed	10.1	11.9	13.0	17.0	14.7	13.4
Non-squeezed	10.9	12.7	13.9	17.7	14.8	14.0
Grazed-fistula						
Squeezed	15.3	15.2	16.6	19.0	18.1	16.8
Non-squeezed	16.5	16.1	16.8	20.0	18.6	17.6
Acid detergent fiber, ^c %						
Clipped-control	44.4	44.2	44.1	42.4	45.8	44.2
Clipped-fistula						
Squeezed	54.5	52.3	53.1	52.1	53.6	53.1
Non-squeezed	55.4	53.0	55.0	52.9	54.5	54.1
Grazed-fistula						
Squeezed	53.2	52.6	53.8	52.3	53.1	53.0
Non-squeezed	52.9	52.4	52.6	51.3	52.6	52.4
Acid insoluble lignin, ^c %						
Clipped-control	5.5	6.2	6.1	6.1	6.7	6.1
Clipped-fistula						
Squeezed	8.9	7.8	8.9	8.9	9.7	8.8
Non-squeezed	8.8	8.1	9.2	9.5	10.0	9.1
Grazed-fistula						
Squeezed	10.0	8.9	9.3	9.2	9.3	9.3
Non-squeezed	10.1	9.0	9.3	9.4	9.8	9.5

TABLE 3 (continued)

Item	Collection Period					Mean
	1 May 31	2 June 27	3 July 25	4 Aug. 22	5 Sept. 19	
Nitrogen-free extract and ether extract, ^c %						
Clipped-control	45.7	43.6	42.4	41.3	40.6	42.7
Clipped-fistula						
Squeezed	35.4	35.8	33.9	30.9	31.8	33.5
Non-squeezed	33.8	34.4	31.2	29.3	30.7	31.9
Grazed-fistula						
Squeezed	31.5	32.2	30.0	28.6	28.8	30.1
Non-squeezed	30.6	31.4	30.6	29.2	28.9	30.1
<u>In vitro</u> dry matter digestibility, ^c %						
Clipped-control	58.1	53.8	55.5	59.4	60.2	57.4
Clipped-fistula						
Squeezed	63.2	55.6	57.6	60.7	60.5	59.5
Non-squeezed	64.7	56.7	58.3	61.0	60.0	60.1
Grazed-fistula						
Squeezed	64.1	56.4	59.8	61.8	60.4	60.5
Non-squeezed	65.0	56.7	60.6	62.0	60.1	60.9
ORCHARDGRASS						
Ash, ^b %						
Clipped-control	8.2	8.3	8.1	8.2	8.3	8.2
Clipped-fistula						
Squeezed	8.5	9.9	9.5	11.6	11.3	10.2
Non-squeezed	11.7	11.6	11.1	12.3	12.1	11.7
Grazed-fistula						
Squeezed	10.7	11.2	11.7	11.7	12.4	11.5
Non-squeezed	12.8	12.9	12.6	12.5	12.3	12.6
Crude protein ^c (N X 6.25), %						
Clipped-control	11.0	19.3	17.6	21.2	15.0	16.8
Clipped-fistula						
Squeezed	10.3	19.5	18.2	21.8	17.6	17.5
Non-squeezed	14.5	22.5	18.6	25.0	21.9	20.5
Grazed-fistula						
Squeezed	14.3	22.1	17.9	24.2	21.2	19.9
Non-squeezed	14.5	22.5	18.6	25.0	21.9	20.5

TABLE 3 (continued)

Item	Collection Period					Mean
	1 May 31	2 June 27	3 July 25	4 Aug. 22	5 Sept. 19	
Acid detergent fiber, ^c %						
Clipped-control	44.8	42/2	41.4	39.3	41.5	41.8
Clipped-fistula						
Squeezed	58.6	48.3	48.1	47.4	50.4	50.6
Non-squeezed	58.7	47.7	49.6	47.7	51.3	51.0
Grazed-fistula						
Squeezed	58.2	52.1	50.5	50.2	50.8	52.4
Non-squeezed	59.3	51.6	51.8	51.6	50.6	53.0
Acid insoluble lignin, ^c %						
Clipped-control	7.4	7.0	6.2	6.1	6.0	6.5
Clipped-fistula						
Squeezed	10.9	10.1	10.3	9.7	9.3	10.0
Non-squeezed	10.7	11.0	10.7	9.7	9.5	10.3
Grazed-fistula						
Squeezed	11.8	10.7	9.9	9.6	9.6	10.3
Non-squeezed	11.6	11.0	10.9	10.1	9.5	10.6
Nitrogen-free extract and ether extract, ^c %						
Clipped-control	44.3	38.5	41.0	39.6	43.4	41.4
Clipped-fistula						
Squeezed	31.1	32.2	33.7	30.9	32.0	32.0
Non-squeezed	29.5	31.6	31.5	29.8	30.8	30.7
Grazed-fistula						
Squeezed	27.5	25.8	31.6	25.6	28.0	27.7
Non-squeezed	26.3	25.9	29.6	23.4	27.4	26.5
<u>In vitro</u> dry matter digestibility, %						
Clipped-control	55.9	58.7	60.5	61.8	63.5	60.1
Clipped-fistula						
Squeezed	58.7	58.1	60.7	62.5	62.4	60.5
Non-squeezed	61.8	59.3	60.7	63.6	62.3	61.5
Grazed-fistula						
Squeezed	58.8	59.2	61.2	63.2	62.3	60.9
Non-squeezed	59.7	59.0	61.8	62.7	61.9	61.0

^aMeans of four and three pastures of fescue and orchardgrass, respectively. Chemical components and in vitro dry matter digestibility for each pasture are shown in the Appendix, Table 8.

^bDry-matter basis.

^cOrganic-matter basis.

All the chemical components except ash are expressed on an organic-matter basis in order to eliminate differences due to ash contamination. The sum of all effects on composition and digestibility brought about by feeding a forage sample to the animal and collecting it through the esophageal fistula will be called "effect of fistula" in the following discussion. This effect of fistula is determined by comparing composition and digestibility of clipped-fistula samples with those of clipped-control samples.

In Table 4, the differences (means of all periods) in composition and digestibility between the two types of samples are reported. The ash content of clipped-fistula samples was significantly ($P < .05$) higher than that of clipped controls in both fescue and orchardgrass pastures. This increased ash was apparently due to saliva contamination and is in agreement with the results reported by Bath *et al.* (1956), McManus (1961), Grimes *et al.* (1965), Blackstone *et al.* (1965), High (1966), Hoehne *et al.* (1967), Wang (1968), and Barth *et al.* (1969a).

In fescue samples, the analysis of variance (Table 5) revealed also a significant ($P < .01$) period x type of sample interaction. The ash content of the forage samples by periods is graphically reported in Figure 1. Ash content of clipped-control samples remained relatively constant throughout the experiment, while ash content of both types of clipped-fistula samples increased in periods 4 and 5. Therefore, ash contamination of the samples by saliva in August and September was higher than in the first three collection periods. This increased ash contamination was observed also in orchardgrass samples, although to a smaller extent.

TABLE 4
EFFECT OF ESOPHAGEAL FISTULA ON CHEMICAL COMPOSITION AND IN VITRO
DRY MATTER DIGESTIBILITY OF FORAGE SAMPLES^a

Types of sample	Ash ^b	Crude protein ^c	Acid detergent fiber ^c	Acid insoluble lignin ^c	Nitrogen-free ether extract ^c	In vitro dry matter digestibility
TALL FESCUE						
CFNS - CC ^d	3.6*	0.9	10.0*	3.0*	-10.9*	2.8*
CFS - CCe	2.8	0.2	9.0	2.7	- 9.2*	2.1
ORCHARDGRASS						
CFNS - CC ^d	3.6*	1.5	9.2*	3.8*	-10.7*	1.4
CFS - CCe	2.0	0.7	8.7	3.5	- 9.4*	0.4

^aMean of five collection periods.

^bDry-matter basis.

^cOrganic-matter basis.

^dDifference between clipped-fistula non-squeezed (CFNS) and clipped-control (CC) samples.

^eDifference between clipped-fistula squeezed (CFS) and clipped-control (CC) samples.

*Significantly different ($P < .05$).

TABLE 5

ANALYSIS OF VARIANCE OF EFFECT OF COLLECTION PERIOD AND TYPE OF SAMPLE ON VARIOUS
CHEMICAL AND DIGESTIBILITY DETERMINATIONS OF FESCUE AND ORCHARDGRASS PASTURES

Source	Degree of freedom	Mean square					
		Ash	Crude protein	Acid detergent fiber	Acid insoluble lignin ether extract	Nitrogen free extract + ether extract	In vitro DDM
TALL FESCUE							
Period	4	13.87**	89.06**	12.24**	2.96**	58.67**	148.60**
Type of sample	4	94.94**	87.06**	331.98**	39.60**	550.76**	38.75**
Period X Type of sample	16	3.04**	2.01	1.30	0.71	2.38	5.21**
Residual	75	0.80	2.89	2.91	0.60	6.51	1.23
ORCHARDGRASS							
Period	4	2.35*	235.07**	183.34**	7.06**	29.08**	51.36**
Type of sample	4	44.79**	37.47**	308.27**	43.77**	515.88**	4.54
Period X Type of sample	16	1.16	3.22	6.50**	0.29	7.03	3.27
Residual	50	0.74	2.58	1.77	0.66	4.57	2.21

* Significantly different ($P < .05$).

** Significantly different ($P < .01$).

TABLE 6

EFFECT OF SELECTIVITY ON CHEMICAL COMPOSITION AND IN VITRO DRY MATTER
DIGESTIBILITY OF FORAGE SAMPLES^a

Types of sample	Ash ^b	Crude protein ^c	Acid detergent fiber ^c	Acid insoluble lignin ^c	Nitrogen- free extract + ether extract ^c	In vitro dry matter digestibility
TALL FESCUE						
GFNS - CFNS ^d	0.7	3.6*	-1.8	0.4	-1.7	0.8
GFS - CFSe	2.0*	3.5*	-0.1	0.5	-3.5	1.0
ORCHARDGRASS						
GFNS - CFNS ^d	0.9	2.2	2.0	0.3	-4.2*	-0.5
GFS - CFSe	1.4	2.5	1.8	0.3	-4.3*	0.5

^aMeans of five collection periods.^bDry-matter basis.^cOrganic-matter basis.^dDifference between grazed-fistula non-squeezed (GFNS) and clipped-fistula non-squeezed (CFNS) samples.^eDifference between grazed-fistula squeezed (GFS) and clipped-fistula squeezed (CFS) samples.* Significantly different ($P < .05$).

from the clipped-fistula samples. An erroneously lower NFE + EE value would result in percentage increases of all other organic nutrient fractions also. For these reasons, it was assumed that selectivity data calculated from the non-squeezed samples more accurately represent the real situation. Therefore, values calculated from squeezed samples will not be discussed further. From the comparison between the non-squeezed grazed- and clipped-fistula samples in Table 6, it was concluded that animals do not select for a higher or lower ash content when grazing fescue pastures.

The crude protein content in non-squeezed grazed-fistula samples was significantly ($P < .05$) higher than that in non-squeezed clipped-fistula samples. The higher percentage of crude protein in the grazed-fistula samples clearly demonstrates that cattle grazing fescue select forages approximately 3.5 percent higher in crude protein. This fact has been suggested previously by many investigators (Hardison *et al.*, 1954; Meyer *et al.*, 1957; Weir and Torell, 1959; Pieper *et al.*, 1959; Bryant *et al.*, 1961; Cook, 1964; High, 1966; Wang, 1968; Jefferies and Rice, 1969); however, their results were less valid, since they did not adjust their data for effects of the esophageal fistula.

As shown in Figure 2a, the crude protein content of clipped-fistula samples remained relatively constant throughout the experimental period. In non-fertilized pastures, the crude protein content increased from 11 percent at the beginning of the trial to 14.8 percent on August 22 and remained approximately the same thereafter. High (1966) indicated that the peak of crude protein content for grazed and clipped forage

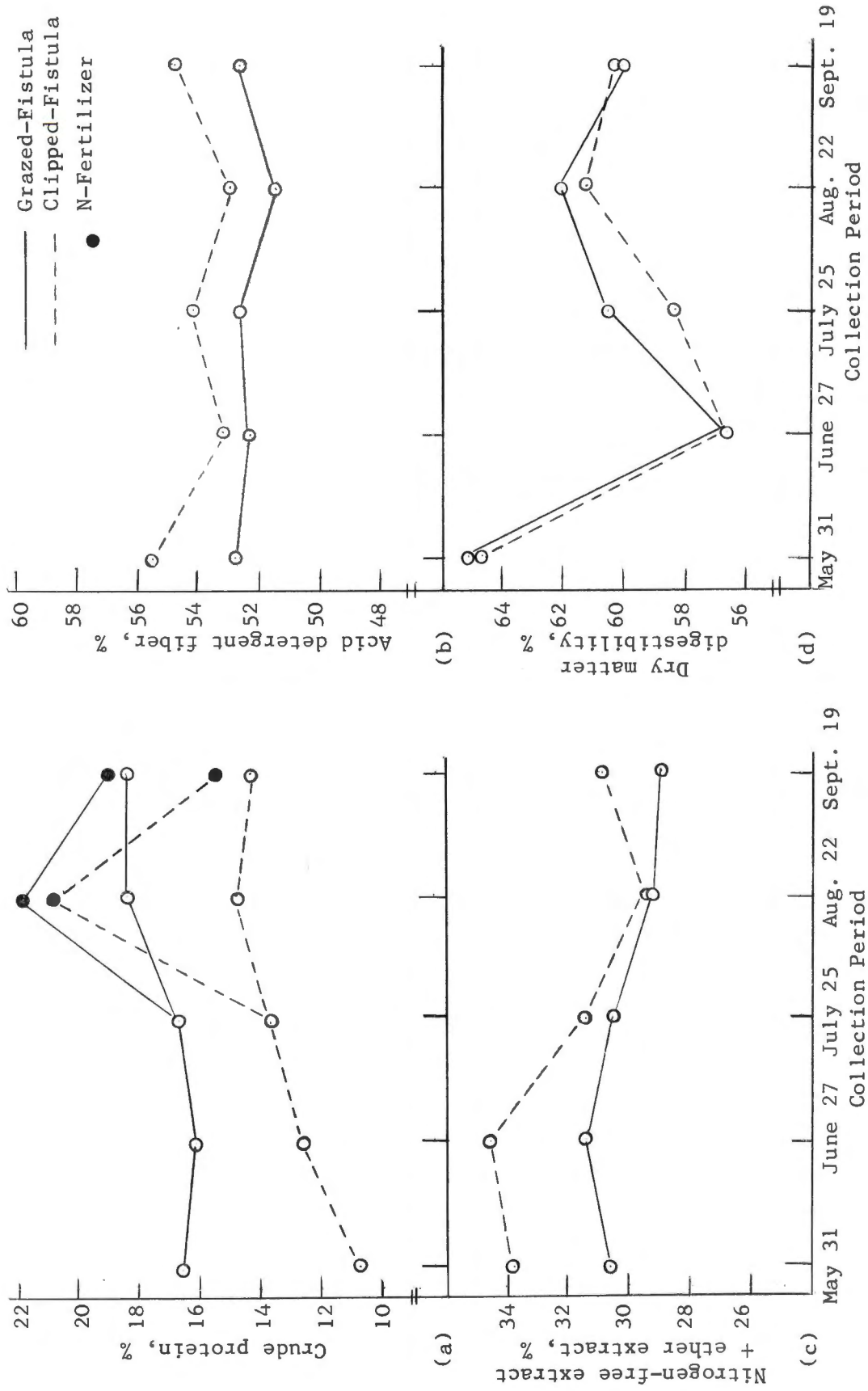


Figure 2. Chemical components (organic-matter basis) and in vitro DDM of non-squeezed, grazed-fistula and clipped-fistula samples from tall fescue pastures during the experimental period.

forage samples was on July 1, while Wang (1968) observed that the peaks were on June 30 and July 28 for grazed and clipped samples, respectively.

Selected forages (grazed-fistula samples) were from 2.5 to 5.6 percent higher in crude protein than the average of available forage (clipped-fistula samples). The degree of selectivity was greatest at the beginning of the trial, when the crude protein content of the available forage was the lowest.

During the first week of August, one-half of the fescue pastures were fertilized with 75 pounds of nitrogen per acre in the form of ammonium nitrate. The crude protein content of the available forage in these fertilized pastures increased from 13.1 percent to 20.7 percent in the following collection period. Reid et al. (1967) reported that nitrogen fertilizer treatment increased the crude protein content in tall fescue pastures. However, the grazing steers selected forages only 0.9 percent higher in protein during that period. In the last collection period, the protein percentage of the available forage (clipped-fistula samples) decreased to 15.3 percent, and the degree of selectivity for higher protein again increased to 3.5 percent.

Non-squeezed clipped-fistula samples were non-significantly higher in ADF than non-squeezed grazed fistula samples. This was expected since the selected samples (grazed fistula) were significantly ($P < .05$) higher in crude protein content. This is in agreement with the findings of many researchers (Weir and Torell, 1959; Weir et al., 1959; Edlefsen et al., 1960; Bredon et al., 1967). However, the AIL content was slightly higher in grazed-fistula samples, which is probably due to a slight error in chemical analyses. Several workers indicated that grazed

samples contain more ADF and AIL than clipped samples (Hill, 1965; High, 1966; Wang, 1968; Kiesling et al., 1969). However, these apparent increases in both ADF and AIL were not due to selectivity but were due to many effects such as saliva contamination, leaching, partial mastication, regurgitation, sample preparation, and selectivity (Table 4, page 34). It appears therefore, that from fescue pastures, grazing animals select a better quality forage than the average of the available forage, because the selected forages are higher in crude protein and lower in ADF.

In Figure 2b, page 43, it can be seen that the ADF content of the available fescue forage remained relatively constant throughout the trial, except for the August 22 collection period, when it was lower. This can be explained by the fact that N-fertilization of some pastures shortly before caused an increase in crude protein (Figure 2a) which usually results also in lower ADF.

As reported in Table 6, page 41, there was a non-significant decrease of the NFE + EE fraction in the selected fescue forage (grazed-fistula samples, non-squeezed). This result was expected because crude protein increased considerably and ADF decreased to a smaller extent. The resulting decrease in the NFE + EE fraction just brings the total organic matter to 100 percent. In Figure 2c, page 43, the NFE + EE values of available and selected forages by periods are graphically presented. It appears that the values themselves and the degree of selectivity (difference between grazed and clipped-fistula samples) are quite variable. This fact, however, should not be emphasized since these results are less valid than previous ones because they were obtained

not from chemical analyses but from calculation by difference and include all the errors of all other chemical determinations.

The grazed-fistula samples were slightly higher in in vitro dry matter digestibility than the clipped-fistula samples. However, the differences were not statistically significant. This result also might be expected since the grazed-fistula samples were higher in crude protein and lower in ADF than the clipped-fistula samples. Hardison et al. (1954) and Lofgreen and Meyer (1956) also reported that selected forages were more digestible than available forages.

Orchardgrass Pastures

The species composition of the orchardgrass pastures are shown in Table 1, page 27, while the chemical composition and in vitro dry matter digestibility of the forage samples obtained from these pastures are presented by period in Table 3, page 30, and Appendix, Table 8, contains the individual observations.

As pointed out previously, the data from the non-squeezed samples were considered to be more meaningful. Therefore, data from the squeezed samples will not be included in the following discussion. The ash content of clipped-fistula and grazed-fistula samples was not significantly different (Table 6, page 41). Therefore, as with fescue pastures, animals do not select for ash content when grazing orchardgrass pastures.

As shown in Table 6, the steers selected forages containing more crude protein than that in clipped-fistula samples. The steers grazing on orchardgrass pastures selected a diet containing more crude protein than steers grazing on fescue pastures (20.5 vs. 17.6 percent). This

may be because the available orchardgrass contained more crude protein than fescue samples (16.8 vs. 13.1 percent). The degrees of selectivity for crude protein from fescue and orchardgrass pastures were 3.6 and 2.2 percent, respectively (Table 6, page 41). There was a lower crude protein selectivity in orchardgrass than in fescue in the third period (Figure 3a) because drought conditions probably affected the orchardgrass pastures more severely and also because the pastures were very short.

As shown in Table 6, the grazed-fistula samples were non-significantly higher in ADF content than clipped-fistula samples. The reason for the higher percentage of ADF in grazed samples is not known. The ADF was higher in both grazed-fistula and clipped-fistula samples in period 1, because the new orchardgrass was very short and the samples obtained actually represented the previous season's growth; also, there were more weeds during that period. This may explain the low content of crude protein (Figure 3a) and high content of ADF (Figure 3b). The selected diet was very slightly higher in AIL content than were clipped-fistula samples (Table 6). This result was expected since the grazed-fistula samples contained more ADF than the clipped-fistula samples. Figure 3b shows that the greatest differences in ADF between grazed and clipped-fistula samples occurred on June 27 and August 25 and corresponded with the peaks of crude protein in the same period (Figure 3a).

Differences between grazed-fistula and clipped-fistula samples in NFE + EE content are reported in Table 6. The NFE + EE content in grazed-fistula samples was significantly ($P < .05$) lower than in clipped-fistula samples. As discussed previously, the NFE + EE percentage was

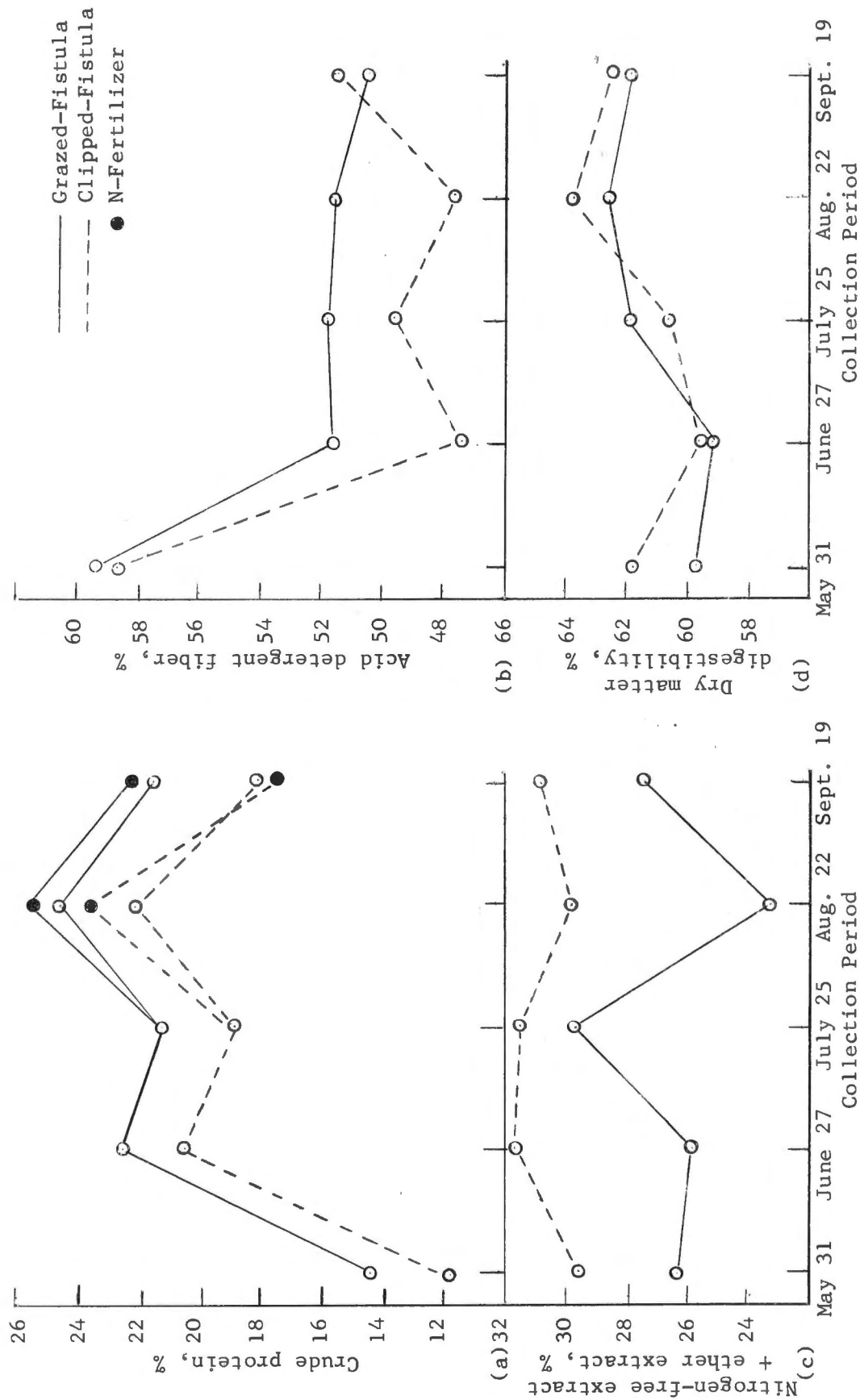


Figure 3. Chemical components (organic-matter basis) and in vitro dry matter digestibility of non-squeezed, grazed-fistula, and clipped-fistula samples from orchardgrass pasture during the experimental period.

calculated by subtracting the percentage of crude protein and ADF from 100. This result was expected since the percentage of both crude protein and ADF were higher in the grazed-fistula samples than in the clipped-fistula samples. Figure 3c indicates that the smallest difference between selected and clipped-fistula samples was on July 25 because the peak of ADF was also in this period.

The percentage of in vitro dry matter digestibility (DDM) of the non-squeezed grazed samples was slightly lower than that of the non-squeezed clipped-fistula samples (Table 6, page 41). This result was expected since the steers selected a diet containing more ADF than the average of the available forages in the pastures. Results in Figure 3d indicate that there was no consistent effect by periods in selectivity for higher or lower digestibility.

CHAPTER V

SUMMARY

During the summer of 1969 (May 30 to September 19) five grazing trials were conducted at 4-weekly intervals, to study the effect of selective grazing on the chemical composition and in vitro dry matter digestibility of forage samples. In addition, the effects of saliva contamination, partial mastication, and sample preparation of fistula samples (squeezed and non-squeezed) also were investigated at 4-weekly intervals by means of pen-feeding studies.

Five esophageal-fistulated Hereford steers and two types of pastures, tall fescue and orchardgrass, were used in the study. To estimate the effect of saliva contamination and partial mastication, hand-clipped forage samples from each pasture plot were each divided into two portions. One portion was fed to an esophageal-fistulated steer and then collected (clipped-fistula sample) through the fistula. The other part (clipped-control sample) was not subjected to further treatment.

The differences between the chemical components and in vitro dry matter digestibility (DDM) of clipped-fistula and clipped-control samples were used to show the effect of the esophageal fistula. The results from both types of pasture showed that clipped-fistula samples contained more ash, crude protein, acid detergent fiber (ADF), acid insoluble lignin (AIL) and less of the nitrogen free extract + ether extract fraction than clipped-control samples. The differences were statistically significant ($P < .05$) except with respect to crude protein. The in vitro

DDM was higher in the clipped-fistula samples than in the clipped-control; however, the difference between the two sample types was statistically significant ($\underline{P} < .05$) only in tall fescue samples, not in orchardgrass samples.

The results of this study indicate that non-squeezed samples represent the true situation of contamination and mastication better than squeezed samples. Therefore, the following results were obtained from the non-squeezed samples only. To estimate the degree of selective grazing, a comparison was made between grazed-fistula samples (selected forages) and clipped-fistula samples (available forages) in chemical components and in vitro DDM. Crude protein was significantly higher ($\underline{P} < .05$) and ADF and NFE + EE were lower in the selected fescue forages. In orchardgrass samples, animals selected forages higher in crude protein and lower in NFE + EE than was available in the pastures.

From this study we assume, therefore, that beef cattle are capable of selecting forages which are higher in crude protein and lower in NFE + EE than the average of the available forages in the pasture. This study shows also that hand-clipping is an inadequate method of measuring the nutritive value of pasture forages.

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APPENDIX

TABLE 7

BOTANICAL COMPOSITION OF PASTURES BY PERIOD^a

Date	Pasture number	Tall fescue pasture				Pasture number	Orchardgrass pasture			
		Fescue	Percent		Weeds		Orchard-grass	Percent		Weeds
			Legume	Other grasses				Legume	Other grasses	
May 31	1	96		2	2	3	75		5	20
	4	98			2	6	70		10	20
	5	96			4	8	75		5	20
	7	95			5					
June 27	1	95	1	2	2	3	75		5	20
	4	94	6			6	75		15	10
	5	92	3		5	8	65	2	25	8
	7	95	2		3					
July 25	1	90	2	6	2	3	65		15	20
	4	92	6		2	6	66	6	20	8
	5	91	5	2	2	8	65	2	28	5
	7	88	3	4	5					
August 22	1	75	3	17	5	3	60	5	15	20
	4	90	2	3	4	6	60	1	30	9
	5	93	5		2	8	70	2	22	6
	7	90	1	6	3					
September 19	1	78	1	16	5	3	55	3	17	25
	4	90	3	4	3	6	55	20	13	12
	5	93		3	4	8	68	1	23	8
	7	90		5	5					

^aBased on visual estimation.

TABLE 8

CHEMICAL COMPOSITION AND IN VITRO DIGESTIBILITY
OF THE FORAGE SAMPLES^a

Date and Item	Tall fescue			Orchardgrass			
	Pasture number			Pasture number			
	1	4	5	7	3	6	8
May 31							
Ash, b %							
Clipped-control	7.7	7.7	7.6	8.1	8.6	7.8	8.1
Clipped-fistula	9.9	8.6	8.8	8.8	8.1	9.2	8.3
Squeezed	11.0	12.1	12.7	11.9	10.6	12.2	12.2
Non-squeezed							
Grazed-fistula	11.9	10.0	10.3	11.1	10.6	10.9	10.5
Squeezed	13.4	11.3	12.8	13.1	13.2	12.8	12.3
Non-squeezed							
Crude protein ^c (N x 6.25), %							
Clipped-control	10.8	9.0	9.4	10.3	9.3	11.3	12.3
Clipped-fistula	12.1	10.0	9.1	9.3	9.2	10.1	11.7
Squeezed	11.5	11.0	10.4	10.7	9.1	11.0	15.2
Non-squeezed							
Grazed-fistula	15.8	14.1	14.7	16.6	14.1	14.7	14.1
Squeezed	17.7	15.5	15.5	17.3	14.1	15.3	14.0
Non-squeezed							
Acid detergent fiber, ^c %							
Clipped-control	42.8	45.1	44.7	44.9	43.0	45.5	45.8
Clipped-fistula	53.6	54.1	55.4	54.8	61.1	56.5	58.1
Squeezed	51.6	54.6	58.1	57.1	61.1	57.4	57.6
Non-squeezed							

TABLE 8 (continued)

Date and Item	Tall fescue				Orchardgrass		
	Pasture number				Pasture number		
	1	4	5	7	3	6	8
Grazed-fistula							
Squeezed	53.7	54.6	52.7	52.0	56.7	56.9	57.6
Non-squeezed	53.0	53.2	53.8	51.6	60.1	59.0	56.5
Acid insoluble lignin, ^c %							
Clipped-control	5.7	5.0	5.6	5.7	8.9	6.9	6.3
Clipped-fistula							
Squeezed	8.3	8.0	8.4	10.7	11.2	11.0	10.4
Non-Squeezed	7.6	9.0	9.0	9.4	12.0	9.8	10.3
Nitrogen-free extract and ether extract, %							
Clipped-control	46.4	45.9	45.9	44.8	47.7	43.2	41.9
Clipped-fistula							
Squeezed	34.3	35.9	35.5	35.9	29.7	33.4	30.2
Non-squeezed	36.9	34.4	31.5	32.2	29.8	31.6	27.2
Grazed-fistula							
Squeezed	30.5	31.3	32.6	31.4	25.8	28.4	28.3
Non-squeezed	29.3	31.3	30.7	31.1	23.6	25.7	29.5
In vitro dry matter digestibility, %							
Clipped-control	60.1	58.1	56.7	57.3	55.1	56.9	55.7
Clipped-fistula							
Squeezed	61.7	61.9	64.3	64.9	57.7	59.7	58.6
Non-squeezed	63.0	65.8	64.2	65.9	59.2	63.6	62.7
Grazed-fistula							
Squeezed	64.9	63.8	63.3	64.4	55.5	59.5	61.3
Non-squeezed	64.7	64.9	65.4	65.2	57.1	60.3	61.6

TABLE 8 (continued)

Date and Item	Tall fescue			Orchardgrass		
	Pasture number			Pasture number		
	1	4	5	7	3	6
June 27						
Ash, b %						
Clipped-control	7.6	7.1	7.3	6.7	8.1	8.4
Clipped-fistula						
Squeezed	8.9	8.2	9.0	8.2	10.6	10.7
Non-squeezed	11.4	9.6	10.9	10.8	11.8	11.1
Grazed-fistula						
Squeezed	11.9	11.5	12.0	11.3	11.2	11.6
Non-squeezed	12.2	11.7	12.7	13.1	14.0	13.3
Crude protein ^c (N x 6.25), %						
Clipped-control	11.4	12.1	13.6	12.1	20.9	19.3
Clipped-fistula						
Squeezed	12.1	10.9	13.2	11.5	22.1	19.0
Non-squeezed	13.0	11.2	13.8	12.8	23.1	19.8
Grazed-fistula						
Squeezed	15.6	15.7	16.1	13.4	23.1	20.0
Non-squeezed	16.5	17.2	17.1	13.8	24.7	21.1
Acid detergent fiber, ^c %						
Clipped-control	45.7	42.8	44.3	43.8	41.5	41.5
Clipped-fistula						
Squeezed	52.2	51.9	51.3	53.8	48.5	48.7
Non-squeezed	53.5	51.7	53.4	53.2	46.8	47.7
Grazed-fistula						
Squeezed	50.2	52.6	53.8	53.8	53.5	51.3
Non-squeezed	49.2	52.3	53.8	54.5	51.5	51.9

TABLE 8 (continued)

Date and Item	Tall fescue			Orchardgrass			
	1	4	5	7	3	6	8
Acid insoluble lignin, ^c %							
Clipped-control	5.4	6.2	6.2	6.9	6.7	6.8	7.6
Clipped-fistula							
Squeezed	7.4	8.3	7.6	8.0	9.3	9.4	11.5
Non-squeezed	7.3	7.7	8.5	8.9	10.9	10.2	11.8
Grazed-fistula							
Squeezed	8.3	8.1	9.8	9.5	10.7	9.6	11.5
Non-squeezed	8.9	8.3	10.0	8.7	11.1	10.3	11.7
Nitrogen-free extract and ether extract, %							
Clipped-control	42.9	45.1	42.1	44.1	37.6	39.2	38.8
Clipped-fistula							
Squeezed	35.7	37.2	35.5	34.7	29.4	32.3	34.8
Non-squeezed	33.5	37.1	32.8	34.0	30.1	32.5	32.3
Grazed-fistula							
Squeezed	34.2	31.7	30.1	32.8	23.4	28.7	25.3
Non-squeezed	34.3	30.5	29.1	31.7	23.8	27.0	26.8
In vitro dry matter digestibility, %							
Clipped-control	53.7	53.4	54.3	53.7	60.2	58.7	57.3
Clipped-fistula							
Squeezed	54.6	55.4	56.0	56.2	59.3	58.3	56.8
Non-squeezed	56.8	56.4	55.6	58.0	59.3	59.7	59.0
Grazed-fistula							
Squeezed	57.0	58.1	53.3	57.3	59.5	57.3	60.9
Non-squeezed	57.2	57.9	54.4	57.3	60.4	57.2	59.5

TABLE 8 (continued)

Date and Item	Tall fescue			Orchardgrass		
	1	4	5	7	3	6
July 25						
Ash, ^b %						
Clipped-control	7.7	7.2	7.3	7.3	8.3	8.2
Clipped-fistula						
Squeezed	9.6	9.0	9.6	8.7	9.9	10.0
Non-squeezed	11.5	10.9	12.2	11.2	11.4	11.4
Grazed-fistula						
Squeezed	11.4	11.7	14.4	14.0	11.2	13.0
Non-squeezed	13.1	12.8	14.4	11.3	13.8	11.9
Crude protein ^c (N x 6.25), %						
Clipped-control	13.2	14.0	14.5	12.5	18.0	17.0
Clipped-fistula						
Squeezed	11.6	13.8	13.9	12.8	19.0	17.6
Non-squeezed	13.9	13.1	15.4	13.2	20.0	17.2
Grazed-fistula						
Squeezed	15.2	16.5	18.8	16.1	16.2	18.0
Non-squeezed	15.7	16.9	18.7	15.8	17.9	18.6
Acid detergent fiber, ^c %						
Clipped-control	45.6	43.6	43.4	43.7	41.9	41.6
Clipped-fistula						
Squeezed	54.2	53.2	55.6	49.5	48.6	48.1
Non-squeezed	55.6	54.3	55.1	54.8	49.4	49.6
Grazed-fistula						
Squeezed	50.5	52.6	56.0	56.0	47.7	52.5
Non-squeezed	49.7	53.3	53.8	53.7	50.4	52.0

TABLE 8 (continued)

Date and Item	Tall fescue			Orchardgrass		
	1	4	5	7	3	6
					8	
Acid insoluble lignin, ^c %						
Clipped-control	5.8	6.2	6.2	6.1	5.8	6.8
Clipped-fistula						5.9
Squeezed	8.6	9.0	8.9	9.0	10.4	9.7
Non-squeezed	9.1	9.4	8.8	9.3	10.8	10.5
Grazed-fistula						10.7
Squeezed	8.5	9.3	9.8	9.6	10.2	10.4
Non-squeezed	8.9	9.5	9.4	9.4	10.8	10.4
						11.5
Nitrogen-free extract and ether extract, ^c %						
Clipped-control	41.2	42.2	42.1	43.8	40.1	41.4
Clipped-fistula						41.5
Squeezed	34.2	33.0	30.5	37.7	32.4	34.3
Non-squeezed	30.5	32.6	29.5	32.0	30.6	33.2
Grazed-fistula						30.8
Squeezed	34.3	30.9	25.2	27.9	36.1	29.5
Non-squeezed	34.6	29.8	27.5	30.5	31.7	29.4
						29.1
						27.6
In vitro dry matter digestibility, %						
Clipped control	56.6	55.7	56.0	53.7	59.3	62.2
Clipped-fistula						60.1
Squeezed	57.0	56.9	57.6	58.9	60.1	60.2
Non-squeezed	57.9	57.7	58.7	58.9	60.2	61.7
Grazed-fistula						60.1
Squeezed	61.6	58.9	60.2	58.7	59.9	61.3
Non-squeezed	61.4	60.7	59.5	60.9	62.9	61.3
						62.4
						61.3

TABLE 8 (continued)

Date and Item	Tall fescue			Orchardgrass		
	1	4	5	7	3	6
August 22						
Ash, b %						
Clipped-control	7.7	7.5	7.3	7.8	8.3	8.3
Clipped-fistula						
Squeezed	10.5	12.6	14.0	14.0	13.2	11.0
Non-squeezed	12.4	13.9	13.8	13.7	14.3	11.2
Crude protein ^c (N x 6.25), %						
Clipped-control	13.4	16.4	16.4	18.8	23.0	21.5
Clipped-fistula						
Squeezed	12.7	17.3	16.2	21.9	24.9	21.3
Non-squeezed	13.5	19.4	16.1	22.0	24.7	23.5
Grazed-fistula						
Squeezed	16.1	20.5	17.9	21.6	24.0	24.5
Non-squeezed	18.3	21.3	18.5	21.8	25.2	24.7
Acid detergent fiber, ^c %						
Clipped-control	45.2	41.4	41.3	41.8	38.7	38.7
Clipped-fistula						
Squeezed	52.0	51.4	51.6	53.4	48.4	46.9
Non-squeezed	53.9	52.8	51.9	53.1	48.7	47.1
Grazed-fistula						
Squeezed	49.2	51.2	54.6	54.4	48.7	51.5
Non-squeezed	48.8	48.7	55.2	52.6	51.2	51.6
Acid insoluble lignin, ^c %						
Clipped-control	5.9	6.0	6.2	6.3	5.9	6.6
Clipped-fistula						
Squeezed	7.6	9.1	8.7	10.2	9.3	9.7
Non-squeezed	8.9	9.9	8.9	10.2	9.3	10.1

TABLE 8 (continued)

Date and Item	Tall fescue				Orchardgrass		
	1	4	5	7	3	6	8
Grazed-fistula							
Squeezed	8.6	9.4	9.2	9.6	10.4	9.7	8.8
Non-squeezed	8.7	9.5	9.7	9.7	10.5	9.9	9.8
Nitrogen-free extract and ether extract, C %							
Clipped-control	41.4	42.2	42.3	39.4	38.3	39.8	40.6
Clipped-fistula							
Squeezed	35.3	31.3	32.2	24.7	26.8	31.8	34.0
Non-squeezed	32.6	27.8	32.0	24.9	26.6	29.4	33.5
Grazed-fistula							
Squeezed	34.7	28.3	27.5	24.0	27.3	24.0	25.5
Non-squeezed	34.9	30.0	26.3	25.6	23.6	23.7	22.9
In vitro dry matter digestibility, %							
Clipped-control	57.7	61.1	60.2	58.7	64.6	60.1	60.7
Clipped-fistula							
Squeezed	60.0	60.4	61.8	60.5	65.0	61.3	61.3
Non-squeezed	59.9	59.7	62.0	62.3	65.7	61.9	63.1
Grazed-fistula							
Squeezed	62.5	63.3	60.7	60.8	64.0	61.8	63.8
Non-squeezed	63.0	63.2	60.6	61.3	62.6	62.6	63.0
September 19							
Ash, b %							
Clipped-control	7.5	7.6	7.4	7.8	8.6	8.3	7.9
Clipped-fistula							
Squeezed	11.1	12.4	12.9	12.3	12.3	10.5	11.1
Non-squeezed	11.8	12.9	13.5	13.2	13.6	11.3	11.3

TABLE 8 (continued)

Date and Item	Tall fescue			Orchardgrass			
	1	4	5	7	3	6	8
Grazed-fistula							
Squeezed	11.6	13.9	14.4	14.2	12.3	13.1	11.9
Non-squeezed	12.8	13.2	14.8	12.1	12.6	12.2	12.1
Crude protein ^c (N x 6.25), %							
Clipped-control	12.0	14.1	15.0	13.4	16.4	13.7	15.0
Clipped-fistula							
Squeezed	12.8	15.5	15.5	14.8	17.6	17.2	18.0
Non-squeezed	12.4	15.3	16.1	15.2	17.8	17.6	18.2
Grazed-fistula							
Squeezed	15.5	18.4	18.8	19.6	20.6	21.5	21.6
Non-squeezed	17.3	18.7	19.4	18.9	21.4	21.4	23.0
Acid detergent fiber, ^c %							
Clipped-control	46.5	46.2	45.7	44.8	42.1	40.7	41.8
Clipped-fistula							
Squeezed	51.4	54.1	54.4	54.4	51.2	49.6	50.5
Non-squeezed	53.5	55.1	55.3	54.3	51.2	50.8	51.1
Grazed-fistula							
Squeezed	50.9	53.0	54.2	54.3	50.6	50.5	51.3
Non-squeezed	50.8	52.4	53.9	53.2	50.8	49.3	51.8
Acid insoluble lignin, ^c %							
Clipped-control	6.6	6.7	6.7	6.6	6.0	6.0	6.0
Clipped-fistula							
Squeezed	8.8	9.9	10.0	10.1	8.8	9.4	9.6
Non-squeezed	8.9	10.1	10.4	10.4	9.1	9.8	9.5
Grazed-fistula							
Squeezed	8.6	9.9	10.3	10.3	10.0	9.4	9.3
Non-squeezed	8.6	10.0	10.4	10.1	9.9	9.1	9.6

TABLE 8 (continued)

Date and Item	Tall fescue			Orchardgrass		
	1	4	5	7	3	6
Nitrogen-free extract and ether extract, ^c %						
Clipped-control	41.5	39.7	39.3	41.8	41.5	45.6
Clipped-fistula						
Squeezed	35.8	30.4	30.1	30.8	31.2	33.2
Non-squeezed	34.1	29.6	28.6	30.5	30.2	31.6
Grazed-fistula						
Squeezed	33.6	28.6	27.0	26.1	28.8	28.0
Non-squeezed	31.9	28.9	26.7	27.9	27.8	29.3
In vitro dry matter digestibility, %						
Clipped-control	59.1	60.9	60.5	60.2	63.9	63.1
Clipped-fistula						
Squeezed	60.2	61.1	60.5	60.1	62.8	62.1
Non-squeezed	59.7	59.6	60.3	60.6	63.6	61.6
Grazed-fistula						
Squeezed	60.8	60.2	60.3	60.5	62.6	61.8
Non-squeezed	60.9	60.0	59.8	59.9	61.6	62.0

^a Means of duplicate samples.^b Dry-matter basis.^c Organic-matter basis.

VITA

Najeeb Tawfik Kazzal was born in Mosul, Iraq, on September 5, 1940. He attended the elementary and secondary schools in Mosul, and was graduated from Al-adadia Al-Markazia High School in June 1961. In June 1965, he received a Bachelor degree in Agriculture with a major in Animal Production from the University of Baghdad, College of Agriculture. He was the second in his major area and the third among 85 students, with a very good average. In September 1965, he joined the University of Mosul as a staff member in both teaching and research. In April 1968, he was awarded one of the University of Mosul - Gulbenkian Foundation Scholarships to study towards a Master degree in the United States. In September 1968, he entered the Graduate School at The University of Tennessee and in December 1969, he received a Master of Science degree with a major in Animal Husbandry.