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Volatile fatty acid production and its relationship with average daily gains of steers grazing two types of pasture

Huei Chyuan Wang

To the Graduate Council:

I am submitting herewith a dissertation written by Huei Chyuan Wang entitled "Volatile fatty acid production and its relationship with average daily gains of steers grazing two types of pasture." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

Charles S. Hobbs, Major Professor

We have read this dissertation and recommend its acceptance:

K. M. Barth, R. R. Shrode, J. K. Bletner, R. H. Feinberg

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

May 20, 1968

To the Graduate Council:

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Karl M. Barth

Robert H. Feinberg

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Graduate Studies and Research

VOLATILE FATTY ACID PRODUCTION AND ITS RELATIONSHIP WITH AVERAGE DAILY GAINS OF STEERS GRAZING TWO TYPES OF PASTURE

A Dissertation

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

Huei Chyuan Wang

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ABSTRACT

The objectives of this study were: (a) to evaluate and compare several methods of estimating average daily gain (ADG) of steers grazing on two types of pasture, (b) to investigate factors that affect ADG of these steers during the spring-summer grazing season, (c) to study the changes of volatile fatty acid (VFA) concentration in the rumen of these steers and their relation to animal performance and (d) to study selective grazing and its relation to ADG of steers.

Two types of pasture, fescue-lespedeza (F-L) and orchardgrass-ladino clover (O-C) were used in this study. A grazing trial with steers was conducted to determine the body weight changes on these two types of pasture during various periods of the grazing season. Esophageal-fistulated steers were used to sample the diet of grazing animals (grazed sample) while hand-clipped samples were used to represent the forage available to the animals. Rumen-fistulated steers were used for *in vivo* VFA production studies. Chemical composition of grazed and clipped forage samples and *in vivo* and *in vitro* VFA production were determined at 28-day intervals during the spring-summer grazing season.

These measures which affect quality of pastures were correlated with average daily gain of steers grazing the two types of pasture. Measures which were highly correlated with ADG were then used to develop equations for predicting ADG by multiple regression analysis.

The results of this study were as follows:

1. ADG of steers grazing O-C pastures was higher than that of

steers grazing F-L pastures. This was especially pronounced in the early part of the grazing season.

2. Grazed samples were significantly higher ($P<.05$) with respect to crude protein content in both types of pasture.

3. A consistently lower protein content, higher acid detergent fiber (ADF) content and acid insoluble lignin (AIL) content in the diet of the steers grazing F-L pastures may have accounted for the lower ADG of these steers.

4. There was no significant correlation between ADG and percent of protein in the grazed or the clipped samples from either type of pasture. The percent of AIL in the clipped samples was negatively correlated with ADG.

5. Total VFA production reached a peak about one hour after the morning grazing and tended to decline thereafter. However, the molar percent of individual VFA in rumen liquor varied little in both types of pasture during the 4 hours after the morning grazing. The pH values and total VFA concentration were negatively correlated. Total VFA concentration was higher in the summer than in the fall.

6. Total and individual VFA concentration in the dorsal area of the rumen was significantly higher than in the ventral area. However, there were no significant differences in VFA ratio between these two locations. In both types of pasture, ADG was more highly correlated with total VFA concentration in samples from the dorsal area than with the same variable in samples from the ventral area of the rumen.

7. For the prediction of ADG of steers grazing F-L pastures, the

equation including the variables _in vivo_ total VFA concentration, AIL and crude protein percentage was the most useful of several similar equations. This multiple regression equation explained 98 percent of the variability in ADG of steers.

8. In O-C pastures, the equation containing the variables _in vivo_ total VFA concentration, percent of AIL and _in vitro_ DDM was most valuable in predicting ADG of steers. This equation accounted for 99 percent of the variation in ADG of steers.

9. Results of this investigation indicate that total or individual VFA production may be an important factor in the prediction of ADG of steers grazing F-L or O-C pastures. Together with other variables considered in this study, VFA concentration accounted for most of the variation in ADG of the steers.

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CHAPTER I

INTRODUCTION

In Southeastern United States the production of beef cattle is based primarily on forage feeding systems, and a major part of this forage is provided by permanent pastures. In Tennessee, Kentucky-31 tall fescue and native orchardgrass with or without legumes are the most common grass species in permanent pastures. Differences in animal response between the two types of pasture and among different seasons within the same type of pasture have been determined. These differences were determined primarily by grazing trials which are the most accurate means of measuring the nutritive value of a pasture for the grazing animal.

However, since grazing trials are very expensive and time consuming, various other measurements of pasture quality have been employed to predict results that would be obtained from grazing trials.

Several of these measurements of pasture quality have been used also to determine the reasons for the observed differences in average daily gains of beef cattle between pasture types, between different stages of plant maturity and between different management systems within the same pasture type. If suitable measures of pasture quality are found that are closely related to the productive capacity of pastures in terms of body weight gains and other economically important criteria of grazing animals, then, hopefully, these suitable measures of pasture quality could be used to develop improved pasture species, improved pasture mixtures or improved pasture management practices.

The objective of the studies discussed herein was to determine how well various measures of pasture quality, singly or in combination, predict the average daily gains of steers grazing on fescue-lespedeza or orchardgrass-clover pastures.

CHAPTER II

REVIEW OF LITERATURE

I. ANIMAL PERFORMANCE ON TWO TYPES OF PASTURE

A series of pasture experiments conducted by the Tennessee Agricultural Experiment Station (Duncan, 1958; Duncan and Felts, 1961; High *et al*., 1965a, High *et al*., 1965b; High *et al*., 1965c; Hobbs *et al*., 1965) has indicated that there are differences in the average daily gains of steers grazing different types of pasture.

This series of experiments has resulted in a recommended program for maximum utilization of perennial pastures in producing slaughter cattle. This program, beginning in the fall with about 500-pound weaned steer calves, involves an economical wintering ration of pasture and/or roughage and grazing these animals on grass-legume pasture without supplemental feed during the spring-summer season. The grazing phase is followed by a 60- to 80-day full-feed of concentrates. This program has resulted in the following average production for the various experiments conducted from 1949 to 1962, inclusive: initial weight, 506 lb.; average daily gain (ADG) during the winter (November through March), 0.80 lb.; daily gain on pasture (April to about mid-August), 1.25 lb.; daily gain on full feed, 2.37 lb.; final weight (November), 1016 lb.; final slaughter grade, High Good to Low Choice; and net return per head above feed and pasture cost, $40.00.

Orchardgrass-legume pastures produced higher daily gains and higher grading cattle during the spring-summer grazing season than fescue,

fescue-legume or orchardgrass pastures. During the fall and winter, fescue pastures produced significantly higher daily gains than orchardgrass pastures, regardless of legume content (High and Hobbs, 1964; Hobbs et al., 1965). Gallagher et al. (1966) and Grimes et al. (1967) found that sheep on grass-clover pastures had significantly higher ADG and higher wool production than sheep on grass pastures. Data reported by High et al. (1965c) and Hobbs et al. (1965) indicated that as clover content decreased, average daily gain decreased. However, the relationship of all factors associated with ADG are not clearly defined. Grimes et al. (1967) indicated that differences in crude protein content of pasture forage had little influence on ADG. This was especially true when the pasture forages were all relatively high in protein content. Clover leaves have two or three times more starch than grass, and Bailey (1964) suggested that this difference in carbohydrate content between grass and clover could explain part of the differences in ADG of animals grazing pastures of varying legume content.

II. DIETARY SELECTIVITY AND ITS RELATION TO ANIMAL PERFORMANCE

Methods Used in Collection of Grazed Forage Samples

In studying ADG obtained from different pastures, it is important to determine the actual diet selected by the grazing animal. Several methods have been used to obtain forage samples ingested by grazing animals. The hand plucking method discussed by Cook (1964) is subject to error. This method depends very much on the judgement of the collector as to what portion of the samples should be collected. The harvesting-before-and-after method (cage method) developed by Cook et al. (1958) had the disadvantage of the assumption that little or no growth of plants occurred during certain grazing periods. Torell (1954) established esophageal fistulas in experimental animals to facilitate the collection of grazed samples. Later Lesperance et al. (1960a) attempted to use rumen-fistulated animals for this purpose. Cook (1964) and High (1966) indicated that this method is laborious and may cause enough stress on animals to cause death.

At the present time, it seems that the esophageal-fistulated animals are widely used by many investigators in studying selectivity of grazing animals (Hardison et al., 1954; Heady and Torell, 1959; Weir and Torell, 1959; Van Dyne and Torell, 1964; High, 1966; Campbell et al., 1968).

Effects of Saliva and Mastication on the Chemical Determination of Forage Components

Effects of saliva and mastication on grazed samples and preparation of samples after collection has complicated the problem of using this method in collecting grazed samples. The studies reported by Bath et al. (1956), Lesperance et al. (1960b) and Blackstone et al. (1965) indicated that saliva contamination significantly modified the composition of fistula samples, especially the ash content. However, the increased ash content in the grazed samples could be adjusted by expressing the percentage of the other chemical constituents on an organic-matter basis. An abnormal increase of acid detergent fiber (ADF) and acid insoluble lignin (AIL) in fistula samples was found also by many investigators (Lesperance <u>et al</u>., 1960b; Connor <u>et al</u>. 1963; Lesperance and Bohman, 1964; High 1966). Van Soest (1963) indicated that the changes in composition of the carbohydrate fraction caused by esophageal-fistula sampling or sample preparation after collection may be due to enzymatic or non-enzymatic browning. Barth <u>et al</u>. (1968a) fed nine species of fresh forage composed of both legumes and grasses to esophageal-fistulated steers without allowing selectivity. They found that there were significant differences in ash, AIL and ADF between fistula and control samples but not in protein. Their data suggested that a proper adjustment for ash, ADF and AIL would be helpful to correct for the increased values of ash, ADF and AIL in samples subjected to saliva and mastication.

<u>Effect of Selectivity</u>

Many investigators indicated that there are some differences in the composition between the forage ingested by grazing animals and the forage available in the pastures (Hardison <u>et al</u>., 1954; Bath <u>et al</u>., 1956; Heady and Torell, 1959; Weir and Torell, 1959; Ridley <u>et al</u>., 1963; High, 1966). These differences indicate that grazing animals have a preference for certain species of plants or even certain parts of the same plant (Bohman and Lesperance, 1967; Cook, 1964). In pastures and ranges where many different species of forage are available for grazing animals, the degree of selectivity is a more important factor in animal performance than in pastures containing only one or two plant species (Bohman and Lesperance, 1967).

Using esophageal-fistulated steers, Lesperance et al. (1960b), High (1966) and the data of Barth et al. (1968b) showed that the crude protein content of grazed samples was higher than that of clipped samples, which indicates that the animals selected a diet higher in protein than the average forage in the pasture. However, the differences in protein content between the grazed and clipped samples became less during the latter part of the growing season. These workers concluded that selectivity was greater during the early part of the grazing season when more forage was available. Hardison et al. (1954) and Weir et al. (1959), in studies of selective grazing on range and pasture plots, found that steers consistently selected forage higher in crude protein and lower in crude fiber than that obtained by hand clipping. Similar results were reported by Bath et al. (1956) and Weir and Torell (1959) in studies using sheep.

III. VOLATILE FATTY ACID PRODUCTION IN THE RUMEN AND ITS RELATION TO ANIMAL PERFORMANCE

Volatile fatty acids (VFA) are the main rumen fermentation end-products of carbohydrates, and it has been recognized that they are an important energy source for ruminant animals. The amount of VFA produced and the ratio of individual VFA in the rumen may have a profound influence on the performance of ruminant animals (Barnett and Reid, 1961; Hungate, 1966).

Importance of VFA to the Ruminant

It is well understood that exogenous glucose does not appear to be an important energy source in ruminants (Hungate, 1966). Its place is taken by the VFA produced in the rumen. The VFA content in the blood of ruminants was higher than in that of nonruminants and remained so even after an extended starvation (Annison, 1960). In cattle it has been shown that 6,000 to 12,000 kilo-calories per day became available from the VFA produced by fermentation in the rumen (Carrol and Hungate, 1954). The total energy turnover of fasting cattle of about 6,500 kilo-calories indicated that VFA provided a major energy source for ruminants (Dougherty _et al_., 1965). They estimated also that VFA accounted for 70 to 80 percent of the total energy intake.

Efficiency of VFA Energy Utilization

The efficiency of sheep utilizing VFA as an energy source for maintenance and lipogenesis was investigated by Armstrong and Blaxter (1957) and Armstrong _et al_. (1958). They found that mixtures containing various proportions of individual VFA were utilized with equal efficiency. But when they were fed above maintenance, acetic acid was utilized less efficiently than either propionic or butyric acids. However, recent studies by Rook _et al_. (1963) and Orskov and Allen (1966) showed that there were no differences in the efficiency of acetate, propionate and butyrate in promoting gains in body tissues of growing lambs. Orskov and Allen (1966) indicated that these differences in results may be due to differences in animals and in techniques used.

Effect of pH on Absorption

The pH value of ruminal fluid varied inversely with concentration of VFA (Balch and Rowland, 1957; Raun et al., 1962; Luther and Trenkel, 1963; Morris et al., 1965). The pH of the rumen liquor is the most important single factor determining VFA absorption from the rumen. Absorption is much greater from an acid solution than from a neutral solution (Lewis, 1961). The fact that the un-ionized volatile fatty acids are absorbed more rapidly than the ionized ones makes the absorption rate higher when the rate of acid production increases. In a normal pH range, the lower the pH value, the more rapidly are the VFA absorbed (Hungate, 1966; Barnett and Reid, 1961). Pfander and Philipson (1953) showed that on a molar basis the order of absorption rate is butyric acid, propionic acid and acetic acid. Shaw (1958), Stewart et al. (1958) and Morris et al. (1965) reported that there is considerable evidence that at slightly acid conditions in the rumen, butyric acid and propionic acid may be absorbed at a relatively more rapid rate than acetic acid.

All the available evidence indicated that VFA absorption from the rumen occurs as a passive process (Dougherty et al., 1965; Hungate, 1966). Simple diffusion of un-ionized VFA through the rumen wall accounted for their movement into blood (Hungate, 1966). The partial blood circulation was positively correlated with the level of VFA concentration in the rumen up to 10 hours after feeding (Bansadoun et al., 1962).

VFA Concentration and Animal Performance

Studies of Shaw et al. (1960) and Balch (1960) showed that there is a relation between the concentration of rumen VFA and animal performance. In a recent study of lambs grazing on fescue and cocksfoot (Orchardgrass) pasture, Grimes et al. (1967) found that variation in molar percent of acetic and propionic acid in the rumen accounted for 48 percent of the variation in live weight gain of animals. The single factor most closely correlated positively with live weight gain was propionic acid. This factor was also closely correlated with amount of soluble carbohydrate in the pasture forage. However, a study of bulls fed corn cobs, orchard-grass and alfalfa hay (Putnam et al., 1965) indicated that only 11 to 14 percent of the total variation in average daily gain was due to variation in rumen VFA concentration. No significant relation existed between ADG and VFA expressed in molar percent.

IV. EFFECT OF SAMPLING LOCATION AND TIME ON VFA CONCENTRATION

The problem of obtaining a representative sample of ruminal contents by the use of a rumen fistula or stomach tube is complicated by the fact that unequal, layer distribution of ruminal contents exists (Lane et al., 1968; Canaway et al., 1965).

Effect of Location of Sampling on VFA Production

In general, the material was drier near the esophageal end than at the omasal end. Balch (1950) indicated that the contents of the ventral sac were always more moist than those of the dorsal sac. Lane et al. (1968) indicated that a statistically significant difference in VFA concentration existed among samples from six different locations. Similar results were obtained by Canaway et al. (1965). They concluded that ruminal contents were not homogeneous mixtures; therefore, the samples collected from only one location were less valid when pH and VFA concentration were used as important criteria.

Effect of Time of Sampling on VFA Production

Sampling time after feeding had a significant effect upon both the concentration of VFA and the molar proportions of acids in the rumen. Fenner et al. (1967) indicated that there were differences in times after feeding when the peak production of each individual VFA was attained. In a study of sheep grazing on range, Morris et al. (1965) found that the concentration of total VFA increased to a maximum at nine hours after the grazing began, and the molar percent of acetic acid gradually increased during the latter stages of digestion, whereas, propionic acid exhibited a sharp peak three hours after feeding. Similar results were reported by Reid et al. (1957). In contrast, Ghorban et al. (1966) showed that the VFA ratio and the molar percent of VFA were rather constant through time after feeding.

V. EFFECT OF DIET ON VFA PRODUCTION

The level of VFA found in the rumen was related directly to the nature of the food (Armstrong et al., 1957). The diets that provided larger amounts of readily available carbohydrates appeared to result in a smaller acetate to propionate (A/P) ratio in the rumen (Blaxter and Wainman, 1963). The fermentation of soluble carbohydrate caused the decrease in the rumen pH. This inhibited the activity of cellulolytic organisms (Donefer et al., 1963). The pH drop is greater when an animal is fed early grass than when it is fed hay or late grass (Barnett and

Reid, 1961). The output of saliva decreased under high grain feeding, resulting in lower pH. This rumen condition favors the production of propionic acid by the microflora (David *et al*., 1964). Johns (1955) indicated that the proportion of acetic acid rose significantly when sheep were changed from pasture feeding to a hay diet.

Effect of the Quality of Pasture Forage on VFA Production

Little work has been done on possible changes in VFA production associated with change in chemical composition of pasture grass and stage of plant development during the grazing season (Barnett and Reid, 1961). In a study using rumen-fistulated sheep which grazed high quality pasture throughout the year, Johns (1955) found a tendency for the total VFA to be higher in summer pasture than in winter pasture. There was less variation in molar percent of VFA with season and stage of maturity of the herbage.

In an *in vitro* study using forage samples collected from an ungrazed sward at monthly intervals during two grazing seasons, Barnett and Reid (1957) found that VFA formation was highest with grass at the young succulent stage when the soluble carbohydrates content was relatively high. Acid production declined with increasing maturity of the grass.

Decreased digestibility of forage material was usually accompanied by an increase in acetic acid production in the rumen (Armstrong, 1964). Legumes usually contained larger amounts of soluble carbohydrates than did grasses (Bailey, 1958).

Fermentation in the rumen is a continuous and complicated process. Therefore, the extent and nature of acid production depends not only on breakdown of one particular component, but also on a relative amount of all the main chemical fractions of grass (Barnett and Reid, 1961).

CHAPTER III

EXPERIMENTAL PROCEDURE

Two types of pasture, fescue-lespedeza and orchardgrass-ladino clover, were used in this study. A grazing trial with steers was conducted to determine the body weight gains on these two types of pasture during various periods of the grazing season. Chemical composition of both grazed and clipped forage samples, *in vivo* and *in vitro* VFA production and *in vitro* digestibility, were determined at 28-day intervals during the grazing season. Legume percentage, legume index and *in vitro* DDM were from data collected in a companion study (David *et al*., 1968).

Two yearling esophageal-fistulated steers were used to obtain the grazed forage samples representing the diets of the grazing animals, and two yearling rumen-fistulated steers were used for *in vivo* VFA production studies. These measures which estimate the quality of pastures were correlated with average daily gains. Measures which were highly correlated with ADG were then used to formulate prediction equations for ADG.

I. PASTURES

The experimental pastures used in this study were four three-acre plots of fescue-lespedeza (F-L) and four three-acre plots of orchardgrass-ladino clover (O-C). The lespedeza was established in old fescue sod in the spring of 1962, and orchardgrass-clover pastures were reseeded in the fall of 1961.

These pastures have been established for years at The University of Tennessee's Blount Farm. They have been used for steer and heifer grazing studies, and typical differences in animal performance between the two types of pasture have been studied. Based on previous animal performance and subjective pasture scores, these eight pastures were divided into four pasture pairs. Two pasture pairs were then allotted to each type of pasture.

II. EXPERIMENTAL ANIMALS

Performance Steers

Sixteen Hereford steers averaging 243 kg. in body weight were allotted to four uniform groups of four steers each on the basis of weight and grade. All animals were dosed with thiabendazol at the start of the experiment. Each group of steers was then randomly assigned to a pasture pair. The animals were placed on their respective pastures on April 21, 1967, and remained there until the middle of October. The steers were rotated between the two pastures within each pasture pair at one- and two-week intervals. These irregular grazing intervals were selected because they allowed alternate sampling of the two pastures within each pasture pair. No supplemental feed was provided. All animals were weighed at the beginning of the experiment and at 28-day intervals thereafter. ADG of steers for each period during the grazing season was calculated.

Experimental Steers

Two yearling esophageal-fistulated steers were used to estimate the diet of the performance steers. The fistulas were established in early March by the fistulation technique of Van Dyne and Torell (1964). A healing period of approximately two months between operation and first sampling was allowed. Post-operation care for these steers was according to the procedure described by High (1966). Throughout the test period, the esophageal-fistulated steers were kept in a pasture adjacent to the test plots which contained a mixture of the four forage species.

Two yearling rumen-fistulated steers were used for the in vitro digestion and in vivo VFA production studies. Throughout the entire grazing season, one rumen fistulated steer was maintained with the production steers on one of the two replicated pasture pairs of each treatment.

III. COLLECTION OF GRAZED AND CLIPPED SAMPLES

Grazed samples which represent the diet that the grazing animals select were obtained by the use of esophageal-fistulated steers while clipped samples, which indicate the forage available in the pasture, were obtained by hand clipping by the investigator. Forage sample collections were started on May 5, 1967, and continued at four-week intervals throughout the experimental period. The last collection was on September 22, 1967. The collections were made on the median day between two weighing days and from those pastures of each pasture pair in which the production steers were grazing at the time. Two steer pairs consisting of one esophageal-fistulated and one companion steer each were used. At 7 a.m. of each collection day, the esophageal-fistulated steers were made ready for sampling. Then steer pair I was allowed to graze a fescue-lespedeza pasture and steer pair II an orchardgrass-clover pasture. When the forage samples were collected from these pastures, steer pair I grazed the other orchardgrass-clover pasture and steer pair II grazed the other fescue-lespedeza pasture. The grazed and clipped samples were collected according to the method of High (1966).

IV. COLLECTION OF RUMEN LIQUOR SAMPLES AND DETERMINATION OF pH VALUES

Rumen liquor was collected from the two rumen-fistulated steers on the median day between two weighings. On sampling day, these steers were taken out of the pastures around 9 a.m. (approximately 3 hours after the start of the morning grazing) and tied to prevent eating and drinking. Rumen liquor was collected at 1-hour intervals from 9 a.m. to 1 p.m. Three samples from different locations were collected from both the dorsal and ventral areas of the rumen. The three samples within each rumen area were composited, thoroughly mixed, filtered through eight layers of cheese cloth and approximately 100 ml. was collected. Using a 50 ml. syringe, 20 ml. of rumen liquor was placed in a 35-ml. sample bottle which contained 1 ml. of 5% $Hgcl_2$ (Erwin et al. 1961). The reagent $Hgcl_2$ prevented further chemical reactions in the rumen liquor by killing the rumen microorganisms. These samples were taken to the laboratory and stored at -10°C for later VFA determinations. The pH of rumen liquor was determined immediately after the collection by the use of a Sargent Model-S 30007 portable pH meter.

V. CHEMICAL ANALYSES

Determination of the Chemical Components in Grazed and Clipped Pasture Samples

The grazed and clipped forage samples were taken to the laboratory immediately after the collection and dried in a forced-air oven at 50°C for 72 hours. After they were air equilibrated, these samples were ground in a Wiley mill using a 20-mesh screen and were stored in glass sample bottles for subsequent chemical analyses, in vitro digestibility and in vitro VFA production studies.

They were analyzed for nitrogen, ash and moisture by the A. O. A. C. (1965) method and for acid detergent fiber and acid insoluble lignin by the Van Soest (1963) method. Significance of differences in chemical composition between grazed and clipped samples and between the two types of pasture were determined by an analysis of variance.

Determination of In Vitro Dry Matter Digestibility of Grazed and Clipped Pasture Samples and Collection of Supernatant Liquor

In vitro dry matter digestibility of grazed and clipped samples was determined by the Tilly and Terry (1963) method. Innoculum was collected from the two rumen-fistulated steers which were grazing on different types of pasture. These steers were used also in the in vivo volatile fatty acid production studies. Supernatant liquor from the first stage of the Tilly and Terry (1963) method was used to determine in vitro VFA production. These samples were stored at -10°C for later VFA determination.

Determination of Volatile Fatty Acids

VFA was determined in duplicate by the method of Erwin et al. (1961). A model 600-C Aerograph gas chromatograph equipped with a hydrogen flame ionization detector was used in this determination. Hydrogen gas for the detector was supplied by a Model A-650 hydrogen generator, and a commercial source of high-purity nitrogen was used as carrier gas. Operation conditions were as follows: (1) oven temperature 120°C, (2) injector temperature 180°C, (3) carrier gas (nitrogen) flow rate at the detector head 20 ml. per minute, (4) hydrogen flow rate 20 ml. per minute, and (5) 15% Tween 80, 2 1/2% H_3PO_4 on 60/80 acid washed chromosorb W column (Erwin et al., 1961). Peak height was used to calculate VFA concentration (Chalupa, 1966). VFA concentration was expressed as minimoles per liter (mmoles/l.) and molar percentage.

The effects of location and time of sampling on VFA production within pasture types were determined by an analysis of variance. Differences in in vitro VFA production from grazed and clipped samples within pastures and between pastures were also assessed by analysis of variance.

VI. COEFFICIENTS OF CORRELATION

Simple coefficients of correlation among ADG, chemical components, in vitro digestibility, in vitro VFA production, pH values and pasture scores within the two pasture types were calculated, using data from each pasture pair within one sampling period as the individual observation. When in vivo VFA production was included as a variable in calculating simple coefficients of correlation, data for individual pasture pairs were not available and mean data of each pasture type for all the other variables were used.

VII. MULTIPLE REGRESSION EQUATIONS

Multiple regression equations which predict ADG in these two types of pastures were developed from a multiple regression analysis. The general form of the prediction equation is:

$$\hat{Y}_i = a + \sum_j b_j X_j$$

Where:

$i = 1, 2, \ldots\ldots\ldots 6$

$j = 1, 2, 3, 4, \ldots\ldots k$

$a = \overline{Y} + \sum_j b_j \ (0 - \overline{X}_j).$

The b_j's are the coefficients of partial regression of the dependent variable on the independent variables.

The X_j's are the independent variables measuring pasture characteristics determined from grazed and clipped samples, and VFA concentrations and pH in the rumen.

The Y_i is the dependent variable, average daily gain.

The $\hat{Y}_i$'s are the predicted value of average daily gains for specified values of the X_j's.

The $\overline{Y}_i$'s are the means of average daily gains.

The $\overline{X}_j$'s are the means of the k-th independent variable.

The calculations were made within each pasture type.

CHAPTER IV

RESULTS AND DISCUSSION

I. AVERAGE DAILY GAINS OF STEERS GRAZING TWO TYPES OF PASTURE DURING THE GRAZING SEASON

The performance of the steers grazing the two types of pasture during the successive collection periods is shown in Table 1. During the total experimental period from April 21 to October 6, the animals gained 0.62 kg. per head per day on the O-C pastures and 0.51 kg. per head per day on the F-L pastures. These gains were somewhat less than the 0.78 kg. and 0.67 kg. per head per day, respectively, which were found by High and Hobbs (1964), who conducted steer grazing trials on the same pastures in 1963 and 1964. The difference in ADG obtained in the two trials was primarily due to the low gain made by the animals in the last period (September 8-October 6).

During the period from April 21 to September 8, the steers in the present trial grazing O-C pastures gained 0.72 kg. per head per day, which was comparable to results obtained by High and Hobbs (1964). During the same period, the steers grazing F-L pastures gained 0.55 kg., which is less than the ADG obtained by High and Hobbs (1964). The main difference between the results of the two trials is the lower legume content in the F-L pastures in the present trial, which was always below 10% as compared to 40% in the previous experiment and probably accounts for the lower gains.

TABLE 1

AVERAGE DAILY GAIN OF STEERS GRAZING TWO TYPES OF PASTURE DURING GRAZING SEASON[a]

		Pasture type					
		Fescue-lespedeza			Orchardgrass-clover		
Period	Date	Group 1	Group 2	Av.	Group 1	Group 2	Av.
		kg.					
1	April 21-May 19	.89	.99	.94	1.08	1.10	1.09
2	May 19-June 16	.38	.14	.26	.73	.65	.69
3	June 16-July 14	.53	.51	.52	.73	.73	.73
4	July 14-Aug. 11	.28	.43	.36	.49	.38	.44
5	Aug. 11-Sept. 8	.75	.60	.68	.69	.63	.66
6	Sept. 8-Oct. 6	.25	.38	.32	.02	.20	.11
Total experimental period		.51	.51	.51	.62	.62	.62

[a]Each group consisted of four steers.

These data indicate that O-C pastures supported consistently higher ADG than F-L pastures early (April to August) in the grazing season. However, later (August to October) in the grazing season the gains of the steers grazing O-C pastures were lower than the gains of the steers grazing F-L pastures. Similar results were obtained by High et al. (1965c), Hobbs et al. (1965) using steers and Barth et al. (1968a) using heifers. The lower ADG in the second and fourth periods may be due to one or more of the following reasons: (1) the grasses were in an advanced stage of maturity, (2) relatively lower rainfall was observed during these periods, and (3) the pastures were clipped on May 15 and August 12.

II. SELECTIVE GRAZING AND ITS RELATION TO ANIMAL PERFORMANCE

Comparison of Chemical Components in Grazed and Clipped Samples During the Grazing Season

The chemical-composition differences between grazed and clipped forage samples obtained from the same pasture plot were used as a measure of the degree of selective grazing. The mean chemical composition of the grazed and clipped samples on an organic-matter basis is presented in Table 2. Both ADF and AIL in this study were adjusted for the effects of saliva and mastication. This adjustment was based on the results of Barth et al. (1968b). Since there were differences between forage species as to the extent of saliva effects, the adjustments were based on the amount of each forage species available in the pasture.

As shown in Table 2, there were significant differences in crude

TABLE 2

COMPARISON OF CHEMICAL COMPONENTS OF GRAZED AND CLIPPED SAMPLES FROM TWO TYPES OF PASTURE[a,b]

Item	Method of sampling	
	Grazed	Clipped
	%	%
	Fescue-lespedeza	
Crude protein[c]	18.8	14.6
Acid detergent fiber[d]	42.7	39.2
Acid insoluble lignin[c,d]	7.8	4.2
In vitro DDM[c,d]	47.5	60.3
	Orchardgrass-clover	
Crude protein[c]	20.5	16.5
Acid detergent fiber[d]	40.0	37.5
Acid insoluble lignin[d]	6.0	5.3
In vitro DDM[d]	63.2	64.3

[a]Organic-matter basis.

[b]Means of six collection periods. Chemical components for each period are shown in Appendix Table 19.

[c]Means of grazed and clipped samples are significantly different ($P<.05$).

[d]Adjusted for the effects of saliva and mastication (Barth *et al.* (1968b).

protein content between the grazed and clipped samples in both types of pasture during the grazing season. The change in protein content of grazed and clipped samples during the grazing season is shown in Figure 1. The greatest degree of selectivity (difference between clipped and grazed samples) occurred in the middle of the grazing season (June 30), while the least occurred toward the end of the grazing season. Similar results were obtained by High (1966) and Lesperance et al. (1960b). These results indicate that selectivity is greatest when more forage is available and when there is more difference in nutritive value between the available pasture species or between the parts of one species.

The failure of the steers to select forages high in crude protein later in the grazing season may be due to the fact that the plants are in a stage of dormancy and are uniformly low in protein content.

The change in ADF and AIL content of the grazed and clipped samples during the grazing season is shown in Figure 2 and Appendix Table 19, page 75. No significant differences between the ADF content of grazed and clipped samples in both pasture types, or between the AIL content of the grazed and clipped samples in the O-C pastures were observed. However, the AIL content of grazed samples from the F-L pastures was significantly ($P<.05$) higher than that of clipped samples. These results seem less reasonable than those obtained with respect to protein since it does not seem unreasonable that animals would selectively graze forages higher in AIL. However, this abnormally high AIL content of grazed F-L forage may mean that either steers selected higher amounts of lespedeza which is high in AIL content, or it may mean that corrections for saliva and mastication are not yet adequate.

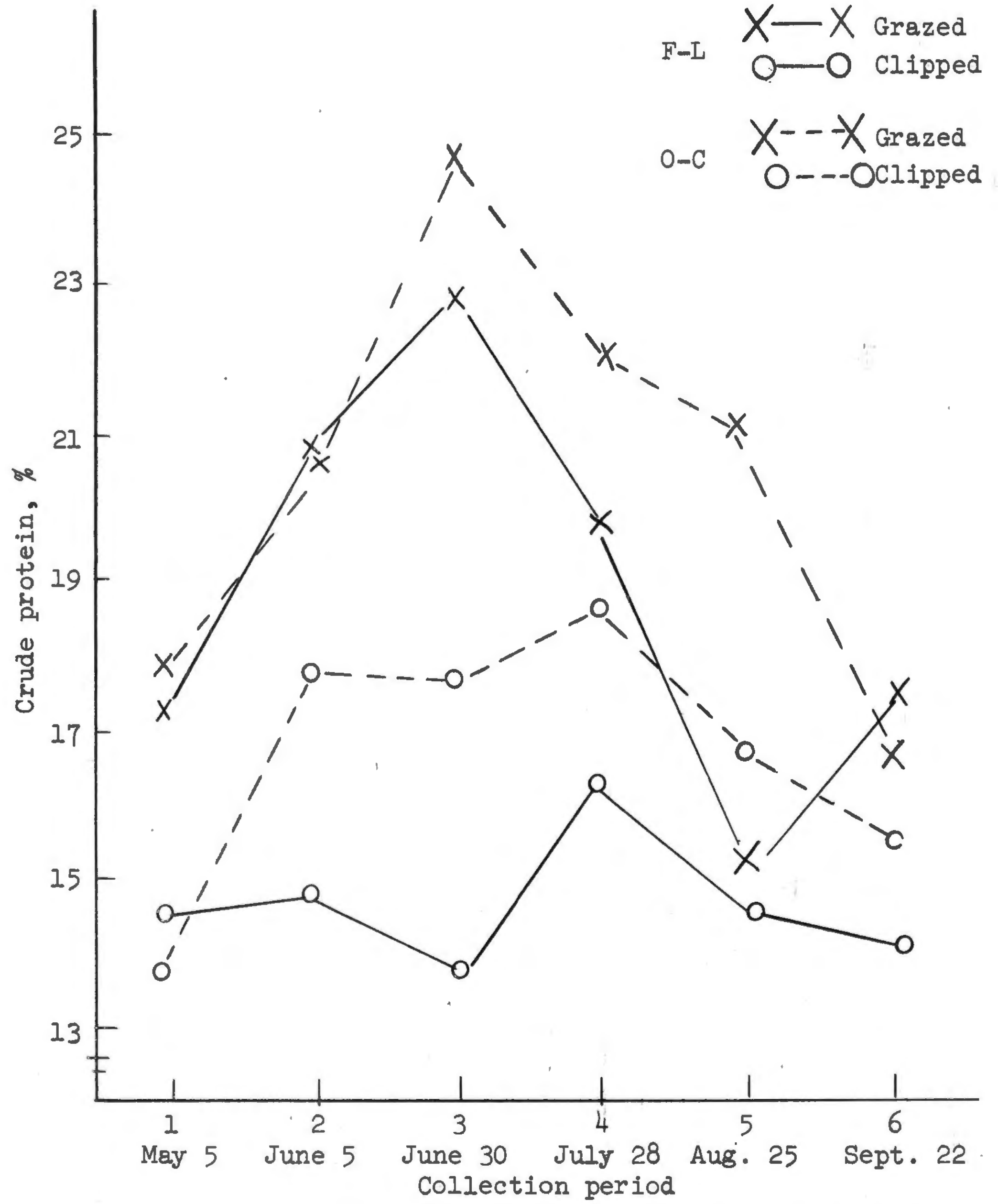

Figure 1. Crude protein content of grazed and clipped samples during experimental period.

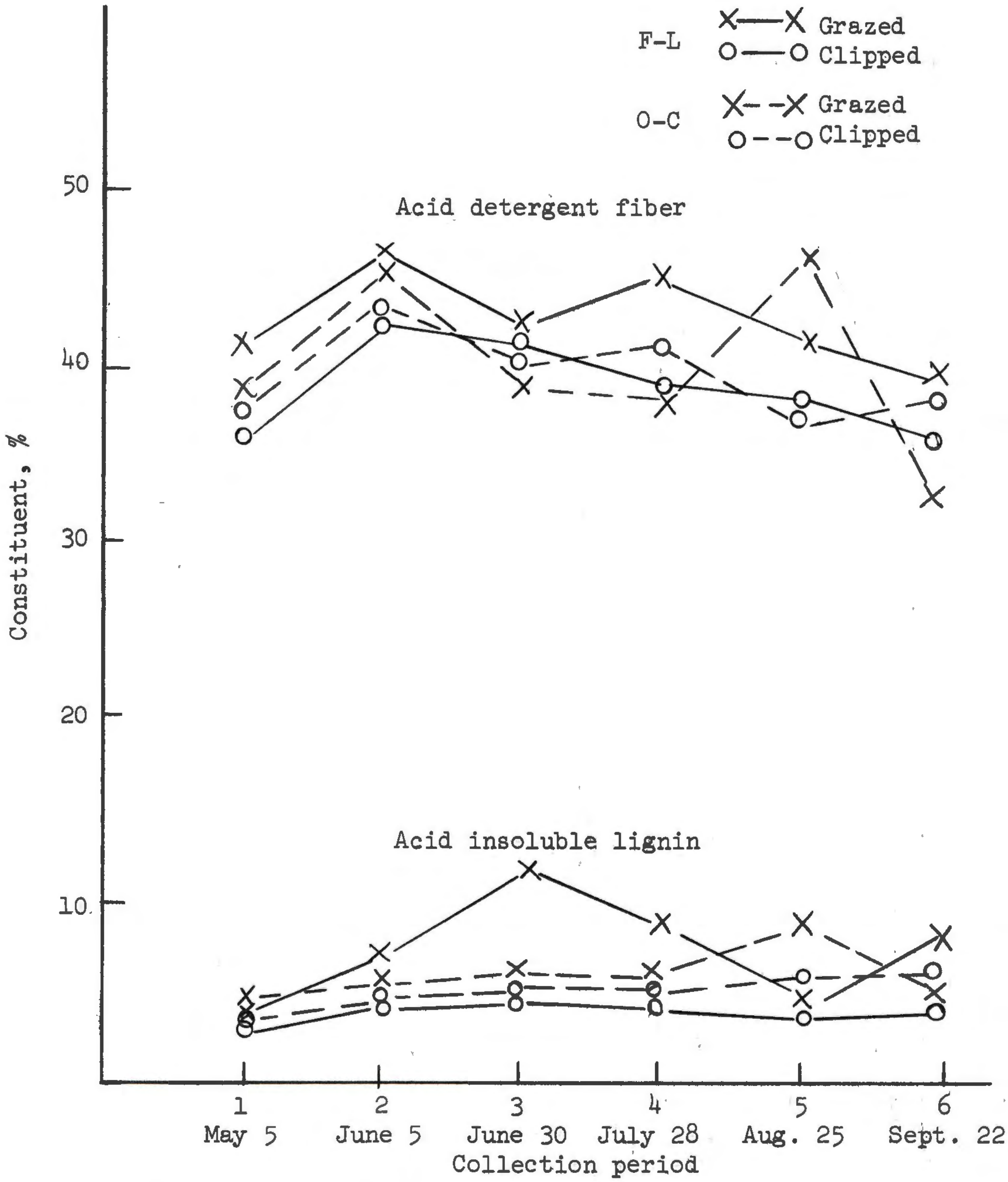

Figure 2. Acid detergent fiber and acid insoluble lignin contents of grazed and clipped samples during experimental period.

Comparison of Chemical Components of the Forage Samples from Two Types of Pasture

Generally, protein, ADF and AIL are considered to be important factors affecting quality in forages. The seasonal means in chemical composition of the grazed forages collected from two types of pasture are presented in Table 2, page 24. The steers in O-C pastures selected forages that had a little higher mean protein content than that selected by steers in F-L pastures (20.5 vs. 18.8 percent). These differences were not statistically significant. As shown in Figure 1, the protein content in diets of steers from the two types of pasture was similar in the early part of the grazing season; but in the middle of the grazing season, the diet of steers grazing O-C pasture contained much more protein than that of steers grazing F-L pasture.

Figure 2 shows the ADF and AIL content of the forage selected by steers from the two types of pasture during the grazing season. In both components, the difference is slightly in favor of F-L pastures, but it is statistically nonsignificant. The generally higher content of ADF and AIL in the diet of steers grazing F-L pasture may account for the lower ADG of these steers. The relatively high AIL content in the diet of steers grazing F-L pastures near the middle of the grazing season may be due to the fact the steers selected more lespedeza in their diets during that time. Van Soest (1963) and Barth et al. (1968b) indicated that ADF and AIL contents of lespedeza are considerably higher than those of grass.

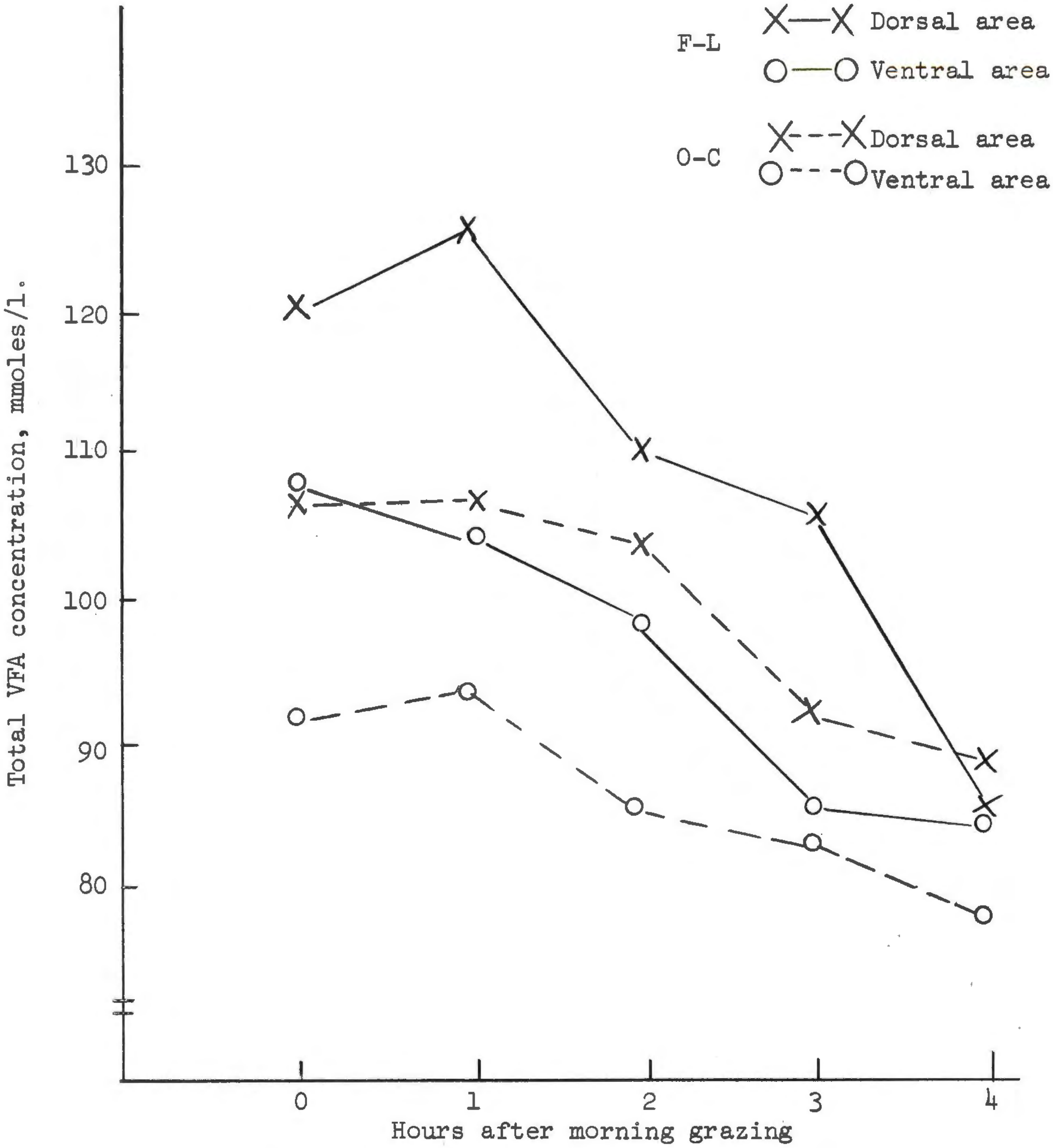

Figure 3. Change in the total VFA concentration of rumen liquor after morning grazing.

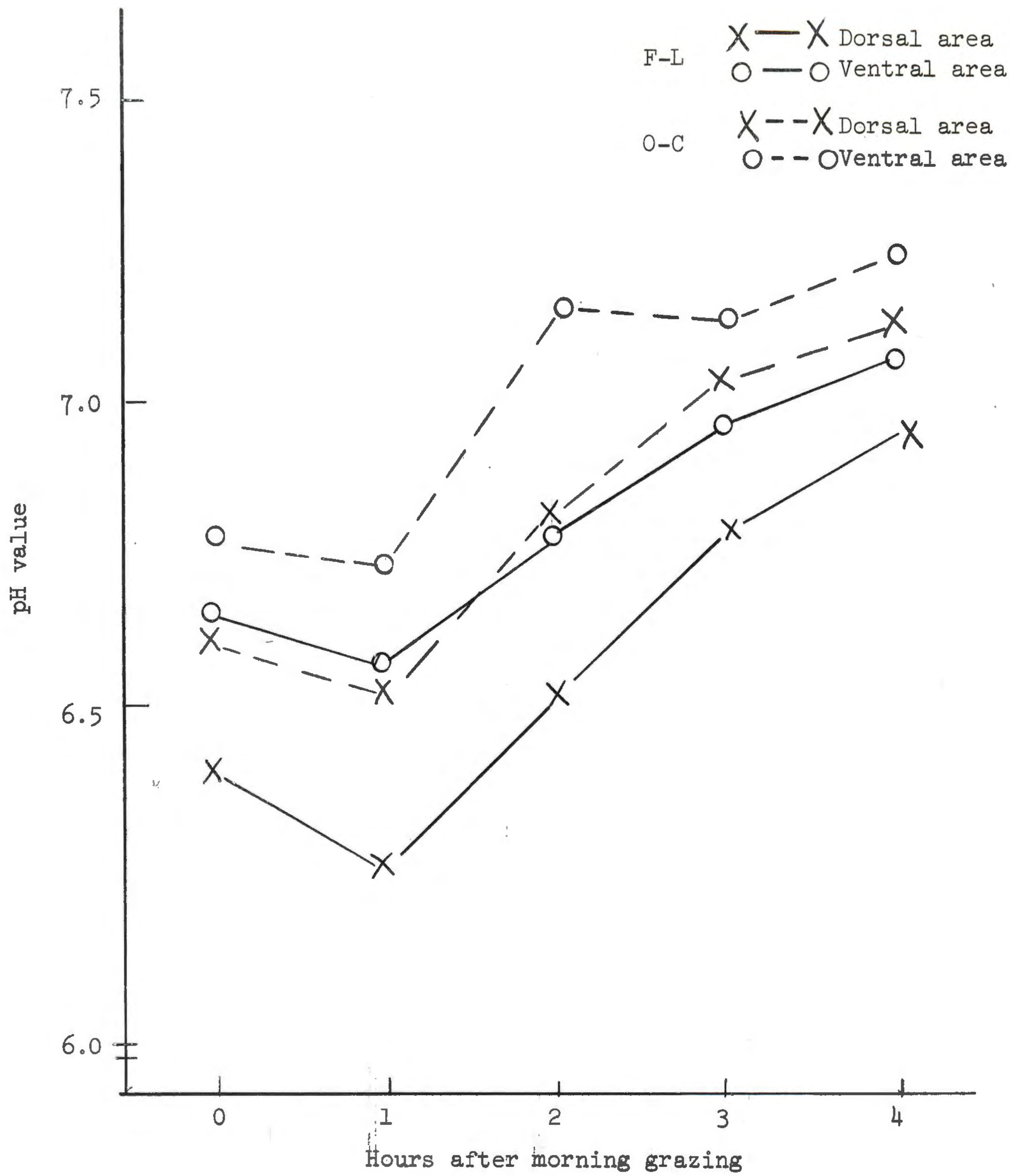

Figure 4. Change in pH of rumen liquor after morning grazing.

TABLE 5

EFFECT OF LOCATION OF SAMPLING ON VFA CONCENTRATION AND pH IN THE RUMEN OF STEERS GRAZING FESCUE-LESPEDEZA PASTURE

Item	Location of samples[a]	Collection period 1	2	3	4	5	6
pH value	D	6.70	6.56	6.62	6.63	6.66	6.46
	V	6.99	6.59	6.89	6.82	6.86	6.61
Acetic acid, mmoles/l.	D	77.2	76.6	79.4	72.8	82.8	71.6
	V	62.3	61.5	66.8	64.4	76.3	58.1
Propionic acid, mmoles/l.	D	22.4	24.3	21.0	20.1	22.0	17.6
	V	17.1	17.9	17.3	18.1	19.8	14.8
Butyric acid, mmoles/l.	D	10.8	7.6	9.8	9.1	9.9	9.0
	V	8.4	5.5	8.4	8.2	9.2	7.1
Total VFA, mmoles/l.	D	116.2	113.7	115.7	107.5	120.3	103.3
	V	92.5	88.6	100.3	95.3	109.8	84.2
Acetic acid, molar %	D	66.6	67.4	68.6	67.7	68.7	69.5
	V	67.8	69.3	68.2	68.0	69.6	69.0
Propionic acid, molar %	D	19.1	21.4	18.1	18.7	18.3	17.5
	V	18.2	20.2	18.0	19.0	18.0	17.6
Butyric acid, molar %	D	9.2	6.7	8.5	8.4	8.6	8.7
	V	9.0	6.2	8.3	8.6	8.2	8.3
A/P ratio	D	3.51	3.15	3.79	3.62	3.82	4.09
	V	3.81	3.38	3.80	3.55	3.86	3.94

[a]D and V represent dorsal and ventral areas of rumen, respectively.

TABLE 6

EFFECT OF LOCATION OF SAMPLING ON VFA CONCENTRATION AND pH IN THE RUMEN OF STEERS GRAZING ORCHARDGRASS-CLOVER PASTURE

Item	Location of samples[a]	Collection period 1	2	3	4	5	6
pH value	D	6.73	6.92	7.14	6.99	6.83	6.93
	V	7.04	7.08	7.23	7.18	6.88	7.00
Acetic acid, mmoles/l.	D	67.2	69.7	69.2	65.1	79.5	55.4
	V	64.4	62.6	55.6	52.3	72.1	47.6
Propionic acid, mmoles/l.	D	18.6	17.5	15.9	16.0	22.0	17.6
	V	18.4	14.7	11.7	11.8	19.8	14.8
Butyric acid, mmoles/l.	D	9.2	10.6	9.6	9.1	9.6	7.8
	V	8.1	8.5	7.3	6.7	9.2	6.2
Total VFA, mmoles/l.	D	100.5	104.3	101.9	96.4	116.9	81.4
	V	94.9	91.9	80.2	75.9	105.9	68.6
Acetic acid, molar %	D	66.0	66.8	67.9	67.7	68.0	68.2
	V	67.9	68.1	69.4	69.1	68.1	69.4
Propionic acid, molar %	D	18.3	16.8	15.6	16.7	18.0	16.5
	V	18.1	15.9	14.8	15.5	17.7	16.2
Butyric acid, molar %	D	9.3	10.1	9.4	9.4	8.9	9.6
	V	8.4	9.2	9.0	8.8	9.0	9.1
A/P ratio	D	3.68	3.99	4.31	4.07	3.78	4.14
	V	3.86	4.28	4.80	4.47	3.84	4.29

[a]D and V represent dorsal and ventral areas of rumen, respectively.

rate of propionic acid absorption as compared to acetic acid absorption or to more acetic acid production than propionic acid production in the ventral area.

The Change of VFA Production During the Successive Collection Periods

The changes in total VFA, VFA proportion and pH in rumen of steers grazing the two types of pasture are presented in Table 7. The highest total VFA concentration occurred in mid-summer (about August 25), and the lowest total VFA concentration occurred at the last collection period. This was more pronounced in O-C pastures. These results agree with those of Johns (1955) who stated that total VFA concentration tends to be higher in the summer than in the fall when grasses and legumes approached dormancy.

As shown in Figure 5, the molar percent of acetic acid was only slightly variable throughout the experimental period. The rumen liquor of steers grazing F-L pastures had a higher concentration of propionic acid than that of steers grazing O-C pastures. These differences were statistically significant ($P<.05$) in the second and third collection periods. In contrast, the rumen liquor of steers grazing O-C pastures had a somewhat higher molar percent of butyric acid. However, the reason for the difference in propionic acid and butyric acid distribution in the rumen of steers grazing these two types of pasture is not obvious.

Relationship Between ADG and In Vivo VFA Concentration

Simple coefficients of correlation between ADG and *in vivo* VFA concentration and pH value are presented in Table 8. In both types

TABLE 7

TOTAL VFA CONCENTRATION AND VFA PROPORTION IN RUMEN OF STEERS GRAZING ON TWO TYPES OF PASTURE

Item	Collection period 1	2	3	4	5	6
Total volatile fatty acid, mmoles/l.						
F-L	104.4	101.2	108.0	101.4	115.1	93.8
O-C	97.7	98.1	91.1	86.1	111.4	75.0
Acetic acid, molar %						
F-L	67.2	68.4	68.4	67.9	69.2	69.3
O-C	67.0	67.5	68.7	68.4	68.0	68.8
Propionic acid, molar %						
F-L	18.7	20.8	18.1	18.9	18.2	17.6
O-C	18.2	16.4	15.1	16.2	17.8	16.4
Butyric acid, molar %						
F-L	9.1	6.2	8.4	8.5	8.4	8.5
O-C	8.9	9.7	9.2	9.1	9.0	9.4
A/P ratio						
F-L	3.66	3.27	3.80	3.59	3.84	4.02
O-C	3.77	4.14	4.56	4.27	3.81	4.22
pH value						
F-L	6.85	6.58	6.76	6.72	6.76	6.54
O-C	6.89	7.08	7.19	7.08	6.86	6.97

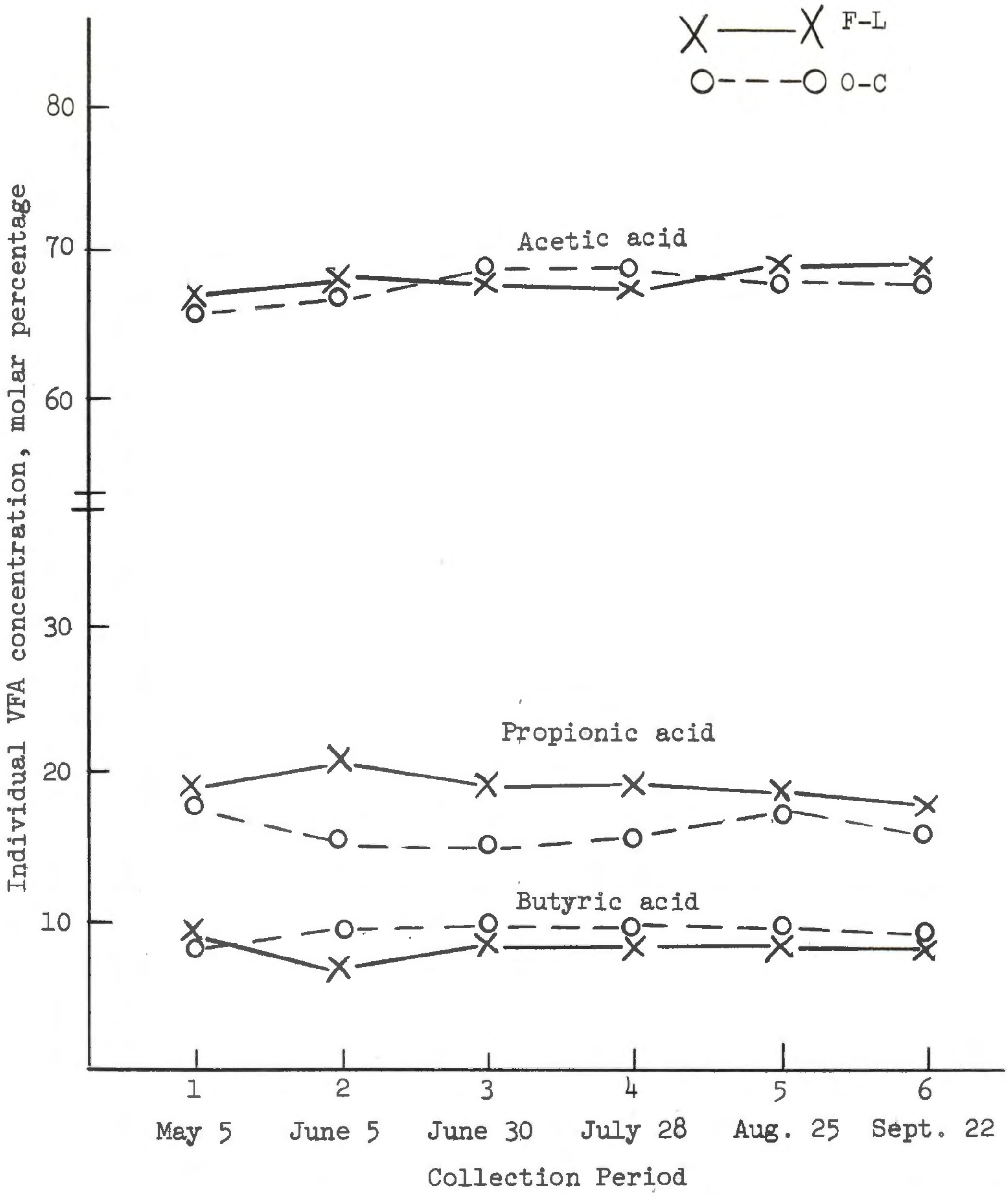

Figure 5. Change in VFA concentration of the rumen liquor of steers during the experimental period.

TABLE 8

SIMPLE COEFFECIENTS[a] OF CORRELATION BETWEEN ADG AND *IN VIVO* VFA CONCENTRATION AND pH IN RUMEN LIQUOR OF STEERS GRAZING TWO TYPES OF PASTURE

Item	Location of samples	Time of sampling 0	1	2	3	4
				Fescues-lespedeza		
Total VFA, mmoles/l.	D	0.62	0.89	0.51	0.15	-.49
	V	0.24	0.65	0.83	0.15	-.60
Acetic acid, molar %	D	-.56	-.35	-.17	-.39	-.05
	V	-.85	-.57	-.77	-.35	0.80
Propionic acid, molar %	D	0.05	-.09	-.00	-.00	-.43
	V	-.21	0.20	-.04	-.10	-.93
Butyric acid, molar %	D	0.51	0.73	0.59	0.73	0.65
	V	0.65	0.77	0.77	0.39	0.03
A/P ratio	D	-.20	0.02	-.03	-.14	0.32
	V	-.04	-.35	-.22	-.07	0.95
pH value	D	-.05	-.38	0.73	0.85	0.92
	V	0.64	0.57	0.89	0.80	0.84
				Orchardgrass-clover		
Total VFA, mmoles/l.	D	0.58	0.63	0.85	0.39	0.61
	V	0.60	0.77	0.67	0.71	0.54
Acetic acid, molar %	D	0.48	0.72	0.13	-.86	-.73
	V	-.69	-.25	-.50	-.58	-.68
Propionic acid, molar %	D	0.19	0.20	0.07	0.72	0.71
	V	0.33	0.15	0.26	0.19	0.72
Butyric acid, molar %	D	-.64	-.52	-.39	0.79	0.21
	V	-.48	0.39	-.00	-.34	-.62
A/P ratio	D	-.05	0.42	0.01	-.77	-.74
	V	-.39	0.13	-.30	-.26	-.72
pH value	D	-.05	-.38	-.10	-.41	-.55
	V	-.05	-.25	-.04	-.04	0.80

[a]Coefficients above 0.75 and below -.75 were significant ($P<.05$) and coefficients above 0.85 and below -.85 were highly significant ($P<.01$).

of pasture, ADG was most highly correlated with total VFA concentration in the rumen liquor collected from the dorsal area of rumen. The correlations between ADG and either molar percent of VFA or acetic to propionic acid ratio were generally low, not consistent, and differed in the two types of pasture. In O-C pastures, the ADG was correlated with molar percent of propionic acid, whereas, in the F-L pastures, the ADG was more highly correlated with butyric acid. Generally, these correlations were not statistically significant. ADG was negatively correlated with molar percent of acetic acid. Similar results were reported by Shaw et al. (1960), Balch (1960) and Grimes et al. (1967).

Recent studies with lambs grazing orchardgrass and fescue (Grimes et al., 1967) indicated that there were positive correlations between ADG and molar percent of propionic acid and negative correlations between ADG and molar percent of acetic acid. However, they found no correlation between ADG and total VFA concentration but indicated that their method of obtaining rumen liquid samples by stomach tube was not accurate because the exact position of sampling could not be determined.

The absence of significant correlations between ADG and molar percent of the individual VFA in this study is in agreement with results reported by Putnam et al. (1965). The negative correlation between ADG and molar percent of acetic acid in this experiment can possibly be explained by the results reported by Armstrong et al. (1958), who indicated that for growth, the efficiency of energy utilization was inversely related to molar percent of acetic acid in the rumen.

IV. *IN VITRO* VFA PRODUCTION FROM FORAGE SAMPLES COLLECTED FROM TWO TYPES OF PASTURE

Difference in VFA Production Between Grazed and Clipped Samples

Means of *in vitro* VFA production from the grazed and clipped samples are presented in Table 9. Generally, *in vitro* VFA production of the clipped samples was higher than that of the grazed samples. These differences were statistically significant in the F-L pasture samples. The lower *in vitro* VFA production in the grazed samples may be due to: (1) the effect of saliva and mastication on the grazed samples, since Barth *et al*. (1968b) found that the increase of ADF and AIL in the fistula samples in fescue and lespedeza are much higher than that in orchardgrass and clover; (2) loss of soluble carbohydrates in the grazed samples, since Grimes and Watkin (1965) indicated that soluble carbohydrates in grass and legumes were easily dissolved by saliva.

Difference in VFA Production Between Forage Samples from the Two Types of Pasture

The mean *in vitro* VFA production of the samples collected from the two types of pasture also is presented in Table 9. Each mean represents 12 observations during the experimental period. There were no appreciable differences between these two types of pasture in *in vitro* VFA production from clipped samples. Grazed samples from O-C pastures had a nonsignificantly higher VFA production than grazed samples from F-L pastures. Generally, the higher lignin contents in F-L grazed samples may account for the lower VFA production in these

TABLE 9

COMPARISON OF IN VITRO VFA PRODUCTION OF GRAZED AND CLIPPED SAMPLES FROM TWO TYPES OF PASTURE[a,b,c]

Item	Method of sampling: Grazed Mean	Clipped Mean
	mmoles/l.	mmoles/l.
	Fescue-lespedeza	
Total volatile fatty acids[d]	36.4	44.4
Acetic acid[d]	20.6	25.0
Propionic acid[d]	9.4	11.7
Butyric acid	3.1	3.8
A/P ratio	2.22	2.16
	Orchardgrass-clover	
Total volatile fatty acid	40.8	44.9
Acetic acid	23.3	25.8
Propionic acid	10.9	11.7
Butyric acid[d]	3.2	3.9
A/P ratio	2.16	2.20

[a]Differences between mean of the two types of pasture are not significant.

[b]In supernatant liquor from the first stage of the Tilley and Terry (1963) fermentation procedure.

[c]Means of six collection periods.

[d]Means of grazed and clipped samples are significantly different ($P<.05$).

forage samples since there usually was a highly significant negative correlation between lignin content and VFA production in F-L pasture samples (Figure 6) in this study. In contrast, no significant correlation between lignin content and VFA production was observed in O-C pasture samples.

Relationship Between ADG and In Vitro VFA Produced from Grazed and Clipped Samples

The coefficients of correlation between ADG and *in vitro* VFA production in the two types of pasture are presented in Table 10. Generally, the coefficients of correlation between ADG and *in vitro* VFA obtained from both grazed and clipped samples were low and inconsistent. This was especially the case in grazed samples. ADG of steers grazing F-L pastures was significantly ($P<.05$) correlated with propionic acid (molar percent) obtained from grazed samples only. This relationship is shown graphically in Figure 6. The significant negative correlation ($P<.01$) between propionic acid (molar percent) and AIL is shown graphically in Figure 6.

In O-C pastures, ADG was positively correlated with acetic acid production (molar percent) and negatively correlated with both expressions of butyric acid production. This relationship between acetic acid production and ADG is presented graphically in Figure 6. In addition, the negative relationship between AIL and acetic acid production in O-C pasture samples is shown. VFA production and AIL content relationships are of interest because, in general, AIL in pasture samples is usually negatively correlated with ADG.

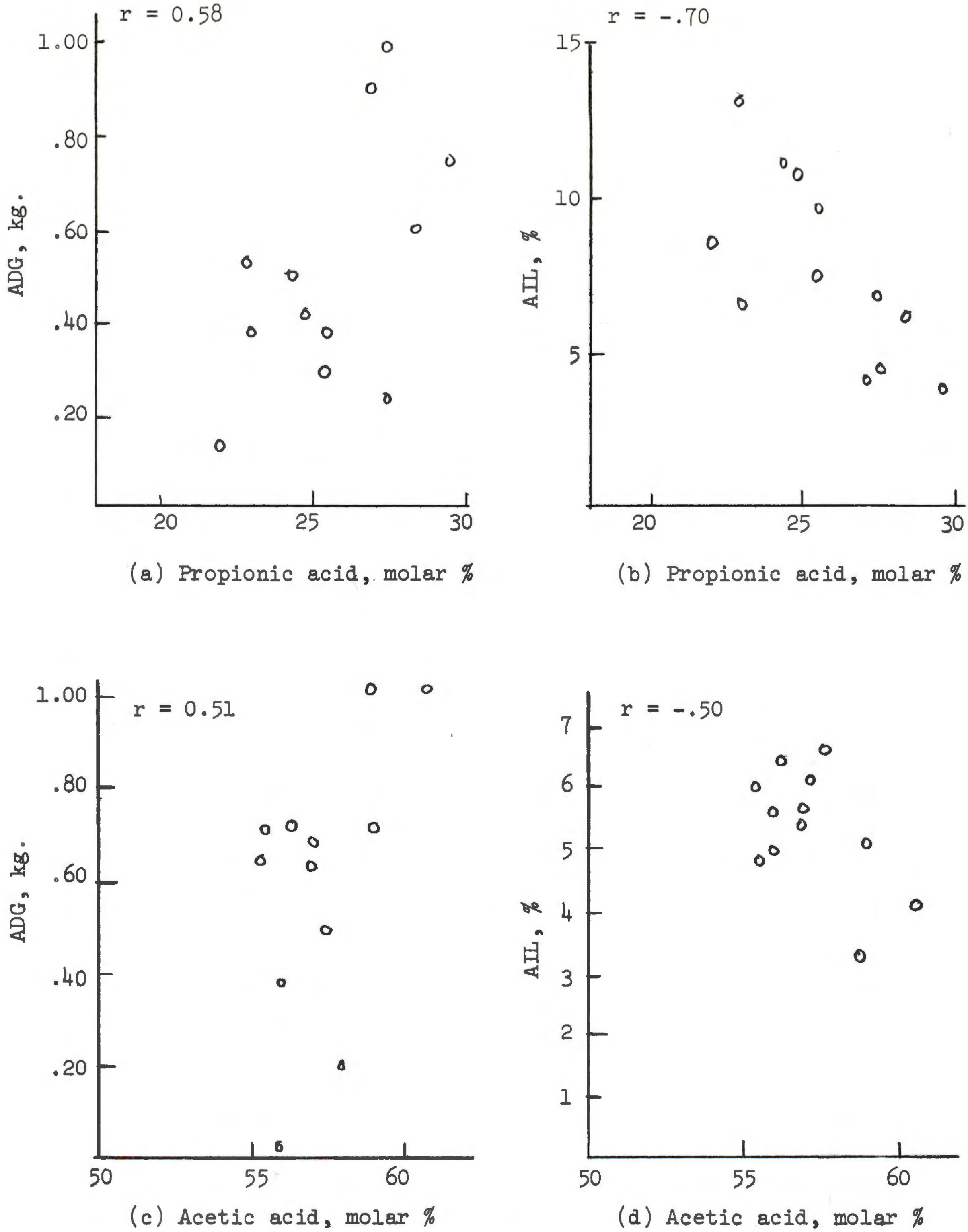

Figure 6. Relationship between (a) ADG vs. propionic acid in F-L pastures, (b) AIL vs. propionic acid in F-L pastures, (c) ADG vs. acetic acid in O-C pastures, (d) AIL vs. acetic acid in O-C pastures.

TABLE 10

SIMPLE COEFFICIENTS[a] OF CORRELATION BETWEEN ADG AND IN VITRO VFA PRODUCTION FROM GRAZED AND CLIPPED SAMPLES COLLECTED FROM TWO TYPES OF PASTURE

Item		Type of pasture	
		Fescue-lespedeza	Orchardgrass-clover
Total VFA, mmoles/l.	Grazed	-.09	-.45
	Clipped	0.46	0.13
Acetic acid, mmoles/l.	Grazed	-.12	-.16
	Clipped	0.46	0.22
Propionic acid, mmoles/l.	Grazed	0.06	-.41
	Clipped	0.34	0.15
Butyric acid, mmoles/l.	Grazed	-.13	-.55
	Clipped	0.25	-.45
A/P ratio	Grazed	-.43	0.49
	Clipped	0.26	0.35
Acetic acid, molar %	Grazed	0.05	0.63
	Clipped	0.02	0.51
Propionic acid, molar %	Grazed	0.58	-.24
	Clipped	-.22	0.15
Butyric acid, molar %	Grazed	-.25	-.73
	Clipped	-.49	-.27

[a]Coefficients above .55 and below -.55 were significant ($P<.05$) and coefficients above .68 and below -.68 were highly significant ($P<.01$).

V. MULTIPLE REGRESSION EQUATIONS

Multiple regression equations to predict ADG were developed using various combinations of the independent variables. These variables included chemical components and *in vitro* digestibility of grazed and clipped samples, percent legume, legume index, *in vivo* VFA concentration and *in vitro* VFA production. The purposes of these analyses was to determine combinations of independent variables which would be relatively easy to obtain and which would be valuable in predicting ADG of steers grazing these two types of pasture.

The general form in which these equations are presented is:

$$\hat{Y} = a + b_1 x_1 + b_2 x_2 + \ldots + b_n x_n$$

Where *a* is a constant, and can be calculated as follows:

$$a = \overline{Y} - b_1 \overline{x}_1 - b_2 \overline{x}_2 - \ldots - b_n \overline{x}_n$$

The b's are partial regression coefficients and are the values tabulated in the tabular presentation of equations (Tables 11 through 18). As shown in Table 11, e.g., equation 4 is for estimating ADG from *in vivo* total VFA, and *in vitro* DDM of grazed samples of F-L pasture; *i.e.*,

$$\hat{Y} = 1.464 + 0.0136\, x_1 + 0.0055\, x_2$$

Where $\hat{Y}$ = predicted value of ADG

x_1 = *in vivo* total VFA concentration collected from the dorsal area of rumen one hour after morning grazing

x_2 = *in vitro* DDM of grazed samples.

TABLE 11

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM *IN VIVO* VFA CONCENTRATION AND ONE OTHER VARIABLE OBTAINED FROM F-L PASTURE

Equation Components	Method of sampling	Equation number 1	2	3	4	5	6	7	8	9	10
Constant		-1.270	-3.019	-1.458	-1.464	-1.181	-3.085	0.545	-.067	-1.302	-1.221
In vivo total VFA, dorsal, 1 hr., mmoles/l.		0.0139	0.0173	0.0125	0.0136	0.0143	0.0164	0.0117	0.0119	0.0129	0.0139
Crude protein, %	Grazed	0.015									
	Clipped						0.1047				
ADF, %	Grazed		0.0136								
	Clipped							-.0385			
AIL, %	Grazed			-.0150							
	Clipped								-.2196		
In vitro DDM, %	Grazed				0.0055						
	Clipped									0.0310	
Legume, %						-.0246					
Legume index											-.0013
R^2		.794	.835	.818	.841	.918*	.879*	.844	.912*	.830	.799

*Significant (P<.05).

TABLE 14

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM IN VIVO VFA CONCENTRATION AND SEVERAL OTHER VARIABLES OBTAINED FROM O-C PASTURE

Equation components	Method of sampling	Equation number 1	2	3	4	5	6	7	8
Constant (a)		-4.299	-3.498	5.273	7.864	-2.518	-.930	8.644	7.903
In vivo total VFA, mmoles/l.	Dorsal, 2 hr.	0.0268	0.0348	0.0067	0.0075				
	Ventral, 1 hr.					0.0145	0.0153	0.0044	0.0043
ADF, %	Grazed	-.0333	-.0360			-.0144	-.0287		
In vitro DDM, %	Grazed	0.0212	0.0358			0.0373	0.0144		
AIL, %	Clipped			-.4481	-.5770			-.5252	-.5493
In vitro DDM, %	Clipped			-.0656	-.0941			-.0879	-.0932
Legume, %			-.0234		-.0110		0.0244		-.0015
R^2		.968*	998*	.989*	.996*	.927	.994	.998*	.999*

*P<.05.

TABLE 17

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM IN VITRO VFA CONCENTRATION AND SEVERAL OTHER VARIABLES OBTAINED FROM F-L PASTURE

Equation components	Method of sampling	Equation number 1	2	3	4	5	6	7	8
Constant (a)		-5.048	-4.400	-1.703	-1.674	-2.414	-2.618	-2.394	-1.874
In vitro propionic acid, molar %	Grazed	0.1557	0.1464	0.0877	0.0922				
In vitro acetic acid, mmoles/1.	Clipped					0.0110	0.0140	0.0201	0.0384
Legume, %		-.0053	-.0038	0.0245	0.0178	0.0244	0.0238	0.0221	0.0133
Crude protein, %	Grazed	0.0841	0.0810	0.1302	0.1386				
ADF, %	Grazed		-.0084	-.0454	-.0697				
AIL, %	Grazed			-.0846	-.0548				
In vitro DDM, %	Grazed				0.0112				
ADF, %	Clipped					-.0972	-.0919	-.0963	-.2291
Crude protein, %	Clipped						0.0012	0.0015	0.0053
AIL, %	Clipped							0.0588	0.1641
In vitro DDM, %	Clipped								-.0676
R^2		.494	.499	.718	.733	.471	.473	.478	.597

TABLE 18

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM IN VITRO VFA CONCENTRATION AND SEVERAL OTHER VARIABLES OBTAINED FROM O-C PASTURE

Equation components	Method of sampling	Equation number 1	2	3	4	5	6	7	8
Constant (a)		-3.470	-3.569	-4.429	-4.298	-2.678	-2.464	-2.239	-0.288
In vitro acetic acid, molar %	Grazed	0.0510	0.0525	0.0307	0.0289				
	Clipped					0.0523	0.0514	0.0541	0.0448
Legume, %		0.0133	0.0138	0.0010	0.0013	0.0158	0.0159	0.0155	0.0113
In vitro DDM, %	Grazed	0.0153	0.0135	0.0407	0.0455				
Crude protein, %	Grazed		0.0064	-.0157	-.0227				
ADF, %	Grazed			0.0257	0.0138				
AIL, %	Grazed				0.0413				
AIL, %	Clipped					0.1340	-.1340	-.1363	-.2220
Crude protein, %	Clipped						-.0013	-.0027	-.0051
ADF, %	Clipped							0.0080	0.0053
In vitro DDM, %	Clipped								-.0215
R^2		.685*	.689	.749	.766	.712*	.712*	.714	.723

*P<.05.

The simple correlations among the dependent variables obtained from one type of pasture were generally significantly different from those obtained from the other pasture type. Therefore, pooling of correlations was not justified. The prediction equations for ADG were calculated on a within-type-of-pasture basis.

ADG Estimated from In Vivo VFA Concentration and One Other Variable

Regression equations and coefficients of determination (R^2) for estimating ADG from in vivo VFA concentration and one other variable obtained from F-L pastures are presented in Table 11, and those from O-C pasture are presented in Table 12. These equations contained in vivo total VFA as the major component and one other variable, such as percent crude protein, ADF, AIL and in vitro DDM of grazed and clipped sample, percent legume and legume index, were used to estimate ADG of steers grazing on these two types of pasture.

In F-L pastures, the percent of in vitro DDM and ADF in combination with total VFA accounted for more of the variation in ADG than any other combination of variables in the grazed samples. However, their coefficients of determination were not statistically significant. The percent crude protein and AIL in the clipped samples accounted for more of the variation in ADG than any other combination of variables, and their coefficients of determination were statistically significant ($P<.05$). The higher coefficients of determination indicated that estimates of ADG from clipped samples might be more accurate than estimates from grazed samples in F-L pastures. Percent legume in the pasture contributed more to variations in ADG than did the legume index of the pasture.

In grazed samples from O-C pastures (Table 12), the percent of ADF or in vitro DDM explained more of the variation in ADG than did percent of crude protein or AIL when combined with total VFA. Within clipped samples, the percent of AIL and in vitro DDM accounted for more variation in ADG than did the other variables. The coefficient of determination in the equation including percent of AIL was highly significant (P<.01). These data indicated that both types of sample (grazed and clipped) were valuable in predicting ADG in O-C pasture. However, clipped samples are easier to obtain. The coefficients of determination in the equations containing either percent legume or legume index were much smaller than those of other equations.

ADG Estimated from In Vivo Total VFA and Several Other Variables from Grazed or Clipped Samples

In vivo total VFA in the rumen liquor collected from either the dorsal or the ventral area of the rumen and one or more variables from grazed and clipped samples were used in the development of the regression equations and coefficients of determination of ADG. These regression equations and coefficients of determination from F-L and O-C pastures are presented in Table 13, page 51 and Table 14, page 52, respectively.

In vivo total VFA collected either from the dorsal or the ventral area of the rumen can be used in predicting ADG of steers on both types of pasture. In F-L pastures, regression equations 3, 4, 7 and 8 had significant coefficients of determination (P<.05). These equations which combine in vivo total VFA and other variables from clipped samples accounted for most of the variation in ADG. However, equations 3 and 7 are more valuable in estimating ADG since the increase of coefficients of determination was small after including in vitro DDM in this equation.

In O-C pastures, regression equations 1, 2, 3, 4, 7 and 8 had significant coefficients of determination. Each of them can be used in predicting ADG since these equations explained most of variation in ADG, but equations 1, 3 and 7 would probably be preferable in estimation of ADG since the addition of percent legume as a variable explained little of the remaining variation in ADG. However, the small number of error degrees of freedom in these equations suggests that a conservative interpretation of these data is advisable even though they have very high coefficients of determination. Nevertheless, these equations did explain most of the variation in ADG of steers grazing these two types of pasture.

ADG Estimated from In Vitro VFA and One Other Variable

Regression equations and coefficients of determination for estimating ADG from percent of legumes, in vitro VFA production and one other variable obtained from grazed and clipped samples in F-L pastures are presented in Table 15, page 53, and those in O-C pastures are presented in Table 16, page 54.

The coefficients of determination in regression equations for estimating ADG in F-L pastures were low and not significant. Percent legume in the pasture and in vitro VFA production from both grazed and clipped samples accounted for little of the variation in ADG. However, equation 2, containing percent legume, in vitro propionic acid (molar percent) and percent protein in grazed samples, explained more of the variation in ADG than did the other regression equations.

In O-C pastures (Table 16, page 54), the coefficients of determination for the equations were relatively high and significant ($P<.05$). These equations indicated that percent legume and *in vitro* acetic acid (molar percent) from either grazed or clipped samples could be used in predicting ADG of steers grazing O-C pastures. Equation 1 and 9 explained more of the variation in ADG, and data on the independent variables in these equations were rather easy to obtain.

ADG Estimated from In Vitro VFA, Percent Legume and One or More Other Variables

Percent legume, *in vitro* VFA production and one or more variables obtained from grazing or clipped samples were used in developing regression equations for predicting ADG of steers grazing one of the two types of pastures. These regression equations and their coefficients of determination for F-L pastures are presented in Table 17, page 55, and those for O-C pastures are presented in Table 18, page 56.

For F-L pastures, the coefficients of determination were low and nonsignificant. If only *in vitro* VFA production data is available, equation 3 containing the independent variables propionic acid, crude protein and AIL from grazed samples and legume percentage in the pasture would probably be used in estimating ADG of steers grazing F-L pastures. This equation explained a large amount of the variation (72 percent) in ADG and the addition of *in vitro* DDM (equation 4) caused very little increase in the coefficients of determination.

Equations in Table 18 indicate that *in vitro* acetic acid (molar percent) from both grazed and clipped samples and other variables can be used in estimating ADG of steers grazing O-C pastures. The coefficients of determination of regression equations 1, 5 and 6 were significant ($P<.05$). But equation 5 would be the most valuable in estimating ADG of steers grazing O-C pastures since the addition of percent crude protein from clipped samples (equation 6) made little contribution to the explanation of the variation of ADG.

ADG Estimated from In Vitro VFA Production

It should be reemphasized that in the present investigation the *in vitro* VFA production results were a by-product of the *in vitro* digestibility determinations conducted according to the Tilly and Terry (1963) method. The length of fermentation period (48 hours) in this method was required to simulate the degree of digestion of feeds in the intact animal.

In other *in vitro* fermentation techniques as in the estimation of voluntary ration intake, the length of the fermentation period may be different from that used when estimating digestibility. It is conceivable that fermentation periods longer or shorter than 48 hours might yield *in vitro* production of total or individual VFA which would be highly correlated with ADG. Therefore, the length of fermentation best suited for *in vitro* VFA production studies with pasture forage should be investigated.

General Discussion

A series of multiple regression equations for the prediction of ADG of steers grazing either F-L or O-C pastures were developed using

VFA production and other independent variables. In several of the equations, the majority of the variation in ADG was explained. In general, ADG of steers grazing O-C pastures could be predicted better than ADG of steers grazing F-L pastures.

The source of the data comprising the independent variables had an effect on the magnitude of the coefficients of determination. VFA data obtained from rumen-fistulated steers generally was more useful in prediction equations than VFA data obtained from in vitro fermentation. Time elapsed after grazing influenced the degree of correlation between ADG and VFA, as did the location within the rumen where VFA samples were obtained. Thus, VFA samples from the dorsal area of the rumen were more useful as components in multiple regression equations for predicting ADG than those from samples obtained from the ventral area.

In theory, grazed samples should yield better predictions of animal performance than would clipped samples. However, results obtained in this study generally show no advantage from including chemical components or in vitro VFA production from the grazed samples in addition to or rather than values from clipped samples when predicting ADG. The reason for this is that effects of saliva and mastication on the analyses of chemical components have not yet been adequately quantified.

Results of this investigation indicate that total or individual VFA production is an important factor in the prediction of ADG of steers grazing the two types of pasture under investigation. If a gas chromatograph is not available, total VFA concentration can be determined by steam distillation and subsequent titration. If a rumen-fistulated animal is not available, rumen liquor can be obtained by stomach tube from intact animals grazing the pastures which are to be evaluated.

CHAPTER V

SUMMARY

The objectives of this study were: (a) to evaluate and compare several methods of estimating average daily gain (ADG) of steers grazing on two types of pasture, (b) to investigate factors that affect ADG of these steers during the spring-summer grazing season, (c) to study the changes of volatile fatty acid (VFA) concentration in the rumen of these steers and their relation to animal performance and (d) to study selective grazing and its relation to ADG of steers.

Two types of pasture, fescue-lespedeza (F-L) and orchardgrass-ladino clover (O-C) were used in this study. A grazing trial with steers was conducted to determine the body weight changes on these two types of pasture during various periods of the grazing season. Esophageal-fistulated steers were used to sample the diet of grazing animals (grazed sample) while hand-clipped samples were used to represent the forage available to the animals. Rumen-fistulated steers were used for <u>in vivo</u> VFA production studies. Chemical composition of grazed and clipped forage samples and <u>in vivo</u> and <u>in vitro</u> VFA production were determined at 28-day intervals during the spring-summer grazing season.

These measures which affect quality of pastures were correlated with average daily gain of steers grazing the two types of pasture. Measures which were highly correlated with ADG were then used to develop equations for predicting ADG by multiple regression analysis.

The results of this study were as follows:

1. ADG of steers grazing O-C pastures was higher than that of steers grazing F-L pastures. This was especially pronounced in the early part of the grazing season.

2. Grazed samples were significantly higher ($P < .05$) with respect to crude protein content in both types of pasture.

3. A consistently lower protein content, higher acid detergent fiber (ADF) content and acid insoluble lignin (AIL) content in the diet of the steers grazing F-L pastures may have accounted for the lower ADG of these steers.

4. There was no significant correlation between ADG and percent of protein in the grazed or the clipped samples from either type of pasture. The percent of AIL in the clipped samples was negatively correlated with ADG.

5. Total VFA production reached a peak about one hour after the morning grazing and tended to decline thereafter. However, the molar percent of individual VFA in rumen liquor varied little in both types of pasture during the 4 hours after the morning grazing. The pH values and total VFA concentration were negatively correlated. Total VFA concentration was higher in the summer than in the fall.

6. Total and individual VFA concentration in the dorsal area of the rumen was significantly higher than in the ventral area. However, there were no significant differences in VFA ratio between these two locations. In both types of pasture, ADG was more highly correlated with total VFA concentration in samples from the dorsal area than with the same variable in samples from the ventral area of the rumen.

7. For the prediction of ADG of steers grazing F-L pastures, the equation including the variables in vivo total VFA concentration, AIL and crude protein percentage was the most useful of several similar equations. This multiple regression equation explained 98 percent of the variability in ADG of steers.

8. In O-C pastures, the equation containing the variables in vivo total VFA concentration, percent of AIL and in vitro DDM were most valuable in predicting ADG or steers. This equation accounted for 99 percent of the variation in ADG of steers.

9. Results of this investigation indicate that total or individual VFA production may be an important factor in the prediction of ADG of steers grazing F-L or O-C pastures. Together with other variables considered in this study, VFA concentration accounted for most of the variation in ADG of the steers.

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APPENDIX

TABLE 19

CHEMICAL COMPOSITION AND IN VITRO DIGESTIBILITY OF GRAZED AND CLIPPED SAMPLES OF TWO TYPES OF PASTURE[a]

Item	Sampling period 1	2	3	4	5	6
Date	May 5	June 5	June 30	July 28	Aug. 25	Sept. 22
			Fescue-lespedeza			
Crude protein, %						
Clipped	14.5	14.7	13.7	16.1	14.5	14.0
Grazed	17.2	20.9	22.7	19.2	15.1	17.4
ADF, %						
Clipped	36.5	41.2	40.9	39.5	39.2	38.1
Grazed[b]	41.1	46.1	42.2	45.4	41.2	40.1
AIL, %						
Clipped	3.4	4.5	4.5	4.2	4.5	4.1
Grazed[b]	4.2	7.6	12.6	9.1	5.0	8.3
In vitro DDM, %						
Clipped	65.1	57.0	54.7	61.1	60.3	63.4
Grazed[b]	53.6	52.8	31.9	53.6	55.9	37.3
			Orchardgrass-clover			
Crude protein,%						
Clipped	13.7	17.6	17.4	18.5	16.6	15.4
Grazed	17.9	20.7	24.6	22.1	21.1	16.6
ADF, %						
Clipped	37.0	41.5	40.3	40.1	37.9	38.4
Grazed[b]	38.5	45.9	39.3	38.5	46.1	32.7
AIL, %						
Clipped	3.6	5.4	5.4	5.2	5.9	6.4
Grazed[b]	4.9	5.8	6.0	5.5	8.3	5.3
In vitro DDM, %						
Clipped	69.0	62.1	61.4	66.1	60.5	61.4
Grazed[b]	68.1	65.4	68.1	63.8	59.0	54.6

[a]Organic-matter basis.

[b]Adjusted for the effects of saliva and mastication.

TABLE 20

EFFECT OF TIME AND LOCATION OF SAMPLING ON pH OF RUMEN LIQUOR OF STEERS GRAZING ON TWO TYPES OF PASTURE

Location of samples	Hrs after morning grazing	Collection period					
		1	2	3	4	5	6
		Fescue-lespedeza					
Dorsal area	0	6.35	6.30	6.25	6.65	6.50	6.35
	1	6.00	6.60	6.25	6.55	6.35	5.85
	2	6.75	6.45	6.50	6.45	6.60	6.65
	3	7.00	6.75	6.95	6.70	6.85	6.70
	4	7.35	6.70	7.15	6.80	7.00	6.75
Ventral area	0	6.80	6.35	6.75	6.85	6.80	6.40
	1	6.80	6.60	6.60	6.65	6.55	6.20
	2	7.00	6.45	6.80	6.75	6.85	6.70
	3	7.10	6.65	7.05	6.85	6.90	6.85
	4	7.25	6.90	7.25	7.00	7.20	6.85
		Orchardgrass-clover					
Dorsal area	0	6.40	6.60	7.10	6.75	6.50	6.35
	1	6.30	6.75	7.20	6.85	6.35	5.85
	2	6.90	6.80	6.80	7.00	6.60	6.65
	3	7.00	7.25	7.20	7.20	6.90	6.70
	4	7.05	7.20	7.40	7.15	7.20	6.75
Ventral area	0	6.70	6.80	7.05	7.15	6.80	6.45
	1	6.90	6.80	7.15	7.00	6.55	6.20
	2	7.00	7.20	7.25	7.10	6.85	6.70
	3	7.20	7.15	7.30	7.40	6.90	6.85
	4	7.40	7.45	7.40	7.25	7.20	6.85

TABLE 21

<u>IN VITRO</u> VFA PRODUCTION FROM GRAZED AND CLIPPED ORCHARDGRASS-CLOVER SAMPLES[a]

Item	Collection period					
	1	2	3	4	5	6
	mmoles/l.					
Total volatile fatty acids						
Clipped	51.9	36.4	40.2	48.6	47.2	45.3
Grazed	39.5	38.0	35.8	42.2	44.7	44.3
Acetic acid						
Clipped	31.0	20.3	23.2	27.5	26.9	25.9
Grazed	24.3	21.6	20.5	24.0	24.8	24.5
Propionic acid						
Clipped	13.3	9.7	10.3	12.8	12.6	11.3
Grazed	10.4	10.3	8.8	11.2	12.5	12.0
Butyric acid						
Clipped	4.4	3.3	3.2	4.2	3.9	4.2
Grazed	2.3	2.7	2.9	3.4	3.7	3.9

[a]In supernatant liquor from the first stage of the Tilly and Terry (1953) fermentation procedure.

TABLE 22

IN VITRO VFA PRODUCTION FROM GRAZED AND CLIPPED FESCUE-LESPEDEZA SAMPLES[a]

Item	Collection period					
	1	2	3	4	5	6
	mmoles/l.					
Total volatile fatty acids						
Clipped	48.3	38.6	42.3	43.3	46.2	47.0
Grazed	33.9	41.4	21.1	41.2	45.2	35.3
Acetic acid						
Clipped	27.9	21.9	24.8	24.3	24.9	26.4
Grazed	19.6	24.5	10.9	24.1	24.9	19.3
Propionic acid						
Clipped	12.8	10.5	11.0	12.0	11.4	12.3
Grazed	9.0	9.4	5.0	10.4	13.1	9.4
Butyric acid						
Clipped	4.1	3.3	3.5	3.8	3.8	4.0
Grazed	2.5	3.7	2.1	3.5	3.7	3.3

[a]In supernatant liquor from the first stage of the Tilly and Terry (1953) fermentation procedure.

TABLE 23

IN VIVO VFA CONCENTRATION IN RUMEN OF STEERS GRAZING TWO TYPES OF PASTURE

Collection period	Location of samples	Hrs. after morning grazing	pH value	Total VFA	Acetic acid	Propionic acid	Butyric acid	A/P ratio
				mmoles/l.	Molar %			
					Fescue-lespedeza			
1	D	0	6.35	124.8	66.0	19.9	9.4	3.32
1	D	1	6.00	144.2	65.0	19.6	10.3	3.31
1	D	2	6.75	114.7	66.8	20.0	9.0	3.34
1	D	3	7.00	105.5	65.9	19.7	9.4	3.35
1	D	4	7.35	92.1	69.4	16.4	8.1	4.22
1	V	0	6.80	94.7	67.1	18.3	9.5	3.69
1	V	1	6.80	109.8	66.1	19.4	9.7	3.41
1	V	2	7.00	104.7	64.7	19.6	9.9	3.30
1	V	3	7.10	85.2	67.3	18.8	8.5	3.57
1	V	4	7.25	68.0	73.8	15.0	7.3	5.08
2	D	0	6.30	107.9	68.1	21.1	6.5	3.23
2	D	1	6.60	109.0	67.3	21.1	6.4	3.19
2	D	2	6.45	115.7	67.5	21.3	6.6	3.16
2	D	3	6.75	111.5	67.0	21.5	6.9	3.11
2	D	4	6.70	124.3	67.0	21.8	3.9	3.07
2	V	0	6.35	86.6	69.0	19.9	6.5	3.46
2	V	1	6.60	85.6	69.2	19.6	6.6	3.53
2	V	2	6.45	90.4	68.2	21.2	6.2	3.22
2	V	3	6.65	91.8	71.1	20.0	5.4	3.56
2	V	4	6.90	88.7	69.0	20.2	6.3	3.14

TABLE 23 (continued)

Collection period	Location of samples	Hrs. after morning grazing	pH value	Total VFA	Acetic acid	Propionic acid	Butyric acid	A/P ratio
				mmoles/l.	Molar %			
3	D	0	6.25	129.1	69.0	17.9	8.4	3.85
3	D	1	6.25	130.3	68.9	17.9	8.3	3.84
3	D	2	6.50	114.4	67.3	19.1	9.1	3.52
3	D	3	6.95	109.3	69.4	17.9	8.3	3.87
3	D	4	7.15	98.3	68.6	17.8	8.2	3.86
3	V	0	6.85	116.8	67.7	18.4	8.5	3.68
3	V	1	6.60	105.9	67.9	18.1	8.5	3.76
3	V	2	6.80	100.9	67.6	19.0	8.7	3.56
3	V	3	7.05	87.3	69.3	17.3	8.0	4.01
3	V	4	7.25	90.2	68.5	17.3	8.0	3.97
4	D	0	6.65	111.8	67.7	18.6	8.5	3.64
4	D	1	6.55	107.0	66.5	19.8	8.8	3.36
4	D	2	6.45	99.2	67.2	18.7	8.6	3.60
4	D	3	6.70	118.0	68.3	18.6	8.4	3.68
4	D	4	6.80	101.6	68.8	18.0	7.9	3.83
4	V	0	6.85	101.3	68.8	18.9	8.9	3.54
4	V	1	6.65	100.0	67.1	19.2	8.8	3.50
4	V	2	6.75	89.9	68.1	18.9	8.3	3.60
4	V	3	6.85	91.8	66.6	19.3	8.8	3.45
4	V	4	7.00	93.7	69.2	18.6	8.2	3.67

TABLE 23 (continued)

Collection period	Location of samples	Hrs. after morning samples	pH value	Total VFA	Acetic acid	Propionic acid	Butyric acid	A/P ratio
				mmoles/l.	Molar %			
5	D	0	6.50	124.2	67.8	18.6	9.1	3.64
5	D	1	6.35	145.1	69.5	18.4	8.4	4.03
5	D	2	6.60	118.2	69.4	17.2	9.0	4.04
5	D	3	6.85	112.8	69.7	18.0	8.0	3.87
5	D	4	7.00	101.3	67.5	19.2	8.6	3.51
5	V	0	6.80	109.3	68.4	18.2	8.9	3.76
5	V	1	6.55	143.5	69.4	18.4	8.8	3.76
5	V	2	6.85	111.3	68.7	18.0	8.7	3.81
5	V	3	6.70	81.3	70.6	16.6	8.3	4.21
5	V	4	6.85	90.5	71.9	16.4	7.8	4.38
6	D	0	6.35	122.5	67.3	17.7	9.7	3.81
6	D	1	5.85	120.5	68.6	17.2	8.8	4.01
6	D	2	6.65	101.7	69.0	16.9	8.7	4.06
6	D	3	6.70	81.3	70.6	16.6	8.3	4.21
6	D	4	6.75	90.5	71.9	16.4	7.8	4.38
6	V	0	6.45	96.2	69.7	17.0	8.8	4.11
6	V	1	6.20	84.3	69.4	17.1	8.4	4.05
6	V	2	6.70	90.7	69.9	17.0	8.7	4.10
6	V	3	6.85	69.8	71.3	16.5	8.0	4.32
6	V	4	6.85	80.0	64.7	20.2	7.8	3.20

TABLE 23 (continued)

Collection period	Location of samples	Hrs. after morning grazing	pH value	Total VFA	Acetic acid	Propionic acid	Butyric acid	A/P ratio
				mmoles/l.	Molar %			
					Orchardgrass-clover			
1	D	0	6.40	114.4	66.8	18.0	9.5	3.72
1	D	1	6.30	112.5	68.9	16.8	8.8	4.11
1	D	2	6.90	115.0	69.4	17.1	8.2	4.08
1	D	3	7.00	85.2	60.8	20.8	11.1	2.92
1	D	4	7.05	75.3	67.1	18.9	8.7	3.56
1	V	0	6.70	94.3	67.5	17.8	9.1	3.79
1	V	1	6.90	108.5	66.5	18.3	9.6	4.11
1	V	2	7.00	92.6	67.4	17.4	9.0	3.89
1	V	3	7.20	93.5	68.3	16.9	8.7	4.04
1	V	4	7.40	85.7	69.8	20.1	5.8	3.46
2	D	0	6.60	99.1	67.2	16.5	10.0	4.08
2	D	1	6.75	107.8	67.6	16.7	10.0	4.06
2	D	2	6.80	115.7	66.3	17.0	10.8	3.91
2	D	3	7.25	94.7	67.1	16.5	9.8	4.08
2	D	4	7.20	104.2	65.9	17.2	9.9	3.83
2	V	0	6.80	94.4	67.0	16.5	9.8	4.06
2	V	1	6.80	95.9	69.4	15.5	8.9	4.47
2	V	2	7.20	95.6	67.5	16.3	9.7	4.13
2	V	3	7.15	91.6	6715	16.0	9.3	4.22
2	V	4	7.45	82.2	67.2	15.3	8.2	4.54

TABLE 23 (continued)

Collection period	Location of samples	Hrs. after morning grazing	pH value	Total VFA	Acetic acid	Propionic acid	Butyric acid	A/P ratio
				mmoles/l.	Molar %			
3	D	0	7.10	111.6	68.5	15.9	9.5	4.13
3	D	1	7.20	105.7	67.8	15.4	9.6	4.39
3	D	2	6.80	104.4	67.3	15.6	9.5	4.29
3	D	3	7.20	100.3	67.6	16.0	9.2	4.22
3	D	4	7.40	87.3	68.4	15.2	9.3	4.51
3	V	0	7.05	92.8	68.6	15.3	9.5	4.48
3	V	1	7.15	85.0	71.4	12.5	9.3	5.69
3	V	2	7.25	82.2	68.4	15.0	9.3	4.56
3	V	3	7.30	78.6	68.1	15.1	9.2	4.52
3	V	4	7.40	62.3	70.6	14.9	7.9	4.73
4	D	0	6.75	101.7	66.7	16.7	10.0	3.99
4	D	1	6.85	116.5	66.8	16.6	10.1	4.02
4	D	2	7.00	93.0	67.8	16.8	9.5	4.04
4	D	3	7.20	94.1	68.0	17.5	9.2	3.88
4	D	4	7.15	76.7	69.4	15.7	8.2	4.41
4	V	0	7.15	87.5	68.3	15.5	9.5	4.40
4	V	1	7.00	89.1	67.7	16.2	9.0	4.18
4	V	2	7.10	71.4	69.9	15.2	8.2	4.54
4	V	3	7.40	70.9	68.8	16.1	8.7	4.27
4	V	4	7.25	60.4	70.9	14.3	7.8	4.95

TABLE 23 (continued)

Collection period	Location of samples	Hrs. after morning grazing	pH value	Total VFA	Acetic acid	Propionic acid	Butyric acid	A/P ratio
				mmoles/l.	Molar %			
5	D	0	6.45	121.1	68.5	17.8	8.7	3.86
5	D	1	6.80	122.8	68.8	17.7	8.4	3.89
5	D	2	6.85	114.6	66.8	18.8	9.4	3.56
5	D	3	6.85	117.6	67.7	18.0	9.1	3.76
5	D	4	7.20	108.3	68.3	17.9	9.0	3.81
5	V	0	6.45	115.4	68.0	18.2	8.8	3.73
5	V	1	6.85	113.2	68.6	17.1	9.0	4.01
5	V	2	6.80	105.1	66.4	18.5	9.7	3.59
5	V	3	7.05	99.2	67.8	17.6	9.0	3.85
5	V	4	7.25	96.5	69.5	17.2	8.5	4.04
6	D	0	6.50	100.0	65.7	17.3	10.7	3.80
6	D	1	6.75	80.4	67.3	17.1	9.8	3.94
6	D	2	6.85	84.5	68.4	16.8	9.5	4.07
6	D	3	7.20	69.2	69.5	15.9	9.0	4.35
6	D	4	7.35	72.9	70.0	15.5	8.8	4.53
6	V	0	6.65	70.6	69.1	16.7	9.7	4.14
6	V	1	7.00	69.8	69.0	16.4	9.0	4.21
6	V	2	7.05	68.5	68.6	16.5	9.5	4.17
6	V	3	7.15	70.2	69.0	16.2	9.2	4.26
6	V	4	7.15	63.8	71.3	15.2	8.0	4.68

VITA

I was born in Taiwan, China on November 18, 1933 and received a B. S. Degree from Taiwan Provincial Chung Hsing University in 1956. In 1957 I enrolled in the Army of the Republic of China as second Lieutenant. After two years of military service, I secured a position as an inspector in the Bureau of Inspection and Quarantine in Taiwan. In 1961 and 1962, I was in charge of the Agricultural Chemistry Section of the same organization. I came to the United States for graduate study in 1963 and received my M. S. Degree from the University of Tennessee in 1965. Since 1965 I have been an assistant in Animal Husbandry at the University of Tennessee.

I am a member of the American Society of Animal Science, American Association for the Advancement of Science, and the Society of Sigma Xi.