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To the Graduate Council:

I am submitting herewith a dissertation written by Delmer Irvin Davis, Jr., entitled "Prediction of Body Weight Gain of Beef Cattle from Volatile Fatty Acids, Visual Pasture Score, and Chemical Analyses of Forage and the Relationship of Body Weight Gain to Forage Intake." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

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We have read this dissertation and recommend its acceptance:

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PREDICTION OF BODY WEIGHT GAIN OF BEEF CATTLE FROM VOLATILE FATTY ACIDS, VISUAL PASTURE SCORE, AND CHEMICAL ANALYSES OF FORAGE AND THE RELATIONSHIP OF BODY WEIGHT GAIN TO FORAGE INTAKE

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

Delmer Irvin Davis, Jr.

December 1969

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ABSTRACT

The objectives of this study were: (a) to investigate several methods of pasture evaluation useful for prediction of the daily gain of beef calves, (b) to study plant factors which are related to body weight gain of grazing heifers, (c) to investigate the reasons for increased daily gain in pastures containing clover, and (d) to test the hypothesis that decreased forage dry matter intake is related to decreased animal performance.

Two grazing trials were conducted with the following four pasture species: (1) Tall fescue (*Festuca arundacea*), (2) Orchardgrass (*Dactylis glomerata*), (3) Ladino clover (*Trifolium repens*), and (4) Kobe lespedeza (*Lespedeza striata*). Experiment 1 was conducted with heifers grazed on tall fescue (FES), orchardgrass-Ladino clover (OC), and fescue-orchardgrass-clover (FOC) pastures. Changes in body weight and subcutaneous fat thickness were determined. Experiment 2 was conducted with steers grazed on fescue-lespedeza (FL) and orchardgrass-clover (OC) pastures. Changes in body weight were determined and forage dry matter intake was estimated. Forage intake was calculated from a total feces collection and *in vitro* dry matter digestibility.

Forage quality measures (visual and laboratory) which were related to body weight gain of cattle were used to develop regression equations for predicting daily gain. The results of this study were as follows:

1. The daily gain and change in fat thickness of heifers grazing OC or FOC pastures was higher than that of heifers grazing FES pastures.

2. Estimates of forage utilization by grazing heifers indicated that the order of preference was clover, orchardgrass, and tall fescue.

3. This study indicated that samples representative of the pasture clipped according to the method used by High were of little value when only chemical or VFA analysis were to be used as evaluation criteria. The same variables obtained from pure samples of the major species were highly associated with ADG.

4. Organic matter digestibility, soluble carbohydrates, and total VFA analysis of clover were the most useful single variables for prediction of ADG from analyses of forage samples.

5. Propionic acid (in vivo) and total VFA (in vivo) were highly correlated with ADG when rumen-liquor samples collected through the rumen fistula were analyzed, but the magnitude of coefficients of correlation was decreased when oral samples were taken from the same animals, possibly because of saliva contamination.

6. In vitro VFA analysis indicated that clover is of higher nutritive value than orchardgrass or tall fescue. It had a greater potential to form the energy-rich VFA's.

7. Clover or legume percentage was consistently indicated as an important factor for desirable gain for beef heifers on pasture. These data indicated that the reason for the advantage in gain due to clover is the higher content of digestible nutrients as indicated by its higher digestible organic matter content, soluble carbohydrates content, and its ability to form volatile fatty acids. These characteristics were consistently high in clover over the growing season, whereas

grasses did not maintain these factors at an adequate level after the point of maturity. These factors alone were ample reasons to expect superior gain on clover-containing pastures under practical management regimes.

8. If intake is to be related to body weight gain, these data indicated that some adjustment in intake estimates must be made for body maintenance.

9. Total digestible nutrient (TDN) intake was greater for cattle grazing forage from OC pastures when equal amounts of dry matter from OC and FL pastures were ingested. Percentage TDN and intake of the forages were closely associated, indicating that intake is associated with quality of forage.

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CHAPTER I

INTRODUCTION

The basis for beef cattle production in the southeastern United States is the utilization of large quantities of forage which can be economically produced in this area. A major part of this forage is provided by permanent pastures. In Tennessee, Kentucky-31 tall fescue and native orchardgrass are the two major grass species. Legumes such as white Dutch clover, Ladino clover, red clover, and lespedeza (Korean and Kobe) are generally grown in combination with these grass species. Past research has revealed differences in animal response between these two grass species. Legumes apparently contribute heavily to body weight gains of animals grazing either tall fescue or orchardgrass since an increased response has been reported when pastures contain a high percentage of legume. These differences were determined primarily by grazing trials in which the differences were measured by average daily gains of beef cattle grazed on different types of pasture; however, since grazing trials are expensive and time consuming, various other methods of pasture forage evaluation have been studied as possible predictors of results that would be obtained from grazing trials.

These measurements of forage quality can be used to reveal the reasons for observed differences in average daily gain of beef cattle grazing different pasture species, to explain the changes in plant chemical composition as related to animal performance, and to show the effects of different management systems within and between pasture types. It is necessary that a measure of pasture forage quality have three important attributes. Firstly, it must be closely related to the production capacity of the pasture in terms of body weight gain or other important economic criteria for evaluating grazing animals. Secondly, it must be able to predict animal performance before the animals have had access to the forage. Thirdly, it must be economical in terms of time and cost.

The experiments reported herein were conducted using heifers and steers, grazing four different combinations of tall fescue, orchardgrass, and a legume such as Ladino clover or Kobe lespedeza. The objectives of this study were: (a) to investigate several methods of pasture evaluation useful for prediction of the ADG of grazing beef calves, (b) to study plant factors which are related to body weight gain of grazing heifers, (c) to investigate the reasons for increased ADG in pastures containing clover, and (d) to test the hypothesis that decreased forage dry matter intake is related to decreased quality.

CHAPTER II

REVIEW OF LITERATURE

I. ANIMAL PERFORMANCE ON DIFFERENT TYPES OF PASTURE

Animal performance is the most reliable indicator and the determinant of the pasture forage value. Many environmental and genetic factors affect animal performance, but in spite of this, research at the Tennessee Agricultural Experiment Station has indicated that under currently used management systems, beef cattle grazing orchardgrass gain more body weight than cattle grazing tall fescue (Duncan, 1958; Duncan and Felts, 1961; High et al., 1965a; High et al., 1965b; High, J. W., et al., 1965).

Recommendations based on research for producing slaughter cattle under Tennessee conditions has resulted from this work which is quite important to the beef producer of this state. During the past years, most of Tennessee's beef calves have been sold as feeders. The majority have been shipped out of state and are finished in the feedlots of the West and Midwest. Selling calves at weaning age fails to take advantage of economical gains that may be made from low cost winter and summer pasture. Presently, the program that is based on past research begins in the fall with calves weaned at approximately 500 pounds. This program involves feeding steer calves a low cost wintering ration of pasture and/or harvested forage such as hay or corn silage with the objective of having them gain about three-fourth pounds per day. By spring they should weigh about 575 pounds. After summer pasture they should weigh close to 800 pounds. By following this summer grazing phase with a 70 to 90 day full feeding phase, steer calves should be finished at approximately 1,000 pounds and will grade high-good and low-choice.

Orchardgrass pastures have consistently out-produced tall fescue pastures in terms of both daily gain and grazing days per acre during the summer grazing period; however, fescue pastures have produced higher winter gains (High et al., 1965a; Hobbs et al., 1965). Research reported by White (1960) indicated that rate of gain on pasture is a function of clover content. These data showed that as clover content decreased, ADG decreased.

When sheep were used to evaluate these two pasture forages, Grimes et al. (1967) reported that sheep above 58 pounds in body weight grazed on orchardgrass pastures had a higher live body weight gain and produced more pounds of wool than sheep grazed on tall fescue pastures. They concluded that clover contributed to the increased production of both body weight and wool.

The botanical and chemical characteristics that affect ADG are not clearly understood; therefore, the explanation for the differences in gain of beef calves grazing orchardgrass and fescue during late spring and mid-summer with and without clover has not been fully investigated.

II. VISUAL ESTIMATION OF PASTURE QUALITY

Ocular estimates of botanical composition give only relative assessment of potential productivity of grassland; however, these methods are valuable tools for measuring land fertility in terms of beef production and efficiency of grazing management. Brown (1954) reported that the line intercept method of botanical analysis accurately measured the ground surface occupied by plants. This method consisted of a horizontal and linear measurement of plants along the course of a line. This same technique was used by Canfield (1941) to estimate utilization of a semi-arid vegetation in the Southwest.

Levy and Madden (1933) described a "point quadrat" method for expressing botanical composition in terms of ground cover. Comparisons between the quadrat and line-transect method were reported by Anderson (1942) who indicated that the transect method was more rapid and more easily performed. This method appeared to give pasture plant species population estimates that were equal to or superior in accuracy when compared to quadrat estimates.

White (1960) analyzed several individual physical characteristics of orchardgrass-legume pastures that could be subjectively evaluated. He found correlations of .67 and .68 between ADG and pasture grade or thickness of sod. The relationship between pasture grade and legume height approached statistical significance (r = .41). Average legume height, thickness of sod, and pasture grade were significantly correlated with total beef gain per acre (.53, .63, and .62, concentration of VFA when bulls were fed corn cobs, orchardgrass, and alfalfa hay; however, Grimes et al. (1967) reported that the single factor most closely correlated with the body weight changes of pasture-grazed sheep was the molar proportion of propionic acid, which was also closely correlated with soluble carbohydrates in the forage being grazed.

The Ruminant and VFA Utilization

The growth of a young ruminant into an adult is characterized by changes in carbohydrate metabolism. VFA and glucose concentrations in the blood of young ruminants are similar to those of monogastric animals, but as the rumen develops and age increases, blood sugar falls and increased blood VFA levels are observed. The latter change can be explained by the production of rumen VFA's by micro-organisms and their subsequent absorption (Annison and Lewis, 1959). Carrol and Hungate (1954) reported that 6,000 to 12,000 kilocalories per day become available from VFA produced in the bovine rumen. This accounted for 40 to 100 percent of the total energy intake of these cattle.

The Efficiency of Utilization of Volatile Fatty Acids

Blaxter (1962) stated that the efficiency of utilization of energy (using stearic acid as a standard) from mixed rumen VFA's is within the range of 89.8 and 91.2 percent depending on the molar proportions in the rumen fluid. Higher concentrations of acetic acid tended to result in decreased efficiency of energy utilization. He found the utilization efficiencies of propionic and butyric acid to be similar and both higher than acetic. In contrast, Orskov and Allen (1966) found no difference in the efficiency of utilization of acetic or propionic acids. Lindsay (1959) found that the sugar economy of ruminants affects the use of acetate. The use of acetic acid was limited by the need for simultaneous use of carbohydrate. This may have had some bearing on the results of Orskov and Allen (1966) since their basal ration contained concentrates, a readily available carbohydrate source.

Effect of pH on VFA Absorption

Gray (1948) found that increased pH decreased the rate of VFA absorption. Most workers (Dobson and Phillipson, 1956; Annison *et al*., 1957; Annison and Lewis, 1959) agreed that rates of VFA absorption are considerably lower at pH values above 7.0 to 7.5. This dependence on hydrogen ion concentration was related to the proportion of VFA in the unionized form. This work also indicated that at normal pH ranges (5.5 to 6.5) a substantial amount of each VFA existed as the free acid, but above pH 7.0 to 7.5 the acids were largely unionized; thus absorption was severely reduced. Other work by Dobson and Phillipson (1956) indicated that blood supply to the rumen was increased by a lowered hydrogen ion concentration of the contents; therefore the rate of removal of VFA's from the rumen was increased. Addition of free VFA's or lowering of the pH when VFA's were present caused an increased absorption of VFA's from the rumen.

Additional work by Danielli *et al*. (1945) showed that at pH 7.5 and with small amounts of free acid, the rate of absorption decreased as molecular size increased. According to their work, the order of absorption was acetate, propionate, and butyrate. This agreed with reports by Barcroft et al. (1944) and Pfander and Phillipson (1953). However, when the pH was lowered to 5.8, the order of absorption rate was reversed and became butyrate, propionate, and acetate. This earlier work was confirmed by recent studies (Shaw, 1958; Stewart et al., 1958; Morris et al., 1965) in which it was found that if the rumen was slightly acid, butyric and propionic acids were absorbed more rapidly than acetic acid.

The Effect of Time and Rumen Location on VFA Concentration

Obtaining a representative sample is an utmost necessity in VFA studies. This problem is complicated to overcome because of unequal layer distribution of rumen contents. To obtain a representative rumen liquor sample by the use of either a rumen fistula or a stomach tube is difficult (Lane et al., 1968; Canaway et al., 1965). Balch (1950) reported that contents from the ventral area of the rumen were more moist than the contents of the dorsal area.

Canaway et al. (1965), Lane et al. (1968), and Wang (1968) found significant differences in VFA concentration among samples from several different locations in the rumen and times after grazing. They concluded that samples collected from one location were less valid than a composite sample from several areas of the rumen when pH and VFA concentration were studied.

Wang (1968) attempted to deal with both the time and location problem in a study using rumen fistulated steers grazing two types of pasture and found that total VFA production reached a peak one hour after morning grazing ceased. Also, total and individual VFA concentration in the rumen were significantly higher in the dorsal area.

IV. RUMEN VFA CONCENTRATION AND CHEMICAL COMPOSITION OF PASTURE FORAGE

Armstrong *et al*. (1957), Blaxter (1962), and Blaxter and Wainman (1963) reported that diets high in carbohydrates result in lower acetate-propionic ratios. Eldsden (1946) used several carbohydrate substrates in *in vitro* experiments and found that the average proportional contents of acetic, propionic, and butyric acids were 64, 20, and 16 percent respectively.

Relation of VFA Concentration to Stage of Growth of Pasture Forage

Davis *et al*. (1964) reported that saliva output decreased when high grain feeding regimes resulted in pH ranges low enough to increase the growth of propionic acid producing microorganisms. Barnett and Reid (1961) reported a lower rumen pH and higher propionic acid concentration in the rumen of animals grazing young grass than for the same animals grazing mature grass. These observations verified the report of Johns (1955) that the proportion of propionic fell when sheep were changed from pasture to a lower quality hay ration considered similar to mature pasture grass.

Relation of VFA Concentration to Soluble Carbohydrate, Protein, and Cellulose Contents

Although the addition of readily available carbohydrates to rations has become a common practice, the ruminant is adapted to digesting large quantities of fiber. Such supplementation may alter the cellulose breakdown in the rumen (Barnett and Reid, 1961). Donefer et al. (1963) found increased butyric and decreased acetic proportions as barley was increased in the ration. This appears to be characteristic of rations containing a readily available source of cabohydrate. Gray and Pilgrim (1952) indicated that the addition of protein nitrogen may alter the pattern of VFA production from cellulose and hemicellulose sources. However, Morris et al. (1965) found no effect of nitrogen or phosphorus on cellulose digestion patterns. Putnam et al. (1966) reported that digestibility of crude protein, crude fiber, and ether extract were lowest when animals were fed high energy levels which indicated an inverse relationship between VFA production and digestibility of fiber and protein. El Shazly (1952) and Sirotnak et al. (1953) demonstrated that ammonia and volatile fatty acids are the main end-products of amino acid fermentation. Shaw et al. (1960) compared pelleted hay and steam rolled corn with long hay and dry rolled corn. Pelleting and steam rolling decreased rumen acetate and increased propionate; at the same time there was a 12 percent increase in digestibility of protein, a 15 percent increase in feed utilization, and a 22 percent increase in body weight gain.

The capability of different forages to be fermented to VFA's is dependent on the chemical composition, particularly soluble carbohydrate (Grimes et al., 1967) and protein content (El Shazly, 1952) which will affect the digestibility of fiber and cellulose in the plants. Barnett and Reid (1961) stated that little work has been done on possible differences in acid production associated with compositional changes of pasture forage from which the ruminant selects its feed.

V. VOLUNTARY INTAKE OF PASTURE FORAGE

Voluntary Feed Intake and Animal Performance

Voluntary feed intake is an important measurement for researchers in evaluating the nutritive value of forages and for studying physiological factors affecting hunger and satiety. It is important to the beef producer because adequate intake is essential for desired animal performance. Making available all the required nutrients and energy is not enough to assure maximum performance. Voluntary intake (VI) is extremely variable, particularly in ruminants; therefore, nutritionists are quite interested in finding the basic factors that control intake. The interest in this area is indicated by the large number of recent review articles which emphasize the importance of VI in research. (Harris *et al*., 1959; McCollough, 1959; Reid *et al*., 1959; Sell *et al*., 1959; Weir *et al*., 1959; Reid, 1961; Balch and Campling, 1962; Johnson, 1962; Fontenot and Blaser, 1965; Conrad, 1966; Van Soest, 1966).

As an indicator of animal performance, the Nutritive Value Index (NVI) for forages was proposed by Crampton *et al*. (1960) as the product of relative intake (RI) and digestibility of energy. The expression of NVI considered forage quality by comparing the intake of high quality alfalfa to the intake of other forages. Reid (1961) showed that quality is a very important factor. He showed a 250 percent increase in feed intake as percentage TDN of the forage was increased 36 percent.

Factors Affecting Voluntary Intake

Several theories regarding factors that regulate intake in ruminants have been promulgated. Balch and Campling (1962) based their thermostatic regulation hypothesis on the existence of thermoreceptors in the hypothalmus, and that one of the end-products of eating is heat production. When this heat increment or specific dynamic action (SDA) causes the temperature to reach a certain point, eating stops.

The chemostatic theory is a collective area concerned with possible effects of several physiological chemicals that may affect VI. Mayer and Bates (1952) demonstrated that glucose had some regulatory action on VI of monogastrics. Dowden and Jacobson (1960) speculated that VFA's play a similar role in the ruminant since they replace glucose as an energy source. They injected VFA's at 12.5 percent of the daily energy requirement and found that voluntary intake was decreased ($P<.005$).

In another series of trials Jacobson (1966) reduced feed intake significantly ($P<.01$) by infusing acetic acid at the rate of 5 to 10 percent of the normal energy intake for three consecutive days. There was a significant interaction of blood levels of butyrate, acetate, and propionate with feed intake which suggested that the short term regulating mechanism of feed intake was not dependent on one metabolite but that it was a complex control mechanism which was apparently affected by several variables. More work is needed to clarify this relationship.

Relationship of Voluntary Intake to Chemical Constituents of Forage

Crampton et al. (1960) indicated that the relative importance of VI and energy digestibility on NVI is 70 and 30 percent, respectively. This suggested that forage intake was of greater importance to animal performance than digestibility. Conrad (1966) and Jacobson (1966) stated that gastro-intestinal fill was not as important to VI as it was first suggested. However, if fill or rumen distention is a limiting factor, feeds high in acid detergent fiber (ADF) and acid insoluble lignin (AIL) would limit intake. Van Soest (1966) synthesized the foregoing into a workable hypothesis as follows: Diets high in cell-wall constituents (ADF and AIL) allow the passage of fiber particles. The back-pressure from this may limit the intake of forages high in cell-wall constituents. Forages low in cell-wall constituents such as early-cut forages and legumes, result in increased fiber digestibility, decreased rumen retention time, and increased VI. Blaxter (1962) observed a depression of intake of rye grass with a high cell-wall constituent.

Relationship of Voluntary Intake with Rumen, VFA and Digestibility

Tenner et al. (1966) investigated the effect of intake on digestibility and rumen fluid components. Within the level of intake studied, the intake of a high quality forage did not affect the digestibility of dry matter or other major nutrients. Increased intake was associated with increased VFA concentrations, lower pH, and lower concentrations of isobutyric and isovaleric acid. Hemsley and Moir (1963) reported that these latter acids aid in fiber digestion.

Relationship of Animal Performance with Changes in Rumen Microbial Activity

Morris et al. (1965) reported that the addition of phosphorus or nitrogen did not affect cellulose digestion. Shaw et al. (1960) demonstrated that both rate and efficiency of gain in beef cattle may be regulated by some control of the rumen microbial metabolism. By altering microbial activity, increased efficiency of utilization of VFA's and increased digestibility of feedstuffs have been accomplished. This manifests itself in the form of increased animal performance--the ultimate goal of the livestock producer.

CHAPTER III

EXPERIMENTAL PROCEDURE

Experiment 1 was conducted using heifers grazed on three pasture types (*viz*. fescue, orchardgrass, clover, and fescue-orchardgrass-clover). *In vivo* and *in vitro* VFA production and *in vitro* dry matter digestibility of the forage were determined monthly during the grazing season. Chemical composition of randomly clipped samples (representative of the pasture) and of samples of each of the major plant species was determined for each pasture during each grazing period. Legume percentage was visually estimated and a legume index (product of legume percentage and legume height) was calculated.

Experiment 2 was conducted using steers grazed on two types of pastures (*viz*. fescue-lespedeza and orchardgrass-clover). Two steers grazing each type of pasture were used to estimate voluntary intake (VI) and the relationship of intake and ADG was studied.

Rumen fistulated steers were used for both *in vivo* and *in vitro* fermentation studies. A fistulated steer was maintained on each type of pasture. Oral rumen liquor for subsequent VFA analysis was taken with a stomach pump from each heifer and rumen fistulated steer.

The heifers and steers were weighed monthly and ADG was calculated. Backfat thickness of the heifers was measured ultrasonically to obtain some measure of the composition of gain resulting from different pasture types. Results from visual and laboratory techniques were used to predict ADG.

I. EXPERIMENTAL PASTURES

Pastures used in Experiment 1 consisted of two five-acre pastures each of fescue (FES), of orchardgrass-clover (OC), and of fescue-orchardgrass-clover (FOC). The fescue pastures had been renovated in the fall of 1952 and the orchardgrass-clover pastures had been seeded in the spring of 1953. The fescue-orchardgrass-clover pastures were a result of the invasion of orchardgrass pastures by the hardier tall fescue. Although these pastures were old and represented diverse seedings, they provided the wide variation in quality of pasture forage needed to test the predictive ability of various evaluation methods. The three pasture types contained the same plant species but differed in their proportions. OC pastures contained some tall fescue (10 to 20 percent), orchardgrass (40 percent), and Ladino clover (40 percent). FOC pastures contained the same major plant species but in different proportions, namely fescue (40 percent), orchardgrass (40 percent), and clover (20 percent). FES pastures contained a low percentage of clover and 15 to 20 percent orchardgrass.

The pastures used in Experiment 2 were two three-acre pastures of fescue-lespedeza (FL) and two three-acre pastures of orchardgrass-Ladino clover (OC). Lespedeza had been established in an old fescue sod in the spring of 1962, and the orchardgrass-clover pastures had been reseeded in the fall of 1961. These pastures at the University of Tennessee Blount Farm had been used for several years for steer and heifer grazing studies. Based on previous animal performance and visual pasture scores, these four pastures were divided into two pasture pairs (two FL and two OC). One pasture-pair of each type, equal in potential productive capability resulted from this arrangement.

II. DETERMINATION OF PASTURE SCORE AND FORAGE UTILIZATION

Each pasture was scored at the beginning and end of each grazing period in Experiment 2 and at two week intervals in Experiment 1. Pastures were visually scored according to the Tennessee pasture scoring procedure (White, 1960). The height and stage of maturity of each of the major species and the percentage that each contributed to the pasture sward was recorded.

Utilization of the current forage growth (defined as percent of total weight of available forage grazed) was estimated by the key forage plant method, an ocular estimate method used by the Bureau of Land Management (1966). Utilization checks were made several times during the grazing season. Both the Tennessee pasture score technique and the key forage plant method for determining utilization were used to adjust the stocking rate using a "put and take" system to attain uniform use of each pasture within each treatment.

III. EXPERIMENTAL ANIMALS

Experimental Heifers

Twenty-four Hereford heifers were used in Experiment 1. These animals were obtained from the University herd at an average weight of 235 kg. Each heifer had been dosed with thiabendazol two weeks before initiation of the experiment. After dividing these animals into six uniform groups of four each on basis of weight, grade, and fat thickness, they were placed on their respective pastures. No supplemental feed was provided during the grazing phase. All animals were weighed and fat thickness at the 12th rib was measured. The ADG and change in fat thickness (estimated ultrasonically) during each of the periods was calculated.

Rumen-fistulated Steers

Rumen-fistulated steers were used in both experiments for *in vivo* VFA production and *in vitro* digestible dry matter studies. Throughout both grazing trials, one rumen-fistulated steer was maintained with production animals on each type of pasture in the study. This required three fistulated steers for Experiment 1 and two fistulated steers for Experiment 2.

IV. ESTIMATION OF SUBCUTANEOUS FAT THICKNESS

A method to measure the composition of body weight gain adds a new dimension to pasture forage evaluation studies. Ultrasonic estimates of subcutaneous fat thickness were made on each of the 24 heifers on Experiment 1. The measurement was made at the end of each grazing period at the time the animals were weighed. The hide and subcutaneous fat thickness of each heifer was measured ultrasonically with a Model 12 Bronson Sonoray over the posterior edge of the twelfth rib at a point three-fourths of the distance from the dorsal midline and the outer edge of the *L. dorsi* muscle.

V. COLLECTION OF RUMEN LIQUOR AND DETERMINATION OF pH

Wang (1968) utilized rumen-fistulated steers to establish the time after grazing in which VFA concentration was the most highly correlated with ADG. Based on results of Wang (1968), it was decided that the heifers and rumen-fistulated steers would be removed from the pasture the evening before (12 hours before) sampling day. They were moved to the pasture for grazing and returned to the corral for rumen liquor collection one to two hours after grazing had ended.

Oral rumen liquor samples were collected from each heifer and each rumen-fistulated steer with a stomach pump. A water aspirator capable of pulling mercury in a vertical tube to a height of 20 mm. was sufficient to remove rumen fluid. Rumen liquor samples from the steers were also taken from the rumen through the fistula. These were for comparison of oral and fistula samples taken from the same animals and for comparison with work by Wang (1968).

Approximately 200 ml. were collected in duplicate and filtered through eight layers of cheese cloth. Each sample was thoroughly mixed before and after the mixing process. Using a 50 ml. syringe, 20 ml. of rumen liquor were placed in a 35 ml. sample bottle which contained 1 ml. of 5% $HgCl_2$ (Erwin et al., 1961). The reageant $HgCl_2$ prevented further chemical reactions in the liquor by killing the microorganisms. The samples were stored in the laboratory at -10° C for later VFA determination. The pH of the samples was determined immediately after the sample was filtered by the use of a Sargent Model S 30007 portable pH meter.

VI. COLLECTION OF FORAGE SAMPLES

During Experiment 1, randomly clipped forage samples which represented the forage available in the pasture and samples of each of the major species were obtained by the investigator on the median day of each weigh period. Only random samples (representative of the pasture) were clipped in Experiment 2. Forage samples in each experiment were clipped on the median day of each weigh period. Random samples were clipped according to the method of High (1966).

VII. CHEMICAL ANALYSIS

Determination of the Chemical Constituents in Pasture Samples

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

The samples were analyzed for nitrogen, ash, and moisture by the A.O.A.C. (1960) method, for acid detergent fiber (ADF) and acid insoluble lignin (AIL) by the Van Soest (1963) method, and for soluble carbohydrates by the Viles and Silverman (1949) method. Significance of differences in chemical composition between species of forages in each pasture were determined by analysis of variance.

<u>Determination of In Vitro Dry Matter Digestibility of the Pasture Samples and Collection of Supernatant Liquor</u>

In vitro digestible dry matter (DDM) of the forage samples was determined by the Tilley and Terry (1963) method. Digestible organic matter (DOM) was calculated as the ratio of percentage DDM and percentage organic matter. Inoculum was collected from rumen-fistulated steers grazing the different types of pasture in each experiment. Each forage sample was analyzed using inoculum from steers grazing the type of pasture from which the samples were clipped. Supernatant liquor from the first stage of the Tilley and Terry (1963) method was used to determine *in vitro* VFA production per gram of forage dry matter. In Experiment 1, supernatant liquor was collected at 12-, 24-, 36-, and 48-hour *in vitro* fermentation times. These samples were stored at -10°C for later VFA determination.

<u>Determination of Volatile Fatty Acids</u>

VFA was determined in duplicate using the method described by Erwin *et al*. (1961). A Model 600-C Aerograph gas chromatograph equipped with a hydrogen flame ionization detector was used in this determination. Nitrogen was used as a carrier gas. Both hydrogen and nitrogen were supplied by high purity commercial sources. Operation conditions were as follows: (1) oven temperature--120°C, (2) injector temperature--200°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_2PO_3 on 60/80 washed chromosorb W column (Erwin *et al*., 1961). Peak height was used to calculate VFA concentration (Wang, 1967). *In vivo* concentration was expressed as millimoles per liter (mmoles/liter) of fluid and molar percentage of total acids measured. *In vitro* VFA production was expressed as millimoles per gram of dry matter per liter of supernatant fluid from the artificial rumen.

VIII. STATISTICAL ANALYSES

Coefficients of Simple Correlation

Coefficients of simple correlation among ADG, *in vivo* VFA concentration, *in vitro* VFA concentration and production, *in vitro* DDM, pH values, and pasture scores within the different pasture-types were used in Experiments 1 and 2. When *in vivo* VFA concentration from rumen-fistulated steers was included as a variable in calculating coefficients of correlation, data for individual pastures were not available and mean data of each pasture type for all the other variables were used.

Multiple Regression Equations.

Multiple regression equations to predict ADG of grazing yearling beef cattle were developed from a multiple regression analyses of these data. The general form of the equations is as follows:

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

Where:

$i = 1, 2, \ldots \ldots \ldots 24$

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

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

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

The X_j's are the independent variables measuring pasture characteristics determined from pasture score, laboratory analyses of clipped samples, in vitro VFA production, and in vivo VFA concentration and pH in the rumen.

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

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

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

The calculations were made ignoring any effect of period or treatment.

IX. ESTIMATION OF VOLUNTARY INTAKE OF PASTURE FORAGE

Two Hereford steers averaging 246 kg. were placed on each type of pasture (one orchardgrass-clover and one tall fescue-lespedeza) and grazed without supplemental feed for five months during Experiment 2 beginning in June and ending in October. Salt and minerals were available ad. lib. There were five monthly grazing periods for which individual animal gains were calculated. Forage samples representative of each pasture were taken in the middle of each period. In vitro dry matter digestibility of these forage samples was determined with the method of Tilley and Terry (1963).

Also in the middle of each grazing period, the steers were fitted with a feces collection harness and bag. They were allowed to graze one or two days with the harness. During this adjustment period weighted burlap bags were attached to the harness to simulate the weight of a full feces bag. Following the adjustment period, the feces bags were attached to the harness and removed after 24 hours. The wet feces were weighed and dry matter content was determined.

Forage dry matter intake (I) was calculated by the following equation of Moore (1966):

$$I = \frac{E \times 100}{100 - D}$$

Where:

I = intake of DM/24 hours

D = digestion coefficient of dry matter

E = excretion of DM/24 hours.

After forage dry matter intake was calculated, it was converted to digestible dry matter intake which is the product of dry matter digestibility and dry matter intake. This was converted to TDN intake with the following equation modified from Heaney and Pidgen (1964):

$$\text{TDN intake} = 5.81 + .869 \text{ DDM intake}$$

An estimate of TDN intake above maintenance was calculated from the maintenance component of Winchester and Hendricks' (1953) formula:

$$\text{MAINTENANCE (lbs. of TDN)} = .0553 \, (W_{\text{lb.}})^{2/3}$$

The TDN required for maintenance of each animal was deducted from total TDN intake in order to estimate TDN intake above maintenance.

The actual intake of DM per 24 hours of each steer was also used to calculate Nutritive Value Index (Crampton, 1960) as the product of relative intake (RI) and *in vitro* dry matter digestibility, where

$$RI = \frac{\text{Actual Intake of DM}}{80\ (W_{kg.})^{3/4}}$$

CHAPTER IV

RESULTS AND DISCUSSION

I. AVERAGE DAILY GAIN AND CHANGE IN FAT THICKNESS OF HEIFERS GRAZING THREE PASTURE COMBINATIONS OF FESCUE, ORCHARDGRASS AND LADINO CLOVER

Data from Experiment 1 shown in Table 1 indicated that these results are similar to results reported by High and Hobbs (1964) and Wang (1968) during relative time periods of the grazing seasons. In the afore-mentioned studies steers were used to evaluate pastures, whereas the data reported herein were collected from heifers. This difference must be considered when these data are compared with previous work. Gains shown in Table 1 are somewhat less than those previously reported for animals grazing these pastures. The heifers gained only .12 kg. on FES pastures, .39 kg. on OC pastures, and .32 kg. on FOC pastures. The gains were less than .78 kg. and .67 kg. per steer per day reported by High and Hobbs on OC and FL pastures, respectively, and gains of .62 kg. and .51 kg. per steer per day were reported by Wang (1968). It should be noted that the fescue pastures used by the above investigators contained lespedeza which reached a grazable height at a time during the grazing season when fescue was least palatable. Such was not true for pastures used in the heifer trial since all legume plants were killed by spraying the fescue pastures with 2-4-D (2,4-dichlorophenoxyacetic acid) at the rate of .40 kg. of acid equivalent per acre. This

TABLE 1

AVERAGE DAILY GAIN OF HEIFERS SUMMER GRAZED ON THREE TYPES OF PASTURE

Period	Date	Pasture Type[1] FES	OC	FOC
		kg.		
1	June	.40	.75	.50
2	July	.38	.37	.64
3	August	-.23	.26	.09
4	September	-.16	.20	.25
Total Experimental Period[2]		.12[a]	.39[b]	.32[b]

[1]Each pasture type represents two replications of four heifers each.

[2]Means with different superscripts are significantly different (P<.05).

concentration of acid did not require removal of the cattle. The gain of .75 kg. attained by the heifers grazing OC pastures was comparable with the .72 kg. per steer per day reported by High and Hobbs (1964) from OC pastures and .69 kg. or .73 kg. per steer per day reported by Wang (1968) from data collected from similar pastures during the same period of the growing season. The heifers grazing the FOC pastures gained .50 kg. and .64 kg. per head per day during the first two periods, respectively. This is somewhat more than the .26 kg. and .51 kg. per steer per day reported by Wang (1968) from FL pastures of similar quality during the same period of the growing season.

No previous data were reported concerning the change in fat thickness of yearling cattle being summer grazed on grass. Table 2 shows the changes in fat thickness of the heifers grazing the three pasture types during successive grazing periods. There were no differences noted between heifers grazing OC and FOC pastures, but there was a significant difference ($P<.05$) in change in fat thickness of heifers grazing FES pastures and either of the other two types. In fact, the data presented in Table 2 indicated that heifers grazing the FES pastures had significantly ($P<.05$) less fat over the thirteenth rib after the 114-day grazing period than they had at the beginning of the grazing trial.

These data indicated that OC pastures consistently supported a larger ADG as well as greater increases in subcutaneous fat. Increased fescue utilization was followed by decreases in daily

TABLE 2

CHANGE IN FAT THICKNESS OF HEIFERS SUMMER GRAZED ON THREE TYPES OF PASTURE

Period	Date	Pasture Type[1]		
		FES	OC	FOC
		mm.		
	Initial fat thickness	1.80	1.67	1.75
1	June	-.15	.25	.55
2	July	.10	.00	.15
3	August	-.30	.15	.10
4	September	.05	.30	-.05
Total Experimental Period[2]		$-.45^a$	$.95^b$	$.70^b$

[1]Each pasture type represents two replications of four heifers each.

[2]Means with different superscript letters are significantly different ($P<.05$).

gain and fat thickness during all periods. The decreased gains in body weight and fat thickness during the latter part of the grazing season were due likely to one or more of the following reasons: (1) by the end of the season tall fescue was the major specie, (2) the grasses were advanced in maturity and of lower nutritive value, (3) the ambient temperature was extremely high which may have directly affected animal performance, and (4) relatively lower rainfall was observed which decreased the growth of the forage plants.

ADG and Change in Fat Thickness

Several individual animals that were apparently gaining small amounts of body weight continued to lose body fat. This raised the question as to how much body weight yearling heifers grazed on pasture must gain per day to maintain subcutaneous fat. Table 3 shows the relationship between fat thickness estimates and changes in body weight (ADG). The simple and partial correlation coefficient between ADG and change in fat thickness was .54 and .45, respectively. A simple regression analysis revealed that the independent variable, change in fat thickness, accounted for only 26 percent of the variation in ADG. The following equation described this relationship:

$$Y_i = .24 + .089\ X_1, \quad r^2 = .26$$

Where:

Y_i = predicted ADG

X_1 = change in fat thickness.

TABLE 3

RELATIONSHIP BETWEEN ADG AND FAT THICKNESS ESTIMATES (mm.)

	Overall Mean	Simple Correlation Coefficient	Partial Correlation Coefficient
ADG (kg.)	0.28	----	----
Initial fat thickness	1.77	-.30	-.29
Final fat thickness	2.19	.25	.17
Change in fat thickness	0.04	.54**	.45*

*P<.05.

**P<.01.

By solving this equation for zero change in fat, it appeared that heifers grazing pastures must gain in excess of .24 kg. per head per day to keep subcutaneous fat at a constant thickness.

II. BEEF PRODUCTION PER ACRE OF PASTURE

Beef production per acre of forage was estimated for each grazing period by the product of grazing days per acre and the ADG of performance or tester animals. Grazing days per acre was the product of the number of "tester" and "put-and-take" animals per acre and number of days grazed per period.

The "put and take" system, whereby extra calves were placed on pastures of abundant forage was used to attain uniform utilization of all pastures. The use of this system made necessary unequal numbers of animals in several pastures. These data were carefully recorded in the pasture score book at bi-weekly intervals.

Shown in Table 4 are the kilograms of beef produced and the grazing days per acre for the entire season. The heifers grazed on FES and OC pastures produced significantly more beef per acre than FOC pastures (35.1 and 29.1 versus 18.4) during the first grazing period; however, FOC and FES produced more the second grazing period (22.2 and 25.2 versus 9.2). Significantly ($P<.05$) less beef per acre was produced on FES pastures the third and fourth grazing periods as compared to the other pasture types. Available forage was never a limiting factor; therefore, the decreased animal performance was due to a change in quality of the forage.

TABLE 4

TOTAL BEEF PRODUCED PER ACRE ON FES, FOC, AND OC PASTURES FROM JUNE 1 UNTIL SEPTEMBER 15

Pasture Type	Period[1] 1	2	3	4	Season Average[1]	Total Grazing Days/Acre[1]
	kg.					
FES	35.1[a]	22.2[a]	-14.4[a]	-2.4[a]	23.6[a]	190.4[a]
OC	29.1[a]	9.2[b]	7.5[b]	4.9[b]	45.9[b]	117.8[b]
FOC	18.4[b]	25.2[a]	4.1[b]	6.3[b]	44.5[b]	137.2[b]

[1]Means in same column with different superscripts are significantly different (P<.05).

These data emphasized the importance of developing accurate techniques for predicting forage quality in terms of beef production so that losses similar to the third and fourth grazing periods could be foreseen before reduction in animal gain are actually experienced by the researcher or beef producer.

III. UTILIZATION OF THE AVAILABLE FORAGE BY GRAZING BEEF HEIFERS

The Utilization Handbook: Key Forage Plant Method by the Bureau of Land Management (1966) was used to measure differences in utilization of different species available in the pasture. Results illustrated in Figure 1 indicated that orchardgrass and clover were both utilized to a much higher degree. The final utilization of each major species was the same for each treatment which indicated that the investigator was successful in attaining a uniform utilization using the "put and take" system of grazing management. At any given grazing period each of the major species had been utilized in the following order: (1) clover, (2) orchard-grass, and (3) tall fescue.

IV. SPECIES COMPOSITION OF THE PASTURE SWARD AND ITS RELATION TO ANIMAL PERFORMANCE

Coefficients of simple correlation were calculated among ADG and percentages of fescue, orchardgrass, clover, and legume index of each pasture. Legume index was calculated as a product of clover height and the percentage of this legume on the sward.

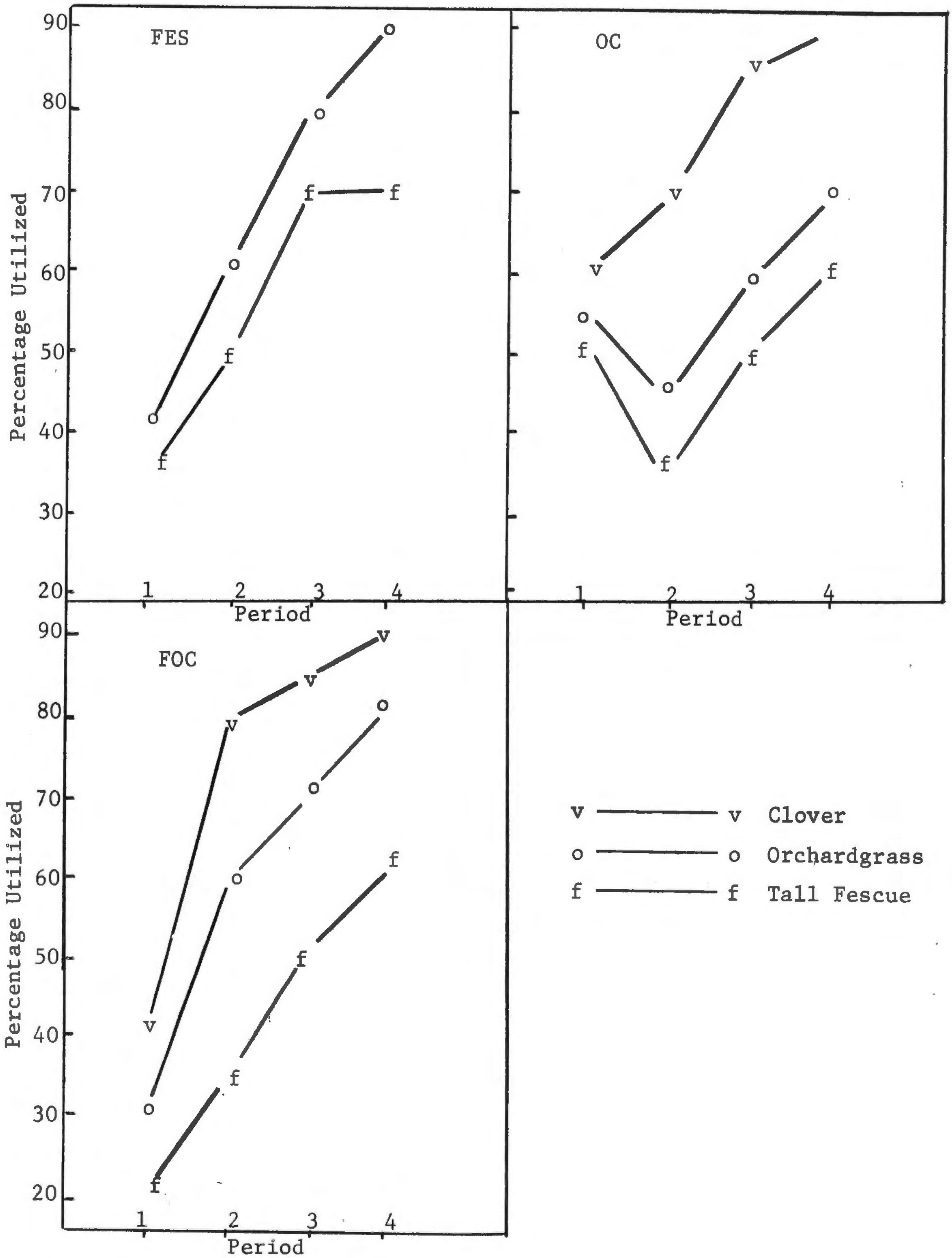

Figure 1. Utilization of major pasture species within each treatment.

This analysis (Table 5) indicates that there is a positive correlation between ADG and percentage of orchardgrass, clover, and legume index. A significant ($P<.05$) negative association is indicated between ADG and percentage fescue. Since orchardgrass and fescue were both included in this analysis, this negative association was due to the fact that fescue will not support ADG on the same level with the ADG attained by cattle grazing orchardgrass; thus, when fescue was increased at the expense of a superior forage (orchardgrass) it necessarily had a negative effect.

V. COMPARISON OF THE CHEMICAL COMPOSITION OF THE MAJOR SPECIES

Differences in chemical composition were used to measure the effects of utilization of different species. Since each of the major species was represented in each treatment in different percentages, the possibility was considered that differences in utilization of each plant species would affect its chemical composition. Figure 2 shows the crude protein content of individual forage species.

Orchardgrass was 1 to 6 percent higher in crude protein (organic matter basis) than fescue throughout the grazing season, but this difference was not significant. The 22 to 30 percent crude protein content of clover was significantly higher than the 10 to 20 percent crude protein in orchardgrass or fescue. This difference became greater as the season progressed since the percentage protein increased in clover and decreased in both fescue and orchardgrass.

TABLE 5

COEFFICIENTS[1] OF SIMPLE CORRELATION AMONG ADG AND PERCENTAGE SPECIES COMPOSITION AS ESTIMATED BY THE TENNESSEE PASTURE SCORING PROCEDURE

Variable Number	1 ADG	2 Percent Fescue	3 Percent Orchardgrass	4 Percent Clover	5 Legume Index
1	1.00	-.50	.54	.70	.71
2			-.54	-.85	-.72
3				.72	.53
4					.92

[1]Coefficients above .38 and below -.38 are significant ($P<.05$), and coefficients above .52 and below -.52 are highly significant ($P<.01$).

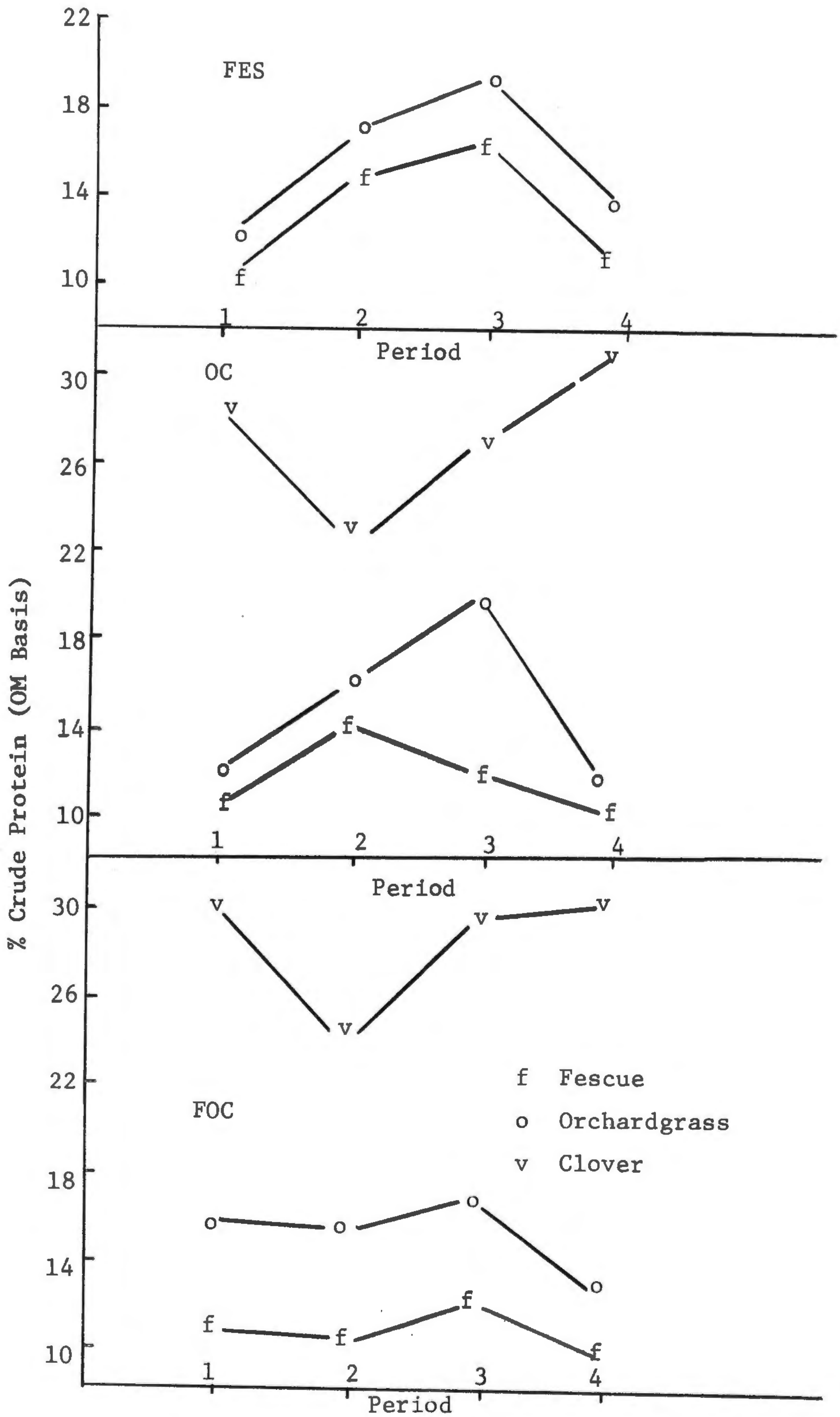

Figure 2. Crude protein content of each species in each treatment.

There was a significant increase (from 10 to 20 percent) in crude protein of orchardgrass and fescue from the first to the third grazing period. This indicated that grazing stimulated the growth of younger plant tissue which is higher in crude protein. After the third grazing period, the decrease in crude protein was probably due to a maturing of the plants and extremely hot weather which decreased regrowth of physiologically younger plant tissue which would have had a higher nitrogen content. Assuming that the animals attempted to select the plants higher in crude protein as indicated by High (1966), plants grazed late in the season (September) were not replaced by new growth, thus the total protein content of the pasture decreased.

Acid detergent fiber (ADF), acid insoluble lignin (AIL), and cellulose (ADF minus AIL) as measures of the cell wall constituents in each of the major species were compared to evaluate the effects of grazing and plant maturation on the cell wall and structural elements in the plants. These were considered to be the least digestible nutrients of importance to the ruminant animal but are deemed to be important factors that affect forage quality. The ADF and cellulose content of the two grass species considered were not significantly different within each period. As shown in Figure 3, the percentage of ADF and cellulose of clover was significantly ($P<.05$) and consistently lower than either of the grasses. There was a tendency for the forage to increase in ADF and cellulose content near the end of the season as the plants matured; but the

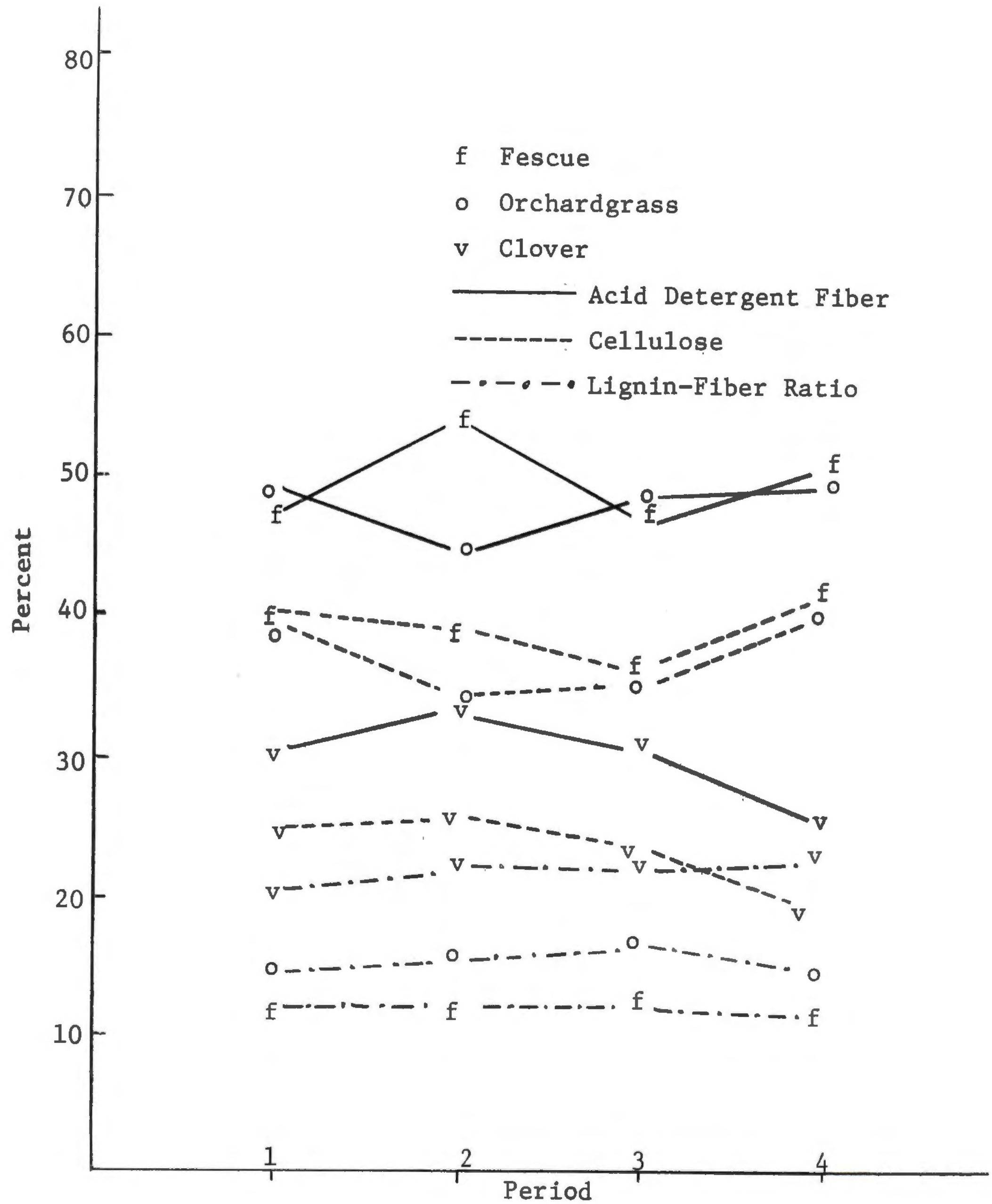

Figure 3. Acid detergent fiber, cellulose, and lignin-fiber ratio represented in each of the major species in three pasture types.

clover continued to decrease in ADF and cellulose because of very high utilization of this particular species. Any clover present near the end of the season was solely a result of new growth; therefore, lower cell wall constituents were expected. The percentage of the ADF that was in reality AIL was calculated for each period but was of no value in predicting ADG.

Lindsay (1959) found that the sugar economy of the ruminant affected the use of VFA's, particularly acetic acid. Grimes et al. (1967) reported that "soluble carbohydrates" (determined directly) are highly associated with ADG. The possibility of using this forage constituent to evaluate orchardgrass and fescue was investigated. The results are illustrated in Figure 4. At the beginning of the season the differences in carbohydrate content of orchardgrass and fescue were quite small and insignificant ($P>.1$). At the end of the season (September 15) the content of this component in orchardgrass or fescue was significantly ($P<.05$) lower (10 percent vs. 2 percent).

Digestible organic matter (DOM) of each of the key species was determined by using the in vitro digestible dry matter technique reported by Tilley and Terry (1963). As indicated in Figure 5, digestibility of organic matter of tall fescue and orchardgrass did not differ within periods, but there was a tendency for digestibility to decrease as the season progressed. This was due to decreases in rapidly metabolizable components such as protein and soluble carbohydrates and slight increases in fiber and lignin later in

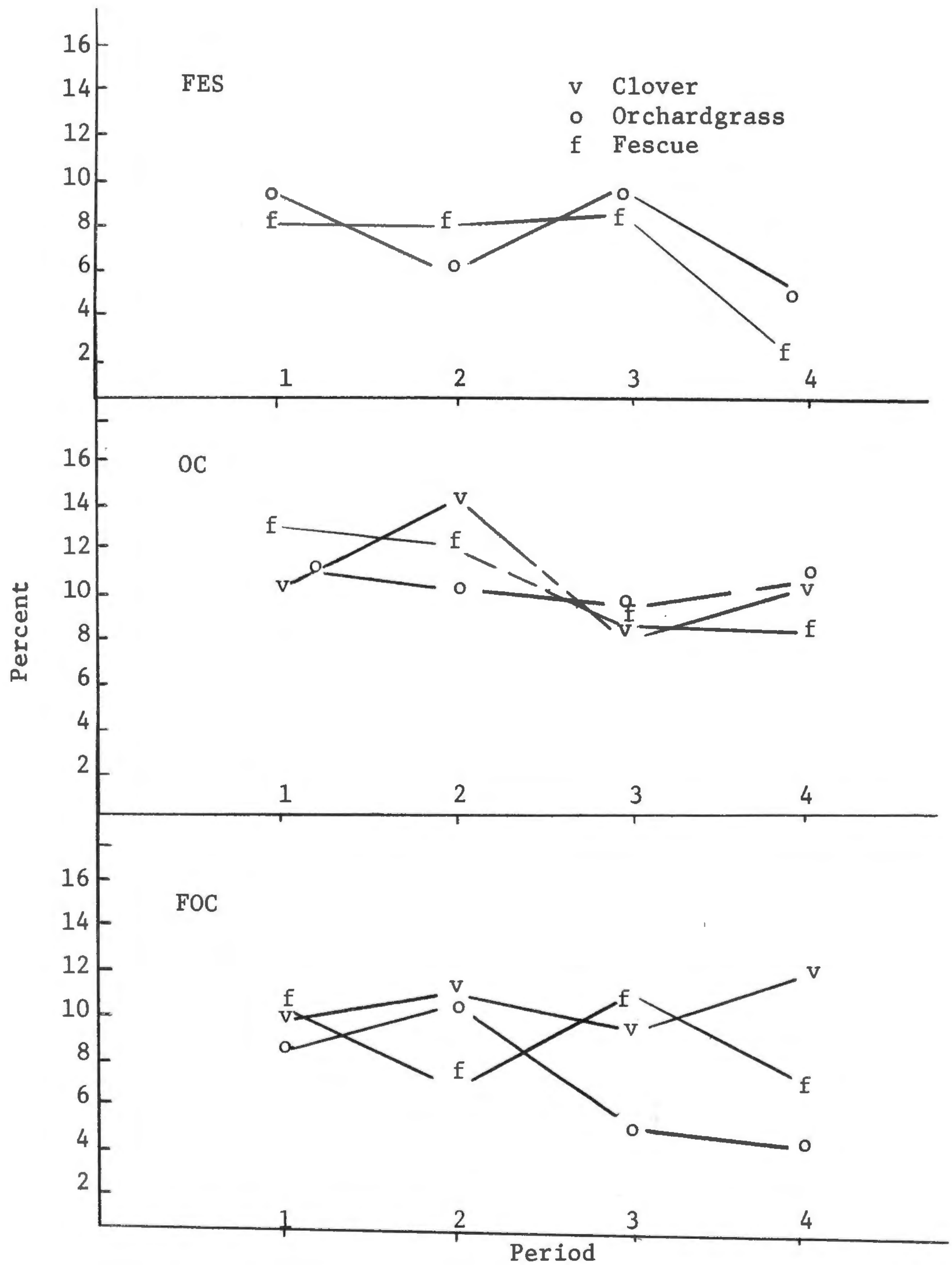

Figure 4. Soluble carbohydrate content of pasture forage in three pasture types.

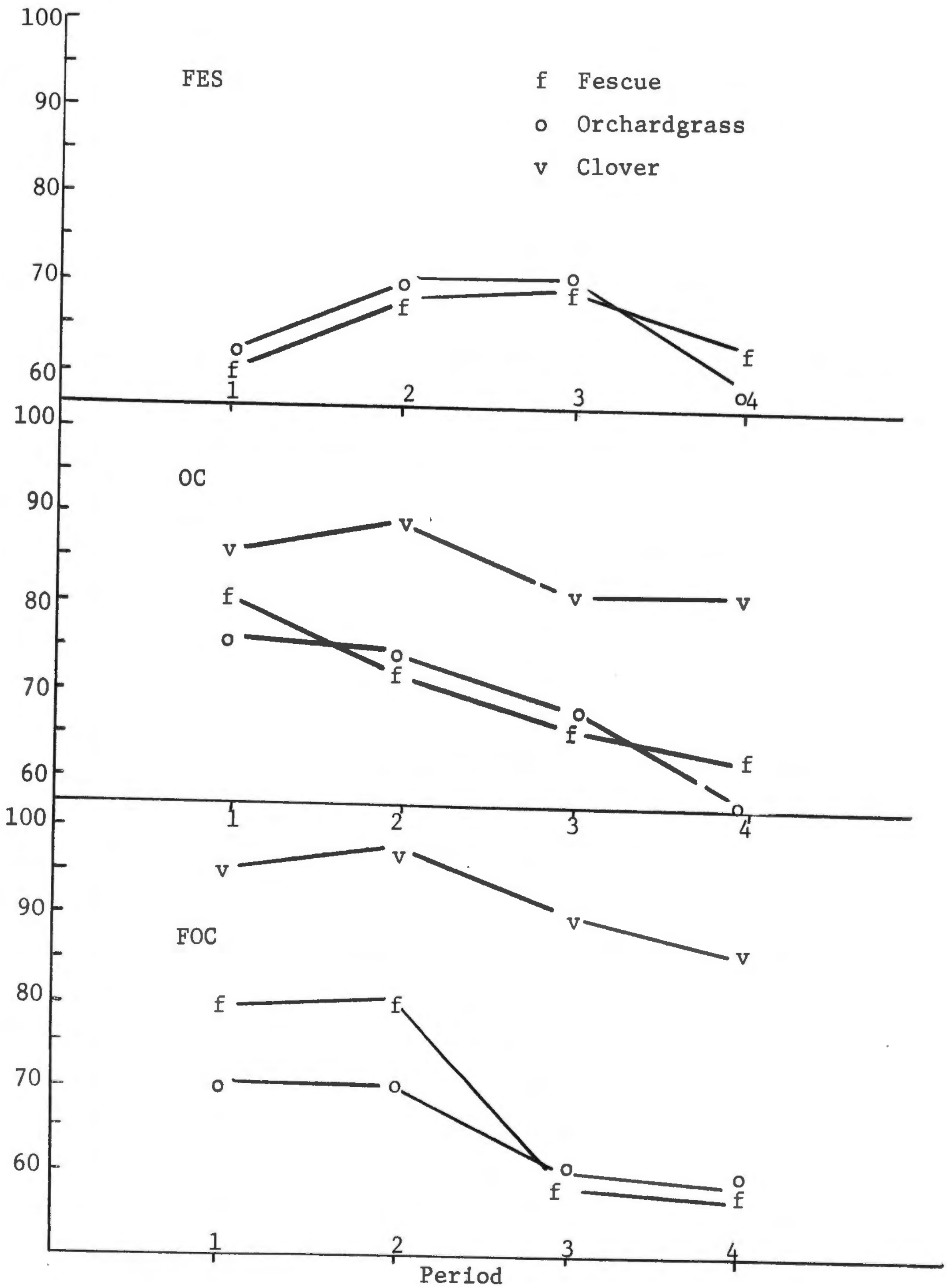

Figure 5. Digestible organic matter content of pasture forage in three pasture types.

the season as shown by chemical analyses of the forage. Clover was significantly ($P<.05$) more digestible (85 to 95 percent) in every period which partially explains its improvement of ADG when this legume is present.

Figure 5 illustrates *in vitro* digestible organic matter in each of the major species. The organic matter digestibility in fescue and orchardgrass was significantly lower in FES pastures (60-65 compared to 70 and 80) during the first grazing period and was slightly lower in the second. During the third and fourth grazing periods, there was no difference in organic matter digestibility of fescue or orchardgrass. The digestibility percentage ranged from 60 to 70 percent during the third period and 55 to 60 percent the fourth period. Orchardgrass tended to be the least digestible near the end of the season as compared to fescue or clover. It also seemed to suffer more as a result of high ambient temperature, lack of moisture, and general droughty conditions predominant near the end of the summer. The pasture score procedure revealed a general browning effect as a result of a dehydrated condition of the orchardgrass which along with physiological maturity may have contributed to its lower digestibility.

Relationship Between ADG and Chemical Constituents of Pasture Forage Samples

Sampling pasture forage is the most important as well as the most difficult part of forage research. If forage quality is to be related to animal production, the pasture sample needs to be a close facsimile of the diet of the animal. Esophageal-fistulated cattle have been used (High, 1965; Wang, 1968), but effects of saliva on nutrient elements of orchardgrass and fescue have been reported (Barth et al., 1969), however, not fully evaluated.

Many improved pastures consist of only two or three major species. Orchardgrass, tall fescue, and a legume are common combinations. It is probable that production is related to the composition of species making up the larger proportion of the diet. In an attempt to answer this question the chemical composition of a random composite sample representative of the pasture and each of the major species was determined. Simple coefficients of correlation between ADG and chemical composition of each of these samples are shown in Table 6. The highest coefficients of simple correlation were found between ADG and the chemical composition of orchardgrass and clover samples.

A more logical approach would be to use a technique which would reflect the relationship between mixtures of plant species being consumed and the production of animals grazing them. Compared to fescue greater percentages of the available orchardgrass and clover were utilized. This indicated that orchardgrass and clover made up a greater percentage of the diet; therefore, more of the ADG could be attributed to orchardgrass or clover than to tall fescue even though they were grown in the same pasture. As shown in Table 6, the chemical components consistently associated with ADG regardless of type of sample were digestible organic matter and soluble carbohydrates. The simple correlation coefficients between ADG

TABLE 6

COEFFICIENTS OF SIMPLE CORRELATION BETWEEN ADG AND CHEMICAL COMPOSITION OF PASTURE FORAGE

Item	Random[1]	Fescue	Orchard.	Clover[2]
Crude Protein (%)[3]	.20	-.24	-.12	-.17
DOM (%)[4]	.47*	.42*	.59**	.32
ADF (%)[5]	-.03	-.03	-.14	.11
AIL (%)[5]	-.01	-.01	-.40*	.25
Cellulose (%)[5]	-.05	-.03	-.57*	.06
AIL (%)[5]/ADF (%)[5]	-.12	-.01	-.35	.10
Sol. Carbohydrates (%)[6]	.32	.31	.46*	.44*

[1]Clipped to represent forage available in pasture.

[2]Clover was not present in FES pastures.

[3]Determined using the A.O.A.C. (1960) method for crude protein analysis.

[4]Determined using the Tilley and Terry (1963) technique for *in vitro* dry matter digestibility.

[5]Determined using the Van Soest (1964) detergent technique for analysing fibrous feeds.

[6]Determined using the Viles and Silverman (1949) anthrone technique.

*P<.05; **P<.01.

and digestible organic matter were .47, .42, .59, and .32 for the random, fescue, orchardgrass, and clover samples, respectively. The simple coefficients of correlation between ADG and soluble carbohydrates were .32, .31, .46, and .44 (Table 6) for the random, fescue, orchardgrass, and clover samples, respectively. This indicates that these two variables may be useful in explaining the variation in ADG of grazing animals.

VI. COMPARISON OF *IN VIVO* VFA CONCENTRATION ON THREE PASTURE TYPES

Collection of In Vivo Rumen Liquor Samples

Two possibilities exist for collection of rumen liquor samples from the live animal. Either rumen-fistulated animals or intact animals can be used. If rumen-fistulated animals are used, the liquor collection is relatively easy; however, if intact animals are used, a stomach tube must be used for liquor collection. Rumen-fistulated animals are expensive and troublesome to maintain when they are not being used for experimental purposes. Collection of rumen liquor from intact animals offers a method for obtaining rumen liquor from many animals, thereby, it is possible to relate VFA concentration of each animal with its production of meat or milk.

Total In Vivo VFA Concentration of Heifers Grazing Different Pasture Types

Table 7 shows the total VFA concentration of each of the pasture types based on liquor samples from 8 individual animals grazing each type of pasture. In the beginning there was the tendency for VFA

TABLE 7

COMPARISON OF IN VIVO TOTAL VFA CONCENTRATION OF ORAL SAMPLES FROM THREE DIFFERENT PASTURE TYPES

Period	Pasture Type[1]		
	FES	OC	FOC
	mmoles/liter		
1	72.06^{ef}	90.19^{ab}	96.21^{a}
2	72.07^{ef}	82.26^{bc}	62.13^{g}
3	71.80^{ef}	79.80^{cd}	68.25^{fg}
4	66.15^{fg}	75.20^{de}	63.49^{g}

[1]Means in same rows and columns with same superscript letters are not significantly different (P>.1).

patterns of rumen liquor from heifers grazing OC and FOC pastures to be alike indicating similarity of these pasture types previously shown by pasture score and animal performance. Statistical analysis showed that there was a tendency for VFA patterns of rumen liquor from FES and FOC pastures to become more alike as the season progressed. This indicated that the diet of the animals on FOC pastures became more like the diet of animals grazing FES pastures. This indication was also verified by the pasture score species composition percentages because the predominant species in both FES and FOC pastures during the last grazing period was tall fescue. The pasture score and utilization techniques indicated that there was a progression over the season to higher percentages of tall fescue and lower percentages of clover and orchardgrass. Clover was more persistent in OC pastures which accounted for persistently high VFA concentrations in heifers grazing this type of pasture.

Relationship of ADG and In Vivo VFA in Samples Collected from Intact Animals

Several factors affected the concentration of VFA's over the entire grazing season. The effects of treatment and period were of interest to the investigators but could be evaluated only if individual biological variation was statistically insignificant. Twenty-four heifers on three treatments were each stomach-pumped during four grazing periods. Variation of VFA concentration between animals was large, and the relationship was not consistent within any one period of treatment. For this reason the ADG's and VFA concentrations for the entire season for each animal were averaged. Since there were 24 heifers, this meant there were 24 ADG's and 24 VFA concentrations for each VFA considered in this analysis. This eliminated the variation of ADG and VFA concentration between periods; therefore, the individual VFA concentrations associated with ADG and differences between treatments could be evaluated without the influence of period variation.

The simple coefficients of correlation summarized in Table 8 indicated that there is a significant ($P<.05$) association between individual ADG and acetic, butyric, acetic-propionic ratio, and total VFA concentration. No significant association between ADG and propionate was indicated which is inconsistent with findings in the literature.

To measure the direct association between ADG and individual VFA's without the influence of their association with other VFA's also associated with ADG, coefficients of partial correlation between ADG and individual VFA's were calculated. When expressed as molar percentage, butyric and propionic acid were significantly correlated (Table 9). Rumen pH and acetic-propionic ratio were also found to be significantly ($P<.01$) correlated with ADG. Millimoles of acetic, butyric, isovaleric, and total volatile fatty acids were significantly correlated at the 5 percent level of probability. Annison and Lewis (1959) found a negative association between pH and VFA absorption. Although no attempt was made to measure absorption in this study, the above findings are in agreement

TABLE 8

COEFFICIENTS[1] OF SIMPLE CORRELATION AMONG ADG AND IN VIVO VFA CONCENTRATIONS[2] (mmoles/liter)

	1 ADG	2 Acetic	3 Propionic	4 Butyric	5 Isoval.	6 Val.	7 A/P	8 Total
1	1.00	.40*	-.19	.51*	.31	.07	.42*	.42*
2			.85**	.74**	.67**	.18	.53**	.99**
3				.58**	.63**	.12	-.85**	.86**
4					.67	-.08	.23	.72**
5						-.06	.23	.72**
6							.13	.20
7								.31
8								1.00

[1]Coefficients above .205 and below -.205 are significant (P<.05), and coefficients above .267 and below -.267 are highly significant (P<.01).

[2]Liquor samples were collected with a stomach pump from individual performance heifers and VFA data were related to ADG of the same heifers.

*P<.05.

**P<.01.

TABLE 9

COEFFICIENTS[1] OF PARTIAL CORRELATION AMONG ADG, IN VIVO VFA CONCENTRATIONS,[2] AND RUMEN pH

Item	mmoles/liter	Molar Percent[3]	pH
Acetic	.21	.07	----
Propionic	.00	-.31	----
Butyric	.39*	.38*	----
Isovaleric	.28	.17	----
Valeric	-.02	-.20	----
Total VFA	.24	----	----
Acetic/Propionic	.35	----	----
Rumen pH	----	----	.46*

[1]Coefficients above .205 and below -.205 are significant (P<.05), and coefficients above .267 and below -.267 are highly significant (P<.01).

[2]Liquor samples were collected with a stomach pump from individual performance heifers and VFA data were related to ADG of the same heifers.

[3]Expressed as a percentage of total mmoles/liter of acid measured.

*P<.05.

because increased pH was associated with decreased ADG, probably because of decreased absorption of VFA's considered.

Relationship of ADG and In Vivo VFA Concentrations in Sample Collected Via Stomach Pump and Fistula

In order to compare VFA from oral and fistula samples from the same animal, rumen-fistulated steers were grazed on each type of pasture and rumen liquor was collected with a stomach pump and through the fistula. An effort was made to collect the fistula samples inside the rumen near the location of the stomach tube used to collect the oral samples. After VFA analyses (Erwin, 1961), the data were related to ADG by calculating coefficients of correlation which were then available for comparison with work by Wang (1968). Table 10 shows the relationship between ADG and each of the VFA's considered. When data from the fistula-samples were analyzed, there were highly significant ($P<.01$) positive associations between ADG and concentrations (mmoles/liter) of acetic, propionic, butyric, and total VFA. A significant ($P<.05$) association was noted between ADG and valeric acid. The coefficients of simple correlation were .68, .71, .73, .55, and .71, respectively. The coefficient for propionic, .71, agreed with that reported by Wang (1968).

When the oral samples from the same fistulated animals were analyzed, no coefficient of simple correlation between ADG and any VFA was highly significant. The magnitude of coefficients of correlation with ADG was reduced in the case of each VFA considered, but the acids referred to above were only significant at the 5 percent

TABLE 10

COMPARISON OF SIMPLE COEFFICIENTS[1] OF CORRELATION BETWEEN ADG AND VFA CONCENTRATIONS USING ORAL- OR FISTULA-RUMEN LIQUOR SAMPLES

Item	Type of Sample: Fistula[2]	Oral[2]	Oral[3,4]
Acetic			
mmoles/liter	.68**	.57*	.40**
Molar percentage[5]	.13	.42	.04
Propionic			
mmoles/liter	.71**	.40	-.19
Molar percentage[5]	-.27	.49	-.40**
Butyric			
mmoles/liter	.73**	.64*	.51**
Molar percentage[5]	.25	.20	.37**
Isovaleric			
mmoles/liter	.33	.00	.31**
Molar percentage[5]	.25	.61*	-.07
Valeric			
mmoles/liter	-.55*	.32	.07
Molar percentage[5]	.25	.14	-.27**
Total VFA			
mmoles/liter	.71**	.56*	.42**

[1]Coefficients above .516 and below -.516 are significant (P<.05), and coefficients above .680 and below -.680 are highly significant (P<.01).

[2]Samples taken from rumen fistulated steers grazing each pasture type.

[3]Coefficients above .205 and below -.205 are significant (P<.05), and coefficients above .267 and below -.267 are highly significant (P<.01).

[4]Samples taken with a stomach pump from 8 normal (nonfistulated) heifers grazing on each pasture type.

[5]Calculated as a percentage of total acids measured.

*P.<05; **P<.01.

level of probability. Propionic and valeric were not associated with ADG when oral samples were analyzed.

Reduction in the magnitude of coefficients of correlation between ADG and VFA, especially in the case of propionic acid, is a serious consequence of taking samples via stomach pump. Further use of this technique demands increased effort to minimize the effect of saliva on VFA concentration. To avoid this problem, Buchanan-Smith _et al_. (1967) injected a 3/8 inch by 5 inch trocar needle posterior to the rib cage and collected 200 ml. of rumen liquor.

VII. _IN VITRO_ VFA PRODUCTION OF DIFFERENT TYPES OF SAMPLES

In vitro experiments allow control of many factors which can not be controlled _in vivo_. Also many more feed samples can be studied using an _in vitro_ system. An _in vitro_ study of either dry matter digestibility or VFA production requires a source of microorganisms for the artificial rumen.

In an attempt to answer questions concerning sampling procedure for VFA analysis, the random sample representing the pasture and pure samples of each specie were analyzed for comparison of acid producing ability. It was postulated that the VFA's produced from plant species primarily utilized by the animals are more related to animal performance than VFA's produced by samples representative of all forage present in the pasture. Knowledgeable identification of these more desirable plants can be made; thus indicator species of pasture quality based on VFA or chemical analysis can be established.

Comparison of Sample Type and the Effect of Grazing Period

A comparison of the effects of sample types of grazing period on *in vitro* VFA concentration is shown in Table 11. Clover was significantly ($P<.05$) higher in all *in vitro* VFA's measured. Orchardgrass had the least potential for producing VFA's. It is likely that the large difference in orchardgrass and clover contributed to the variation in the random sample. Disproportionality of these two species relative to forage actually grazed caused the random sample to not be representative of forage actually utilized. In general, results of VFA analysis of a random sample resembled the analysis of either fescue or orchardgrass probably due to the proportion of these two species in the sample.

Grazing period is an important effect since differences in VFA-producing ability in each period were initially postulated to be important criteria for predicting ADG. All *in vitro* VFA's measured were significantly ($P<.05$) reduced in the available forage during the last grazing period except for valeric acid. Valeric acid was significantly ($P<.05$) increased during the last period. Variation in total volatile fatty acid was due to variation in acetic acid since this acid was approximately 65 percent of the total acids measured. The tendency for the available forage to decrease in volatile fatty acid producing potential was evident during the July grazing period. This suggested a possible explanation for the decrease in quality of the forage reflected in the decreased body weight gains of the grazing heifers during this period.

TABLE 11

LEAST SQUARES CONSTANTS[1] FOR IN VITRO VFA'S (mmoles/liter) EXPRESSED AS DEVIATIONS OF THE MEAN

	Volatile Fatty Acid[2]						
	C_2	C_3	C_4	$i\text{-}C_5$	$n\text{-}C_5$	C_2/C_3	Total
Mean	83.50	26.35	9.96	2.84	1.80	3.17	124.30
	Deviation from Mean						
Sample Type							
Random	-3.07^{a}	-1.69^{a}	-0.55^{a}	-0.06^{a}	-0.21^{a}	-0.07^{a}	-5.92^{a}
Fescue	-6.02^{a}	-0.05^{b}	-0.80^{a}	-0.74^{b}	0.08^{b}	-0.22^{b}	-6.38^{a}
Orchardgrass	-14.32^{b}	-4.04^{c}	-1.39^{b}	-0.06^{a}	-0.60^{c}	-0.03^{ab}	-21.22^{b}
Clover	23.41^{c}	5.78^{d}	2.74^{c}	0.86^{c}	0.73^{d}	0.18^{c}	33.52^{c}
Grazing Period							
June	5.47^{a}	-0.07^{a}	-0.98^{a}	0.04^{a}	-0.26^{a}	0.21^{a}	4.31^{ac}
July	10.65^{a}	1.67^{b}	0.70^{b}	0.16^{a}	-0.25^{a}	0.19^{a}	12.88^{bc}
August	-3.26^{b}	0.40^{a}	0.52^{b}	0.13^{a}	0.23^{ac}	0.09^{a}	-2.32^{a}
September	-12.86^{c}	-2.00^{c}	-0.24^{b}	-0.33^{a}	0.28^{bc}	-0.49^{b}	-14.87^{d}

[1] Constants in each column with different superscripts are significantly different ($P<.05$).

[2] C_i is the specific VFA relative to the number of carbon atoms it contains, such that C_2 is acetic acid; C_3, propionic acid; C_4, butyric acid; $i\text{-}C_5$, isovaleric acid; $n\text{-}C_5$, normal valeric acid; and C_2/C_3 is the acetic-propionic acid ratio.

Butyric, isovaleric, and valeric acids did not vary to any great extent during the first three grazing periods, but the decrease in forage quality was reflected by a decrease in butyric acid and an increase in valeric acid.

There was an unexpected decrease in acetic-propionic (A/P) ratio which indicated an increase in propionic acid which is generally associated with an increase in forage quality; however, acetic and propionic acid were significantly ($P<.05$) decreased which actually indicated reduced forage quality. A greater decrease in acetic acid relative to propionic acid occurred which explained the reduced ratio during the last grazing period.

Relationship Between ADG and In Vitro VFA Produced from Different Sample Types

The coefficients of simple correlation between ADG and *in vitro* VFA production from random and pure species samples are presented in Table 12. In general, coefficients resulting from the analyses of data from random samples were low. This agreed with conclusions based on a similar study by Wang (1968). When data from VFA analysis of liquor from pure fescue fermentation were analyzed, there was significant ($P<.05$) association between ADG and isovaleric acid (mmoles/liter/gm. of organic matter). The association between ADG and the amount of acetic, propionic, and total VFA produced from clover was highly significant ($P<.01$). The simple coefficient of correlation between ADG and acetic-propionic ratio was also significant ($P<.05$).

TABLE 12

SIMPLE COEFFICIENTS OF CORRELATION[1] BETWEEN ADG AND *IN VITRO* VOLATILE FATTY ACID PRODUCTION (mmoles/liter/gm. OM) FROM DIFFERENT PASTURE GRASS SAMPLES

Type of Samples	Volatile Fatty Acid[2]						
	C_2	C_3	C_4	i-C_5	n-C_5	C_2/C_3	Total
Random	.27	.17	.22	.01	.06	.33	.28
Fescue	.10	.01	.11	.49*	.15	.20	.10
Orchardgrass	.49*	.39*	.09	.29	.07	.20	.45*
Clover[3]	.71**	.56**	.01	-.14	.20	.45*	.72**

[1]Coefficients above .38 and below -.38 are significant (P<.05) and coefficients above .52 and below -.52 are highly significant (P<.01).

[2]C_i = the specific VFA relative to the number of carbon atoms it contains. C_2 is acetic; C_3, propionic; C_4, butyric; i-C_5, isovaleric; n-C_5, normal valeric; and C_2/C_3, the acetic-propionic ratio.

[3]Based on 16 observations.

*P<.05.

**P<.01.

The coefficients of correlation presented in Table 13 between ADG and VFA's (molar percent) were statistically insignificant (P>.1) when VFA production from the random or orchardgrass samples were considered. The same was true for consideration of tall fescue except for a significant (P<.05) coefficient of correlation which related ADG with valeric acid.

Orchardgrass, which was utilized (percentage removed from pasture) much more rapidly than tall fescue, was more associated with ADG based on the VFA analysis. Coefficients of simple correlation between ADG and acetic acid, propionic acid, and total VFA's measured were .49, .39, and .45 which were significant (P<.05). The Utilization Handbook: Key Forage Plant Method (1966) which has been used by the Bureau of Land Management indicated that a greater percentage of the available clover as compared to other available species was removed from the pastures. This indicated that VFA analysis of pure clover samples should account for a great percentage of the variation in ADG. Table 13 shows simple correlation coefficients between ADG and VFA production from clover samples. Significant coefficients are indicated between ADG and acetic, butyric, isovaleric, and valeric acids. Coefficients of correlation between ADG and VFA production from clover samples were significant (P<.05).

When VFA's were expressed in molar percentage units, the VFA's produced by pure clover samples were statistically associated with ADG. Coefficients of correlation between ADG and VFA production from clover samples were significant (P<.05), but only at a lower level of

TABLE 13

SIMPLE COEFFICIENTS OF CORRELATION[1] BETWEEN ADG AND *IN VITRO* VOLATILE FATTY ACID PRODUCTION (molar %)[2] FROM DIFFERENT PASTURE GRASS SAMPLES

Type of Sample	Volatile Fatty Acid[3]				
	C_2	C_3	C_4	i-C_5	n-C_5
Random	.06	-.33	.15	-.17	.06
Fescue	.02	-.01	.11	.49	.15
Orchardgrass	.37	.23	.10	.20	-.26
Clover[4]	.52*	-.32	-.71**	.46*	.38

[1]Coefficients above .380 and below -.380 are significant (P<.05), and coefficients above .520 and below -.520 are highly significant (P<.01).

[2]Organic-matter basis and expressed as a percentage of total acids measured.

[3]C_i = the specific VFA relative to the number of carbon atoms it contains. C_2 is acetic; C_3, propionic; C_4, butyric; C_5, isovaleric; and n-C_5, normal valeric.

[4]Based on 16 observations.

probability. Results of these data indicated that higher relationships between VFA producing ability and ADG can be obtained by selecting pure species samples of the pasture forage that cattle utilized to the greatest extent. Conclusions could be established if cattle were grazed on relatively pure stands so that species composition of diets could be more accurately known, but this would yield little information regarding the best pasture mixture.

VIII. MULTIPLE REGRESSION EQUATIONS

Multiple regression equations (Tables 14 through 28) using various combinations of independent variables were compared to evaluate their accuracy in predicting ADG. The following techniques were utilized in obtaining the independent variables from forages available to grazing heifers:

1. Tennessee Visual Pasture Score
    a. Pasture type
    b. Fescue and orchardgrass percentage
    c. Clover percentage
    d. Legume index.
2. Laboratory Analyses
    a. Crude protein
    b. *In vitro* digestible organic matter
    c. Acid detergent fiber (ADF)
    d. Acid insoluble lignin (AIL)
    e. Cellulose (ADF minus AIL)
    f. AIL/ADF
    g. Soluble carbohydrates.

TABLE 14

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM PASTURE TYPE AND *IN VIVO* VFA CONCENTRATION[1] OF HEIFERS GRAZING THREE TYPES OF PASTURE SWARDS

Equation Components	Equation Number 1	2	3	4	5	6
Constant	0.3400	-0.0075	-0.2689	-0.4356	-0.7856	-2.4253
Fescue	0.1988	-0.2914	-0.2702	-0.2712	-0.2585	-0.2629
Orchardgrass-Clover	0.0288	-0.0496	-0.0821	-0.0570	-0.0510	-0.0331
Propionic Acid						
mmoles/liter	------	------	------	------	------	------
Molar percentage	------	------	------	------	------	0.0631
Butyric Acid						
mmoles/liter	------	------	0.0346	0.0315	0.0270	0.0304
Molar percentage	------	------	------	------	------	------
Isovaleric Acid						
mmoles/liter	------	------	------	------	------	------
Molar percentage	------	------	------	0.0807	0.0941	0.1243
Valeric Acid						
mmoles/liter	------	0.3266	0.3088	0.3026	0.2929	0.2291
Molar percentage	------	------	------	------	------	------
Acetic/Propionic	------	------	------	------	0.0728	0.2161
R^2	.44**	.57**	.62**	.63**	.64**	.64**

[1]Rumen liquor samples collected with a stomach pump.

*P<.05; **P<.01.

TABLE 15

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM IN VIVO VFA CONCENTRATION[1] OF HEIFERS GRAZED ON THREE TYPES OF PASTURE SWARDS

Equation Components	Equation Number 1	2	3	4	5	6
Constant	-0.2497	-0.9553	-3.4247	-3.9718	-3.7094	-3.9817
Propionic Acid						
mmoles/liter	------	------	------	------	-0.0356	-0.0300
Molar percentage	------	------	------	------	------	------
Butyric Acid						
mmoles/liter	0.0643	0.0515	0.0526	0.0728	0.1193	0.1371
Molar percentage	------	------	------	------	------	-0.0703
Isovaleric Acid						
mmoles/liter	------	------	------	------	------	-0.1148
Molar percentage	------	------	------	------	------	------
Acetic/Propionic	------	0.1638	0.1831	0.1829	0.1239	0.1238
pH	------	------	0.3110	0.4022	0.4514	0.5026
R^2	.26*	.32*	.38*	.40*	.41	.42

[1]Rumen liquor samples collected with a stomach pump.

*P<.05.

TABLE 16

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM PERCENTAGE PLANT SPECIES COMPOSITION OF SWARDS AS DETERMINED BY VISUAL PASTURE SCORE

Equation Components	Equation Number						
	1	2	3	4	5	6[1]	7[1]
Constant	-0.0006	-0.4627	0.2032	0.0837	-0.5539	0.1810	-0.1240
Fescue	0.2038	0.3678	------	------	------	------	------
Orchardgrass	-0.0165	-0.0933	------	------	------	------	------
Percent Fescue	------	------	------	------	0.0063	------	------
Percent Orchardgrass	0.0194	0.0195	------	0.0052	0.0165	------	0.1010
Percent Clover	------	0.0120	------	------	------	------	------
Legume Index	------	------	0.0028	0.0022	0.0027	0.0030	0.0025
R^2	.44**	.52**	.43**	.45**	.50**	.51**	.55**

[1]Data collected from pastures without clover were eliminated from the analysis. Results were based on 16 observations.

*P<.05; **P<.01.

TABLE 17

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM LABORATORY ANALYSES[1] OF RANDOM PASTURE FORAGE SAMPLES FROM PASTURE SWARDS GRAZED BY YEARLING HEIFERS

	Equation Number					
Equation Components	1	2	3	4	5	6
Constant	-0.7059	-0.9842	-1.7065	-1.8983	-2.0238	7.0971
Crude Protein	-------	-0.0345	-0.0415	-0.0432	-0.0437	-0.0483
Digestible Dry Matter	0.0150	0.0258	0.0291	0.0303	0.0302	0.0317
Acid Detergent Fiber	------	------	0.0130	0.0171	0.0147	-0.1815
Acid Insoluble Lignin	------	------	------	------	0.0361	1.2421
Lignin-Fiber Ratio	------	------	------	------	------	-0.5630
Soluble Carbohydrates	------	------	------	-0.0012	-0.0013	-0.0011
R^2	.22*	.28*	.31	.32	.34	.40

[1]Data adjusted to organic-matter basis.

*P<.05.

TABLE 18

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM LABORATORY ANALYSES[1] OF SAMPLES OF TALL FESCUE FROM PASTURE SWARDS GRAZED BY YEARLING HEIFERS

Equation Components	Equation Number					
	1	2	3	4	5	6
Constant	-0.8844	-3.8028	-3.5760	-2.8309	-3.1822	-2.2579
Crude Protein	------	------	------	-0.0359	-0.0302	-0.0295
Digestible Dry Matter	0.0178	0.0335	0.0317	0.0341	0.0337	0.0337
Acid Insoluble Lignin	------	------	------	------	0.0342	0.1620
Cellulose	------	0.0463	0.0415	0.0288	0.0301	0.0098
Lignin-Fiber Ratio	------	------	------	------	------	-0.0688
Soluble Carbohydrates	------	------	0.0017	0.0020	0.0027	0.0028
R^2	.18*	.35*	.38*	.41*	.43	.43

[1]Data adjusted to organic-matter basis.

*P<.05.

TABLE 19

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM LABORATORY ANALYSES[1] OF SAMPLES OF ORCHARDGRASS FROM PASTURE SWARDS GRAZED BY YEARLING HEIFERS

Equation Components	Equation Number					
	1	2	3	4	5	6
Constant	-0.7428	-0.5485	-0.2288	-0.2093	-0.6799	-5.2804
Crude Protein	------	-0.0428	-0.0398	-0.0398	-0.0360	-0.0306
Digestible Dry Matter	0.0157	0.0220	0.0208	0.0206	0.0215	0.0200
Acid Insoluble Lignin	------	------	------	------	------	-0.5230
Cellulose	------	------	------	------	0.0077	0.1147
Lignin-Fiber Ratio	------	------	-0.0157	-0.0141	-0.0113	0.2614
Soluble Carbohydrates	------	------	------	0.0008	-0.0007	-0.0004
R^2	.35**	.56*	.59**	.59**	.60**	.65**

[1]Data adjusted to organic-matter basis.

*P<.05; **P<.01.

TABLE 21

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM IN VITRO VFA PRODUCTION[1,2] OF RANDOM SAMPLES FROM PASTURE SWARDS GRAZED BY YEARLING HEIFERS

Equation Components	Equation Number 1	2	3	4	5	6
Constant	-0.5453	-0.7622	-1.9092	-2.3116	-4.4574	-4.9772
Acetic Acid						
mmoles/liter	------	------	------	------	0.0070	0.0059
Molar percentage	------	------	-0.0530	-0.1095	-0.1697	-0.1639
Propionic Acid						
mmoles/liter	------	------	------	------	------	------
Molar percentage	------	------	------	0.1914	0.3454	0.3455
Butyric Acid						
mmoles/liter	------	------	------	------	------	------
Molar percentage	------	------	------	------	------	0.0188
Valeric Acid						
mmoles/liter	------	------	------	------	------	------
Molar percentage	------	-0.0805	-0.1634	-0.1601	-0.1459	-0.1600
Acetic/Propionic	0.2671	0.3656	0.6815	1.9192	2.6557	2.6822
R^2	.11	.15	.25	.29	.34	.35

[1]Data adjusted to organic-matter basis.

[2]Measured in supernatant liquor after 48-hour in vitro digestion of a random sample using Tilley and Terry (1963) fermentation technique.

TABLE 22

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM IN VITRO VFA PRODUCTION[1,2] FROM SAMPLES OF TALL FESCUE CLIPPED FROM SWARDS GRAZED BY YEARLING HEIFERS

Equation Components	Equation Number					
	1	2	3	4	5	6
Constant	-0.0839	-0.4496	-1.5887	-1.9502	-3.2629	-3.0444
Acetic Acid						
mmoles/liter	------	------	------	------	------	------
Molar percentage	------	------	------	-0.0293	-0.0195	-0.0225
Propionic Acid						
mmoles/liter	------	------	------	------	------	------
Molar percentage	------	------	0.0271	0.0711	0.0870	0.0831
Butyric Acid						
mmoles/liter	------	------	------	------	------	-0.0117
Molar percentage	------	------	------	------	0.0225	0.0379
Isovaleric Acid						
mmoles/liter	------	------	------	------	------	------
Molar percentage	0.1839	0.1849	0.1859	0.1651	0.1668	0.1657
Acetic/Propionic	------	0.1224	0.3001	0.7552	0.8001	0.8196
R^2	.29**	.33*	.34*	.36	.37	.40

[1]Data adjusted to organic-matter basis.

[2]Measured in supernatant liquor after 48-hour in vitro digestion of a tall fescue sample using Tilley and Terry (1963) fermentation technique.

*P<.05; **P<.01.

TABLE 23

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM IN VITRO VFA PRODUCTION[1,2] FROM SAMPLES OF ORCHARDGRASS CLIPPED FROM SWARDS GRAZED BY YEARLING HEIFERS

Equation Components	Equation Number 1	2	3	4	5	6
Constants	-0.1592	0.5149	0.6394	-0.2936	-0.3276	1.5500
Acetic Acid						
mmoles/liter	0.0068	0.0057	0.0041	0.0149	0.0221	0.0182
Molar percentage	------	------	------	------	------	------
Propionic Acid						
mmoles/liter	------	------	------	------	------	------
Molar percentage	------	------	------	------	------	-0.0409
Butyric Acid						
mmoles/liter	------	------	------	-0.0984	-0.1409	-0.1071
Molar percentage	------	-0.0710	-0.1198	-0.0154	0.0218	-0.0225
Isovaleric Acid						
mmoles/liter	------	------	------	------	------	------
Molar percentage	------	------	0.2052	0.2880	0.3021	0.2682
Acetic/Propionic	------	------	------	------	-0.1396	-0.3189
R^2	.24*	.40**	.58**	.62**	.67**	.69**

[1]Data adjusted to organic-matter basis.

[2]Measured in supernatant liquor after 48-hour in vitro digestion of an orchardgrass sample using Tilley and Terry (1963) fermentation technique.

*P<.05; **P<.01.

TABLE 24

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM IN VITRO VFA ANALYSIS[1,2] OF CLOVER FROM PASTURE SWARDS OF HIGH CLOVER PERCENTAGE GRAZED BY YEARLING BEEF HEIFERS

Equation Components	Equation Number 1	2	3	4	5	6
Constant	-0.9512	0.3294	0.6776	-1.1937	-1.4595	0.0138
Butyric Acid						
mmoles/liter	------	-0.0912	-0.1818	-0.1775	-0.1703	0.1506
Molar percentage	------	------	------	------	------	------
Isovaleric Acid						
mmoles/liter	------	------	------	-0.3625	-0.3961	0.2906
Molar percentage	------	------	0.1716	0.8244	0.8957	-0.3356
Valeric Acid						
mmoles/liter	------	------	------	------	0.0177	-0.5836
Molar percentage	------	------	------	------	------	0.9300
Total VFA						
mmoles/liter	0.0083	0.0049	0.0046	0.0147	0.0160	0.0077
R^2	.51**	.59**	.65**	.67*	.67*	.72*

[1]Data adjusted to organic-matter basis.

[2]Measured in supernatant liquor after 48-hour in vitro digestion of a clover sample using the Tilley and Terry (1963) fermentation technique.

*P<.05; **P<.01.

TABLE 25

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM VISUAL PASTURE SCORE, LABORATORY ANALYSES[1] OF RANDOM SAMPLES, AND *IN VITRO* VFA PRODUCTION[1,2] FROM RANDOM SAMPLES FROM THREE PASTURE SWARD TYPES GRAZED BY YEARLING HEIFERS

Equation Components	Equation Number 1	2	3	4	5	6
Constant	0.2032	0.3244	0.0192	0.2683	0.3378	0.4279
Orchardgrass Percentage	------	------	------	0.0083	0.0096	0.1078
Legume Index	0.0028	0.0034	0.0037	0.0029	0.0024	0.0024
Crude Protein	------	------	------	------	------	0.0099
Propionic Acid						
Molar percentage	------	------	------	------	-0.0270	-0.0288
Butyric Acid						
Molar percentage	------	0.1130	0.0508	0.0597	0.0572	0.0619
Valeric Acid						
Molar percentage	------	------	-0.1685	-0.1785	-0.2059	-0.1975
R^2	.43**	.52**	.63**	.68**	.69**	.70**

[1]Data adjusted to organic-matter basis.

[2]Measured in supernatant liquor after 48-hour *in vitro* digestion of a random sample using Tilley and Terry (1963) fermentation technique.

*P<.05; **P<.01.

TABLE 26

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM VISUAL PASTURE SCORE, LABORATORY ANALYSES[1] OF FESCUE SAMPLES, AND IN VITRO VFA PRODUCTION[1,2] FROM FESCUE SAMPLES FROM THREE PASTURE SWARD TYPES GRAZED BY YEARLING HEIFERS

Equation Components	Equation Number					
	1	2	3	4	5	6
Constant	0.2032	0.0203	0.1590	-0.2239	0.3066	-1.1864
Legume Index	0.2801	0.0029	0.0030	0.0042	0.0038	0.0039
Cellulose	------	------	------	------	------	0.0199
Soluble Carbohydrates	------	0.0031	0.0030	0.0030	0.0025	0.0022
Butyric Acid						
Molar percentage	------	------	------	0.0692	0.0650	0.0672
Isovaleric Acid						
Molar percentage	------	------	------	------	0.0672	0.0753
Valeric Acid						
Molar percentage	------	------	-0.1053	0.2202	-0.2153	-0.1741
R^2	.43**	.54**	.61**	.71**	.74**	.77**

[1]Data adjusted to organic-matter basis.

[2]Measured in supernatant liquor after 48-hour *in vitro* digestion of a fescue sample using using Tilley and Terry (1963) fermentation technique.

*P<.05; **P<.01.

TABLE 27

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM VISUAL PASTURE SCORE, LABORATORY ANALYSES[1] OF ORCHARDGRASS SAMPLES, AND IN VITRO VFA PRODUCTION[1,2] FROM ORCHARDGRASS SAMPLES FROM THREE PASTURE SWARDS GRAZED BY YEARLING HEIFERS

Equation Components	Equation Number					
	1	2	3	4	5	6
Constant	0.2032	0.7306	0.8239	1.1283	1.1122	1.0622
Legume Index	0.0028	0.0024	0.0019	0.0017	0.0016	0.0015
Lignin-Fiber Ratio	------	------	------	-0.0150	-0.0168	-0.0158
Butyric Acid						
mmoles/liter	------	------	------	------	------	0.0994
Molar percentage	------	0.0610	0.0977	-0.0993	-0.0913	-0.0975
Isovaleric Acid						
mmoles/liter	------	------	0.1129	0.1039	0.1359	0.0923
Molar percentage	------	------	------	------	0.0644	-0.0766
R^2	.43**	.54**	.69**	.71**	.73**	.74**

[1]Data adjusted to organic-matter basis.

[2]Measured in supernatant liquor after 48-hour in vitro digestion of an orchardgrass sample using Tilley and Terry (1963) fermentation technique.

*P<.05; **P<.01.

TABLE 28

MULTIPLE REGRESSION EQUATIONS FOR ADG ESTIMATED FROM VISUAL PASTURE SCORE, LABORATORY ANALYSES[1] OF CLOVER SAMPLES, AND IN VITRO VFA PRODUCTION[1,2] FROM CLOVER SAMPLES FROM PASTURES CONTAINING HIGH CLOVER PERCENTAGE GRAZED BY YEARLING HEIFERS

Equation Components	Equation Number 1	2	3	4	5	6
Constant	-0.9152	-1.5992	-1.8473	-1.7407	-1.4049	-1.8237
Orchardgrass Percentage	------	0.0220	0.0233	0.0273	0.0247	0.0223
Acid Insoluble Lignin	------	------	------	-0.0497	-0.0485	0.0136
Soluble Carbohydrates	------	------	0.0343	0.0307	-0.0352	0.0595
Butyric Acid mmoles/liter	------	------	------	------	0.0322	0.0768
Valeric Acid Molar percentage	------	------	------	------	------	0.1533
Total VFA mmoles/liter	0.0083	0.0078	0.0067	0.0075	0.0081	0.0100
R^2	.51**	.73**	.81**	.84**	.87**	.92**

[1]Data adjusted to organic-matter basis.

[2]Measured in supernatant liquor after 48-hour *in vitro* digestion of a clover sample using Tilley and Terry (1963) fermentation technique.

**P<.01.

The purpose of these analyses was to determine combinations of independent variables which would be practical and easy to obtain and would be valuable in predicting ADG of yearling beef cattle to be grazed on pastures of various plant-specie combinations.

The general form of the equations presented herein is:

$$\hat{Y} = a + b_1\bar{x}_1 + b_2\bar{x}_2 + \ldots + b_i\bar{x}_i$$

Where:

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

$$a = \bar{Y} - b_1\bar{x}_1 - b_2\bar{x}_2 - \ldots - b_i\bar{x}_i.$$

The b_i's are partial regression coefficients and are the values tabulated in Tables 14 through 28. The x_i's are the independent variables (equation components). As shown in Table 14, Equation 3 is for estimating ADG from pasture type (fescue, $x_1 = 1$; orchardgrass-clover, $x_2 = 1$) and the amount of butyric (x_3) and isovaleric (x_4) concentration of grazing heifers; i.e.,

$$\hat{Y} = -0.2689 - 0.2702\ x_1 + 0.0346\ x_3 + 0.0388\ x_4$$

Where:

Y = predicted value of ADG

x_1 = 1, if pasture is classified as predominantly fescue; otherwise, it is equal to zero;

x_2 = 1, if the pasture to be grazed is predominantly orchardgrass-clover; otherwise, $x_2 = 0$ if pasture is predominantly fescue;

$x_1 = x_2 = 0$, if fescue and orchardgrass contribute equally to the species composition.

x_3 = in vivo concentration of butyric acid (mmoles/liter)

x_4 = in vivo concentration of valeric acid (mmoles/liter).

The original objective was to evaluate pasture forage techniques which would account for and explain the differences in ADG of heifers grazing different pasture forages. Pastures differing in species composition were used in an effort to obtain a variation in order to test the ability of techniques to account for differences obtained. It was hoped that a combination of variables could be found which would account for differences due to treatment (different plant species) and differences due to period of grazing (season). For this reason data from all treatments were pooled.

ADG Estimated from Pasture Type and In Vivo VFA Concentration

Regression equations and coefficients of determination (R^2) for estimating ADG from in vivo VFA concentration and pasture type are presented in Table 14, page 64. Similar data is presented in Table 15, page 65, except that pasture type was deleted as a variable. Specifying pasture type (fescue or orchardgrass-clover) accounted for 44 percent of the variation in ADG. If pasture type was specified, the addition of butyric (mmoles/liter), valeric (mmoles/liter), isovaleric (molar percentage), and acetic-propionic ratio as variables increased the explained variation by 20 percent. Deletion of pasture type as a variable changed the relationship. Table 15, page 65, illustrates this fact. Deletion of pasture types decreased the percentage of variation explained by 14 percent. This analysis indicated that rumen pH, butyric, and isovaleric acid and acetic-propionic ratio when included in a prediction equation accounted for 40 percent of the variation in ADG. This gave impetus for attempting the use of in vitro VFA production as a possible predictor of ADG.

ADG Estimated from Percentage Plant Species Composition of Swards as Determined by Visual Pasture Score

Percentage plant species composition of swards as determined by the Tennessee Pasture Scoring Procedure was used to estimate fescue, orchardgrass, and clover percentage, legume index, and to classify the pasture as predominantly fescue or orchardgrass. Specifying pasture type as fescue or orchardgrass-clover explained 44 percent of the variation in ADG (Table 14, page 64), and the addition of orchardgrass percentage did not increase the percentage of the variability explained, but the addition of both percentage orchardgrass and percentage clover increased the explained variation by 8 percent (Equations 1 and 2 in Table 16, page 66).

In Equations 3 through 7 of Table 16 specifications for orchardgrass-clover or predominantly fescue were deleted from the equations. Forty-five percent of the variation in ADG was accounted for when percentage orchardgrass and legume index were included as variables. This strengthened previous suggestions of the importance of legume on the body weight changes of grazing beef calves. In

Equation 6 of Table 16, page 66, legume index alone accounted for 51 percent of the variation in ADG. The addition of orchardgrass percentage increased the explained variation 4 percent. These data indicated that visual pasture score data are valuable in predicting ADG of grazing heifers. Legume index was indicated to be a very important variable in predicting gain and raised questions regarding the chemical components in legumes responsible for its indicated superior nutritive value.

ADG Estimated from Chemical Analyses of Four Forage Sample Types

Random samples to represent forage available in pastures were used by High (1966) and Wang (1968). Chemical analyses of forage samples representative of the actual diet would be more desirable but as already explained, acceptable techniques for duplicating dietary forage are not available. For this reason random samples representative of the pasture were compared with random samples of each of the major species utilized by the grazing animals. Table 17 through 20 (pages 67 through 70) show the regression equations using the chemical analysis of a random, tall fescue, orchardgrass and clover samples, respectively.

Only Equation 1 and 2 in Table 17, page 67, were significant ($P<.05$). By using a random sample, only crude protein and digestible dry matter when used as variables in combination were indicated to be associated with ADG. This accounted for only 28 percent of the variation.

Tall fescue ranked third in importance as a forage utilized by grazing heifers. When the chemical components of a random fescue sample were used as independent variables for predicting ADG (Table 18, page 68), crude protein and digestible dry matter were the two most important variables. The addition of cellulose and soluble carbohydrates in tall fescue increased the coefficients of determination by 7 percent. These data indicated that a sample of pure fescue from pastures containing several plant species accounted for more of the variation in ADG than a random sample representative of the pasture even when the same variables (viz. crude protein and digestible dry matter) were used in a prediction equation.

Table 19, page 69, shows the equations using chemical components of orchardgrass. Since orchardgrass was second only to clover as a utilized forage, it was conceivable that these variables would explain a greater percentage of the variation in ADG than the same components in fescue, apparently, a less preferable forage. Crude protein and digestible dry matter included as variables accounted for 56 percent of the variation in ADG. A 9 percent increase in the coefficient of multiple determination was observed when lignin-fiber ratio, soluble carbohydrates, cellulose, and acid insoluble lignin of orchardgrass were added as variables in a regression analysis. The six chemical components included in Equation 6 in Table 19, page 69, accounted for 65 percent of the variation in ADG. This resulted in a significant increase in the coefficient of multiple determination (.65 versus .41) when a pure orchardgrass sample, instead of a pure fescue sample was randomly clipped from pastures.

Of the major species considered in this study, clover was utilized at the fastest rate and to the greatest extent. When chemical components of clover were used as variables, crude protein, digestible dry matter, lignin-fiber ratio, and soluble carbohydrates were all necessary variables for significant ($P<.05$) explanation of variation in ADG (Equation 4, Table 20, page 70). The addition of cellulose and acid detergent fiber to Equation 4 in a regression analysis increased the coefficients of multiple determination by 16 and 17 percent, respectively. These results are shown in Equations 5 and 6 of Table 20, page 70.

Analyses of laboratory data indicated that all the chemical components considered in this study are useful in predicting ADG. The coefficients of multiple determination (R^2) were very acceptable for each of the pure samples collected, and results of any one of the pure samples were more useful than random samples representing whole pastures. This indicated that researchers would have the option of using pure samples if they felt it represented the plant species most responsible for animal performance.

ADG Estimated from In Vitro VFA Production from Four Forage Sample Types

Samples for *in vitro* VFA analyses were analyzed in the same sequence as those for laboratory analyses, namely random, fescue, orchardgrass, and clover. Multiple regression equations estimating ADG from VFA production of each of these sample types is presented in Tables 21 through 24 (pages 71 through 74). The original postulation was that differences in VFA production would explain the variation in gain due to different pasture types and different grazing periods. When random samples were analyzed as to their potential to produce VFA, there was no significant (P>.1) association between ADG and any combination of variables used in regression analysis. This indicated that no consistent predictions of ADG are possible using a random sample representative of pasture. This conclusion agreed with that of Wang (1968).

When tall fescue samples were analyzed for *in vitro* VFA production, 34 percent of the variation in ADG was accounted for by molar percentage of propionic and isovaleric acids and acetic-propionic ratio. No significant (P>.1) association was found when other combinations of VFA determination were added.

When the *in vitro* production potential of VFA's of pure orchardgrass samples were measured, a further increase in coefficients of multiple determination was noted. Inclusion of acetic acid (mmoles/liter) as the variable, explained 40 percent of the variation in ADG. As molar percentage of butyric and isovaleric, millimoles of butyric acid, acetic-propionic ratio, and molar percentage of propionic acid were added to the equation in a stepwise regression analysis, the coefficient of multiple determination was increased from .40 to .69. The association between ADG and each combination of variables considered was highly significant (P<.01) with the exception of the use of acetic acid alone.

In vitro VFA analysis appeared to strengthen the view that clover accounts for larger percentages of the variation in ADG.

Fifty-one percent of the variation was explained when total VFA from clover (mmoles/liter) was included as a variable. In a stepwise regression analysis millimoles of butyric acid and molar percentage of isovaleric acid was added to this basic equation. The coefficient of determination was increased from .51 to .65, and the association was highly significant ($P<.01$). Further increase of 7 percent in the explained variation was noted when millimoles of isovaleric acid and valeric acid, and molar percentage of valeric acid were added in a stepwise analysis.

When the combination of VFA's in Equation 6 in Table 24, page 74, were combined, 72 percent of the variation in ADG was explained. This emphasized usefulness of VFA's as a prediction of ADG and indicated that either a sample of orchardgrass or clover was superior to a tall fescue or a random sample when these species were grown in combination.

ADG Estimated from an Integration of Visual Pasture Score, Laboratory Analysis, and In Vitro VFA Analyses

Results of an analysis which included visual pasture score, chemical analyses, and VFA as components is presented in Tables 25 through 28, pages 75 through 78. Chemical and VFA analyses of random, fescue, or orchardgrass were combined with visual pasture score. Legume index accounted for about 57 percent of the explained variation. When clover samples were used, legume index was replaced with total VFA (mmoles/liter) and about the same percentage of the variation accounted for was explained by this single variable. Either variable, when used as the single variable in an equation, accounted for about the same amount of the variation; therefore, it is possible that legume index, when used as a single equation component, accounted for a portion of the variation due to total VFA producing ability of clover. This indicated that the potential of clover to form energy-rich VFA's upon microbial digestion was a partial explanation of its improvement of ADG when grown in combination with pasture grasses. When total VFA (mmoles/liter), orchardgrass percentage, and soluble carbohydrates of the clover were used as variables in a stepwise regression analysis, 81 percent of the variation in ADG was explained. This association was highly significant ($P<.01$). Stepwise addition of AIL, butyric acid, and valeric acid increased the explained variation another 11 percent. Hemsley and Moir (1963) indicated that these latter two acids aid in the digestion of fiber which suggested another contribution of clover to the productive ability of a pasture since clover was significantly higher in butyric and valeric acids (Table 11, page 58).

General Discussion of Multiple Regression Equations

A stepwise regression analysis was used to develop a series of multiple regression equations for the prediction of ADG of heifers grazing pastures containing mixtures of tall fescue, orchardgrass, and Ladino clover. Several of the equations accounted for large percentages of the variation in ADG.

From a theoretical standpoint, data from forage actually being utilized should be more useful in predicting ADG. This possibility was investigated. Chemical and VFA data from orchardgrass or clover samples gave higher coefficients of multiple determination than similar data collected from tall fescue or a random sample.

In vivo VFA concentration or *in vitro* VFA production accounted for a significant percentage of the variation in ADG; thus, the importance of these end-products of rumen metabolism was illustrated.

Visual pasture score was the most practical and least complicated technique used in this study. Legume index obtained from this technique accounted for 51 percent of variation in gains of heifers grazing clover containing pastures. If variables from the visual pasture scores were combined with variables from chemical and VFA analysis of forage samples, the percentage of the variation in ADG was much larger than the use of data from one technique. The magnitude of the coefficients of determination were dependent upon the type of sample from which the variables were collected. Variables collected from clover samples when included with visual pasture score accounted for 92 percent of the variation in ADG. Either orchardgrass or tall fescue samples were useful in predicting ADG but in each case different variables were considered. Legume index and orchardgrass percentage were the two most useful variables from the Tennessee pasture score. Crude protein, soluble carbohydrates, and some measure of the cell wall constituents (ADF, AIL, and cellulose) were the most important when chemical analyses were to be combined with visual pasture score. If laboratory analysis alone was used, digestible dry matter was an important variable in the prediction of ADG.

When VFA analysis was combined with other evaluation procedures, the importance of particular acids was dependent on the type of sample used. Propionic, butyric, and valeric acids were the most important when a random sample was analyzed. When pure fescue or orchardgrass samples were used, the higher VFA's (butyric, isovaleric, and valeric acids) were the important variables. As previously suggested (Hemsley and Moir, 1963), these may exert their influence on fiber digestion. Total VFA producing ability of clover accounted for more variation (51 percent) in ADG than any other single VFA and replaced legume index as a variable in a stepwise regression analysis.

Either a pure grass or pure clover sample was useful in predicting ADG, but the results of this study suggested that clover samples may reflect the plant factors affecting ADG with more precision than fescue or orchardgrass samples. Since clover is not always a pasture component, these data suggested that the researcher has the option of analyzing (VFA or chemical) the grass species he has predetermined to be utilized more readily by grazing livestock, and which is available in enough quantity to contribute to animal performance.

IX. EXPRESSIONS OF FORAGE INTAKE AND THEIR RELATION TO THEIR BODY WEIGHT GAIN OF GRAZING BEEF STEERS

Average Daily Gain and In Vitro Dry Matter Digestibility

The daily gains of steers grazed in Experiment 2 and *in vitro* dry matter digestibility associated with FL and OC pastures in each of five grazing periods are reported in Table 29. Gain and digestibility were less closely associated in FL pastures than in OC pastures. Lespedeza did not begin growing until late in the season. Digestibility of forage from the fescue pasture increased during the third grazing period at approximately the same time that lespedeza reached a grazeable height, suggesting the importance of this legume in compensating for the lower dry matter digestibility of the tall fescue. However, the increased gain due to the presence of the legume was not noted until the fourth grazing period.

Dry Matter Intake

The dry matter intake of forage within each period is illustrated in Figure 6. In order to correct for differences in size of steers, intake was adjusted to a constant metabolic size by the following formula:

$$\text{Intake/100 kg. MS} = \frac{\text{Actual Intake of DM}}{W_{kg.}^{2/3}} \times 100.$$

Intake and weight gain on orchardgrass-clover was relatively constant throughout the first four periods. But both intake and daily gain dropped drastically during the last period, when there was no gain, and the steers were eating at maintenance levels. Estimated TDN equivalent of dry matter intake of steers eating at a maintenance level was 1.1 lb. of TDN per day above the theoretical value of maintenance requirement proposed by Winchester and Hendricks (1953). This value, though higher than the theoretical value, is not unreasonable since it was estimated with grazing animals, while the theoretical

TABLE 29

AVERAGE DAILY GAIN AND *IN VITRO* DRY MATTER DIGESTIBILITY[1]

Grazing Period	Orchardgrass-Clover ADG (lb.)	Orchardgrass-Clover DDM (%)	Fescue-Lespedeza ADG (lb.)	Fescue-Lespedeza DDM (%)
June	1.34	61.5	0.88	57.1
July	1.11	60.5	0.99	53.9
August	1.54	66.5	0.53	60.9
September	0.88	62.4	1.41	60.1
October	0.00	60.9	0.59	61.3

[1]Estimated using the Tilley and Terry (1963) *in vitro* digestion technique.

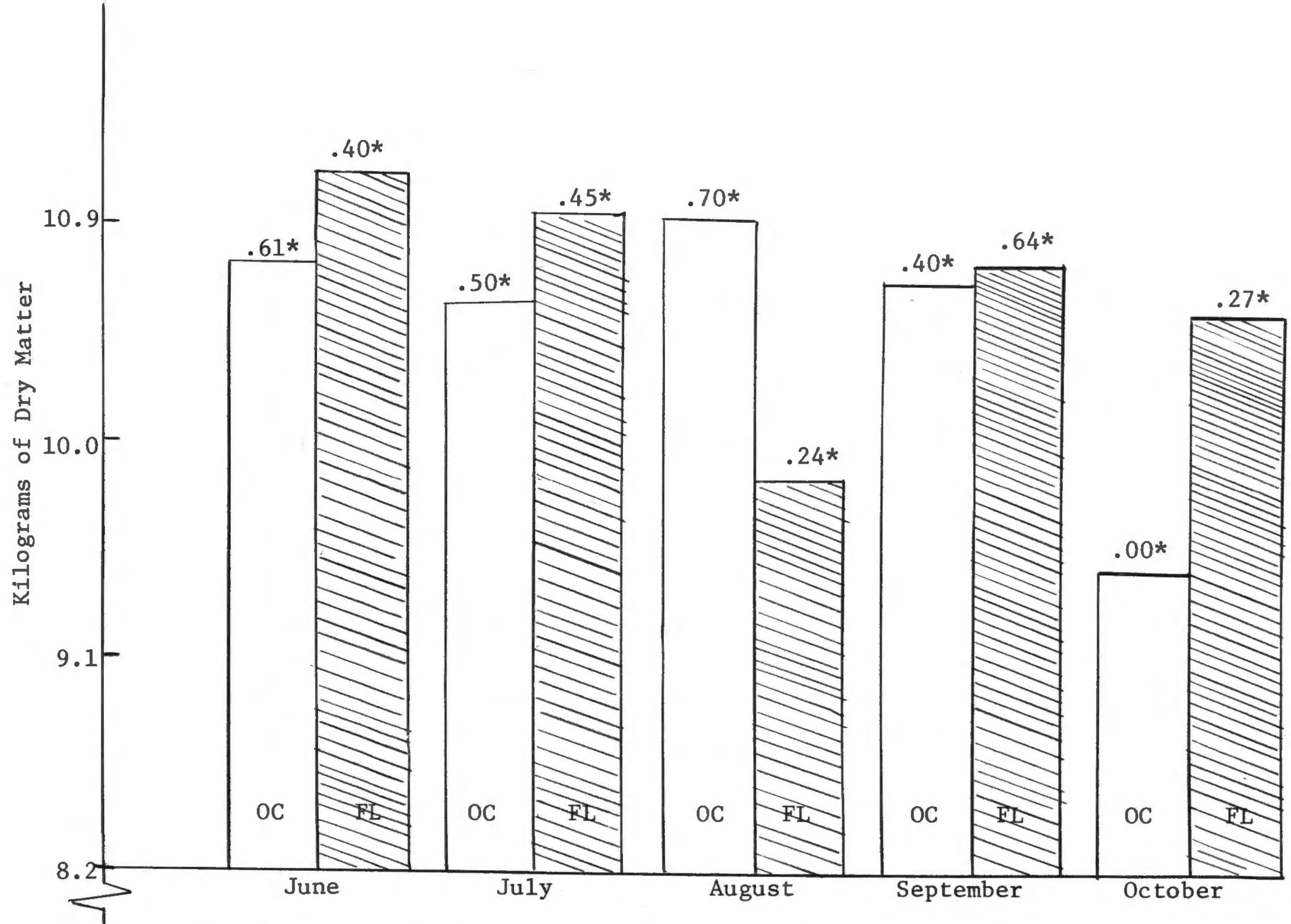

Figure 6. Dry matter intake within each period adjusted to a constant metabolic size (MS) of 100 kilograms.

*ADG which resulted from indicated intake.

value was calculated for animals in the feedlot.

The dry matter intake of steers grazing fescue-lespedeza pastures was higher than those grazing orchardgrass-clover in all periods except the third, but one must also consider the amount of digestible dry matter that was ingested. However, when digestibility and dry matter intake were both considered, intake of digestible dry matter of orchardgrass-clover was greater than that of fescue-lespedeza. The greater digestible dry matter intake of orchardgrass-clover forage was reflected in greater gains of the animals grazing on that forage as compared to those grazing tall fescue-lespedeza. Digestible dry matter intake apparently accounted for the difference in gain between the groups of steers grazing orchardgrass-clover and tall fescue-lespedeza.

Relationship of ADG and Nutritive Value Index

Figure 7 illustrates the relationship between NVI and daily gain. The NVI was calculated because it is a commonly used method of expressing digestible dry matter intake and to allow a comparison of present data with earlier work. Crampton et al. (1960) found simple correlations between this index and daily gain to be as high as .85. In this study, the correlation between average daily gain and the NVI of orchardgrass-clover was .90. However, the correlation of the Nutritive Value Index of fescue-lespedeza and average daily gain was only .50.

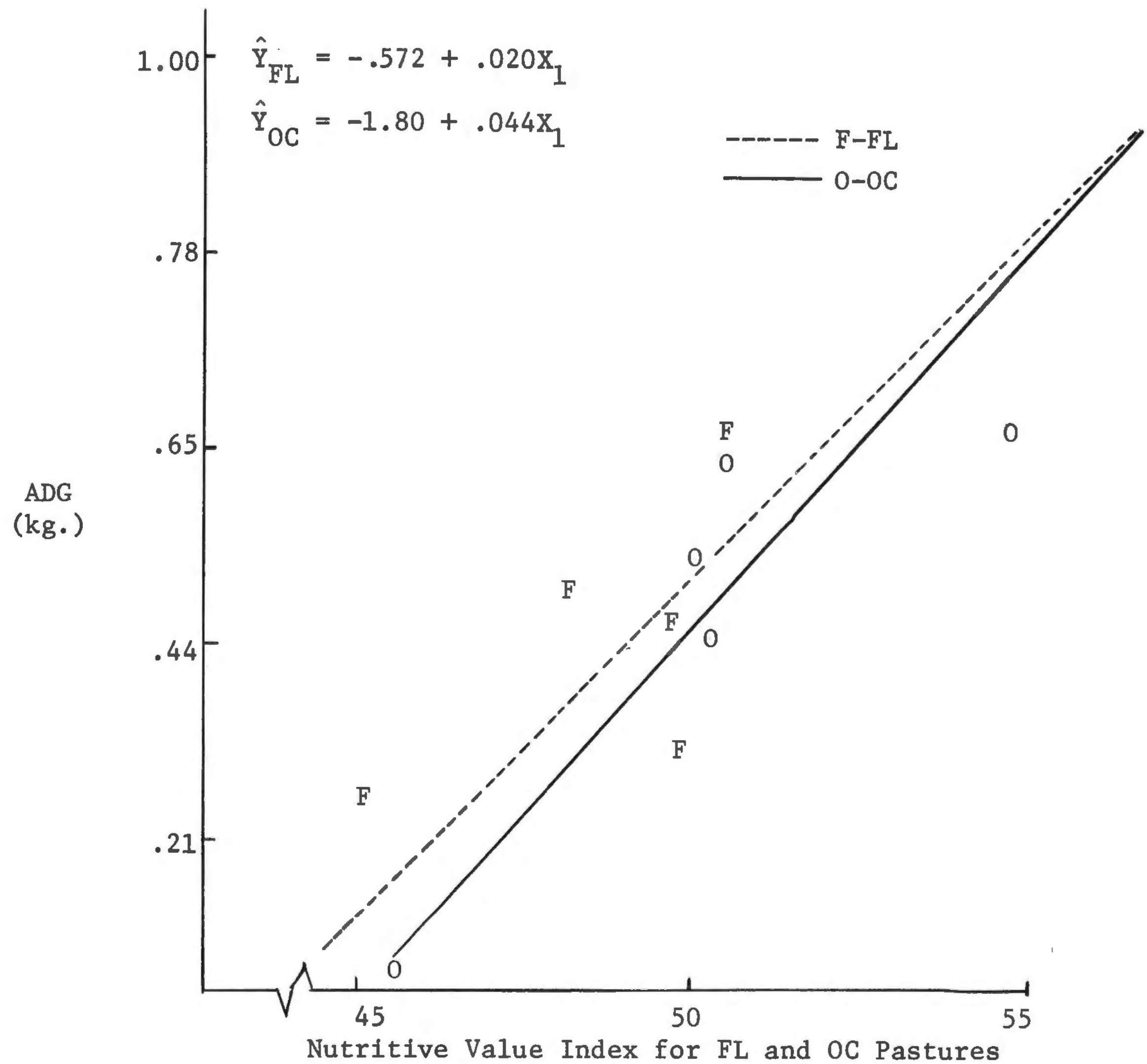

Figure 7. ADG and Nutritive Value Index for FL and OC pastures.

$\hat{Y}$ = predicted ADG and X_1 = NVI for FL or OC pastures.

Relationship of ADG and Dry Matter Intake

The relationship between adjusted dry matter intake and gain is shown in Figure 8. In orchardgrass-clover, the simple correlation between these two variables was .98. However, on fescue-lespedeza pastures, the simple correlation was only .62. Compared to the previously observed relationship between NVI and ADG, the correlation coefficient was increased from .90 to .98 with orchardgrass-clover and from .50 to .62 with fescue-lespedeza.

Relationship of ADG and TDN Intake Above Maintenance

Body maintenance is an energy requirement that must be satisfied from energy of the feed ingested before energy is available for production of body weight gain. An attempt was made to further increase the correlation of the results by calculating TDN intake and then subtracting the TDN required for maintenance. The result was TDN intake above maintenance for each steer which could be related to the daily gain of that animal. In essence, this was done to relate that portion of TDN intake which was available for the production of gain.

Compared to adjusted dry matter intake shown in Figure 9, there was less variation from the regression line when intake of fescue-lespedeza was expressed as TDN intake above maintenance. The correlation coefficient was increased from 0.62 to 0.70. In orchardgrass-clover the coefficient was not improved but it was already very high (viz.--.98) when adjusted dry matter intake was considered.

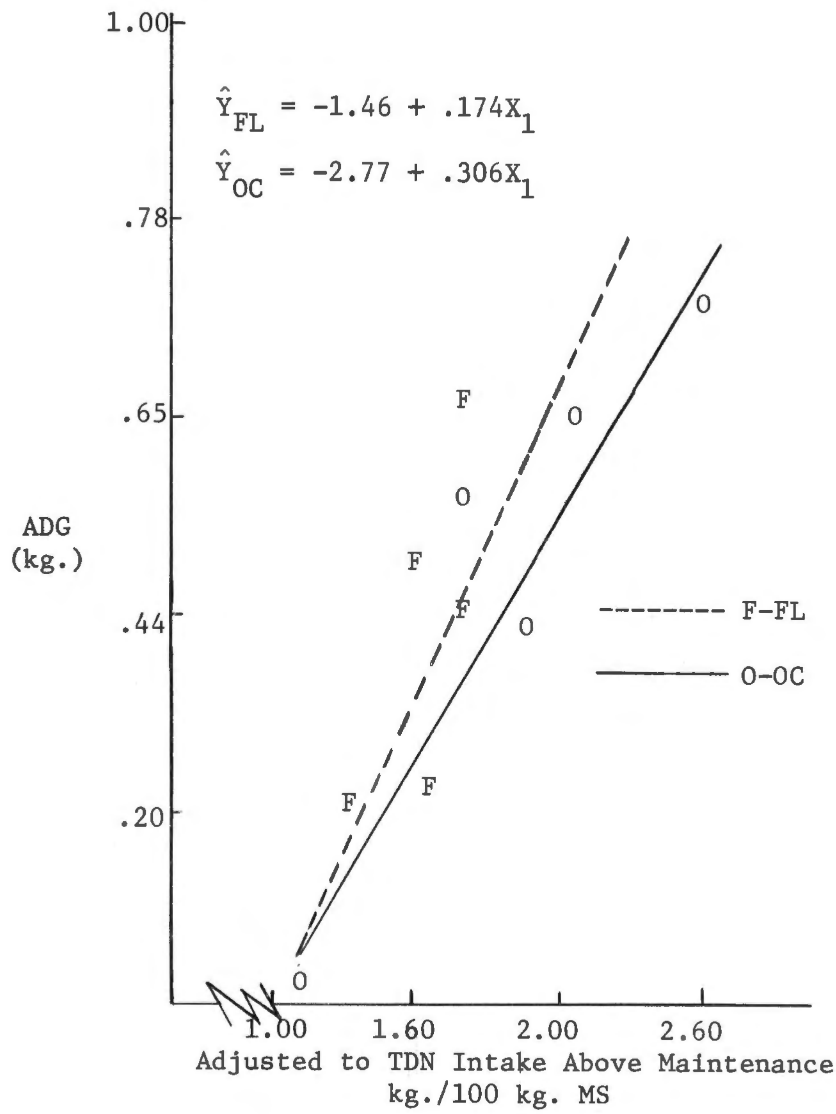

Figure 8. ADG and Adjusted TDN Intake.

$\hat{Y}$ = predicted ADG and X_1 = adjusted TDN intake above maintenance for FL or OC pasture forage.

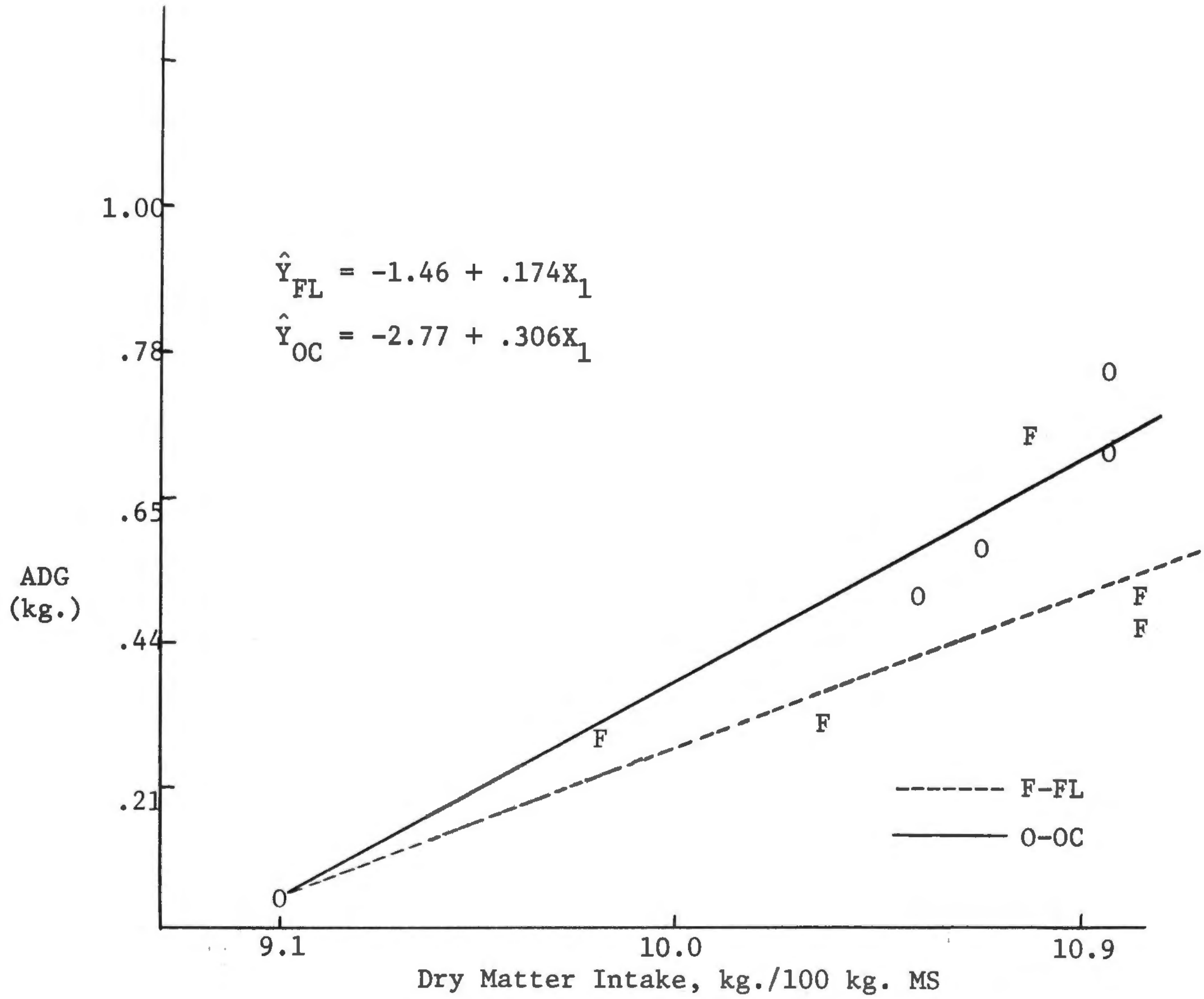

Figure 9. ADG and Dry Matter Intake.

$\hat{Y}$ = predicted ADG and X_1 = DM intake/100 kg. MS

The results of this experiment indicated that differences in average daily gain of steers grazing orchardgrass-clover and fescue-lespedeza were clearly due to differences in dry matter digestibility and not dry matter intake of these two forages. This means that even if a steer ingests somewhat more tall fescue-lespedeza forage, the actual TDN intake may not be as high as another steer eating somewhat less orchardgrass-clover forage.

As postulated initially, the method of expressing intake has an effect on the predictive efficiency or the reliability of intake as a predictor of average daily gain. In orchardgrass-clover pasture, the relationship between average daily gain and each of the three expressions of forage intake were consistently high. TDN intake above maintenance explained 96 percent of the variation in gains. In fescue-lespedeza pastures, there was more variation in gains which could not be accounted for on the basis of the various indices considered in this study. Nutritive Value Index explained only one-fourth of the variation, adjusted dry matter intake explained 38 percent, and one-half of the variation in gains was explained by TDN intake above maintenance.

Relationship Between Dry Matter Intake and In Vitro VFA Production

Since the amount of VFA's produced in the rumen have been reported by several workers (Dowden and Jacobson, 1960; Jacobson, 1966) to be regulators of voluntary intake of feed by ruminants, the relationship between *in vitro* VFA produced from clipped samples was studied. There was a significant difference ($P<.05$) in intake of these two forages during the latter part of the grazing season; therefore, intake of the forages was studied separately. _In vitro_ VFA's were measured at 12-, 24-, 36-, and 48-hour intervals (Shumway and Barth, 1969) using different test tubes at each interval to avoid interference with the VFA concentration due to volume changes of supernatant liquor.

It was originally postulated that the relationship between intake and _in vitro_ VFA concentration would be different for different fermentation times. Shown in Table 30 is a summary of coefficients of correlation between intake and _in vitro_ VFA concentration of each of the fermentation times considered. Orchardgrass and fescue were considered separately in the analysis. The coefficients of correlation between intake of orchardgrass were highest for the 48-hour fermentation time. The relationship was similar for orchardgrass and tall fescue, but was highest for each grass species at different fermentation times. As shown in Table 30, the significant associations between intake and VFA concentration produced from fescue samples occurred at the 12-hour fermentation time in contrast to the higher values for orchardgrass at the 48-hour fermentation time.

The association of VFA production at these two fermentation times was positive which indicated that intake and _in vitro_ VFA concentration increased together. Donefer _et al_. reported correlations indicating that 12-hour _in vitro_ cellulose digestion is associated with voluntary consumption. These workers concluded that 24-hour and longer _in vitro_ cellulose digestion

TABLE 30

COEFFICIENTS OF SIMPLE CORRELATION AMONG INTAKE PER 100 KG. MS AND IN VITRO VFA PRODUCTION[1] FROM 12-, 24-, 36-, AND 48-HOUR FERMENTATION TIMES

Item	Fermentation Time 12-hr.	24-hr.	36-hr.	48-hr.
Orchardgrass				
Acetic	-.35	.08	.51	.63*
Propionic	-.49	.02	.45	.75**
Butyric	-.27	-.10	.29	.64*
A/P	.17	.10	-.30	-.36
Total VFA	.38	-.07	.50	.69**
Fescue				
Acetic	.51	.62*	.13	.33
Propionic	.60*	.58*	.41	.35
Butyric	.57*	.24	-.25	.46
A/P	.07	.28	-.34	.05
Total VFA	.55*	.61*	.18	.38

[1]Measured in supernatant liquor after 12-, 24-, 36-, and 48-hour in vitro digestion of a random forage sample (representative of the pasture) using the Tilley and Terry (1963) fermentation technique.

*P<.05; **P<.01.

ultimately measures energy availability which may indicate that VFA production from fescue was associated with intake of dry matter while in the case of orchardgrass VFA production from longer fermentation times measured the intake of available energy in the forage. It is likely that the intake of these two forages was not controlled by concentration of VFA, but was limited by high content of cell wall constituents (ADF and AIL) since these components were relatively high in the forages considered. The VFA concentrations reflected the quality of the forage; thus the forage with the highest VFA concentration was of highest quality. Increased quality resulted in increased intake. The conclusion is supported by results reported by Reid (1961) in which significant increases in intake were observed when percentage TDN (quality) of alfalfa forage was increased.

CHAPTER V

CONCLUSION

The objectives of this study were: (a) to investigate several methods of pasture evaluation useful for prediction of the daily gain of beef calves, (b) to study plant factors which are related to body weight gain of grazing heifers, (c) to investigate the reasons for increased daily gain in pastures containing clover, and (d) to test the hypothesis that decreased forage dry matter intake is related to decreased animal performance.

Two grazing trials were conducted with the following four species: (1) Tall fescue (*Festuca arundacea*), (2) Orchardgrass (*Dactylis glomerata*), (3) Ladino clover (*Trifolium repens*), and (4) Kobe lespedeza (*Lespedeza striata*). Experiment 1 was conducted with heifers grazed on tall fescue (FES), orchardgrass-Ladino clover (OC), and fescue-orchardgrass-clover (FOC) pastures. Changes in body weight and subcutaneous fat thickness were determined. Experiment 2 was conducted with steers grazed on fescue-lespedeza (FL) and orchardgrass-clover (OC) pastures. Changes in body weight were determined and forage dry matter intake was estimated. Forage intake was calculated from a total feces collection and *in vitro* dry matter digestibility.

Forage quality measures (visual and laboratory) which were related to body weight gain of cattle were used to develop regression equations for predicting daily gain. The results of this study were as follows:

1. The daily gain and change in fat thickness of heifers grazing OC or FOC pastures was higher than that of heifers grazing FES pastures.

2. Estimates of forage utilization by grazing heifers indicated that the order of preference was clover, orchardgrass, and tall fescue.

3. This study indicated that samples representative of the pasture clipped according to the method used by High were of little value when only chemical or VFA analysis were to be used as evaluation criteria. The same variables obtained from pure samples of the major species were highly associated with ADG.

4. Organic matter digestibility, soluble carbohydrates, and total VFA analysis of clover were the most useful single variables for prediction of ADG from analyses of forage samples.

5. Propionic acid (*in vivo*) and total VFA (*in vivo*) were highly correlated with ADG when rumen liquor samples collected through the rumen fistula were analyzed, but the magnitude of coefficients of correlation was decreased when oral samples were taken from the same animals, possibly because of saliva contamination.

6. *In vitro* VFA analysis indicated that clover is of higher nutritive value than orchardgrass or tall fescue. It had a greater potential to form the energy-rich VFA's.

7. Clover or legume percentage was consistently indicated as an important factor for desirable gain for beef heifers on pasture. These data indicated that the reason for the advantage in gain due to

clover is the higher content of digestible nutrients as indicated by its higher digestible organic matter content, soluble carbohydrates content, and its ability to form volatile fatty acids. These characteristics were consistently high in clover over the growing season, whereas grasses did not maintain these factors at an adequate level after the point of maturity. These factors alone were ample reasons to expect superior gain on clover-containing pastures under practical management regimes.

8. If intake is to be related to body weight gain, these data indicated that some adjustment in intake estimates must be made for body maintenance.

9. Total digestible nutrient (TDN) intake was greater for cattle grazing forage from OC pastures when equal amounts of dry matter from OC and FL pastures were ingested. Percentage TDN and intake of the forages were closely associated, indicating that intake is associated with quality of forage.

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LITERATURE CITED

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APPENDIX

TABLE 31

COMPARISON OF *IN VIVO* VFA CONCENTRATION OF ORAL SAMPLES FROM THREE DIFFERENT PASTURE TYPES

Item	Period (1)	(2)	(3)	(4)
	mmole/l.			
Acetic				
FES	49.22	52.17	56.56	45.37
OC	62.64	58.94	58.33	52.17
FOC	67.35	44.37	49.93	42.59
Propionic				
FES	11.73	10.62	11.54	8.87
OC	12.59	12.82	11.53	10.10
FOC	15.02	9.08	9.79	8.08
Butyric				
FES	7.26	6.49	7.41	9.35
OC	10.10	8.61	7.37	10.55
FOC	9.67	6.25	5.95	10.52
Isovaleric				
FES	1.81	1.24	2.36	1.61
OC	2.65	1.66	1.74	1.33
FOC	2.64	1.49	1.71	1.38
Valeric				
FES	2.04	1.28	1.13	0.94
OC	2.21	1.21	0.77	1.02
FOC	1.52	0.94	0.86	0.93
Total VFA				
FES	72.06	72.07	71.80	66.15
OC	90.19	82.26	79.80	75.20
FOC	96.21	62.13	68.25	63.49

TABLE 32

COMPARISON OF CHEMICAL COMPOSITION[1] OF CLIPPED SAMPLES FROM THREE PASTURE TYPES

Collection Period	Pasture Type	Sample Type	Protein	Acid Detergent Fiber	Acid Insoluble Lignin	Cellulose	Lignin-Fiber Ratio	Soluble Carbohydrates	Digestible Organic Matter
			%						
1	FES	Random	10.79	48.33	7.62	40.72	15.69	8.61	64.90
1	FES	Fescue	9.29	54.16	7.09	47.07	13.10	8.42	61.48
1	FES	Orch.	10.54	52.74	9.00	43.74	17.85	6.06	63.01
1	OC	Random	15.47	43.76	7.50	36.26	17.05	12.19	77.63
1	OC	Fescue	10.95	46.17	7.93	38.24	16.98	9.08	72.30
1	OC	Orch.	13.53	45.26	6.89	38.38	15.23	11.27	75.07
1	OC	Clover	29.26	30.99	7.38	23.60	23.83	14.29	88.92
1	FOC	Random	15.52	44.01	6.76	37.25	15.35	5.66	73.05
1	FOC	Fescue	11.88	45.84	6.43	39.41	14.02	7.18	72.87
1	FOC	Orch.	14.68	47.97	8.31	39.67	17.36	10.85	80.62
1	FOC	Clover	31.26	30.08	6.56	23.52	21.77	11.37	98.10

TABLE 32 (continued)

Collection Period	Pasture Type	Sample Type	Protein	Acid Detergent Fiber	Acid Insoluble Lignin	Cellulose	Lignin-Fiber Ratio	Soluble Carbohydrates	Digestible Organic Matter
			%						
2	FES	Random	11.73	45.37	6.59	38.78	14.91	8.43	70.18
2	FES	Fescue	12.88	47.55	5.97	41.58	12.54	8.64	68.99
2	FES	Orch.	15.69	42.42	8.71	33.70	20.63	9.88	73.76
2	OC	Random	16.62	44.26	7.69	36.57	17.39	9.69	79.32
2	OC	Fescue	14.26	42.57	6.92	35.64	16.27	13.77	80.18
2	OC	Orch.	15.33	40.42	6.09	34.43	14.92	11.59	78.57
2	OC	Clover	22.86	33.75	8.12	25.63	24.04	10.59	85.15
2	FOC	Random	13.99	44.38	6.51	38.07	14.68	6.59	75.23
2	FOC	Fescue	11.37	45.06	5.23	39.83	11.61	10.41	72.66
2	FOC	Orch.	14.74	45.64	7.79	37.85	17.12	8.09	78.15
2	FOC	Clover	22.81	34.91	7.13	27.77	20.44	10.28	95.95

TABLE 32 (continued)

Collection Period	Pasture Type	Sample Type	Protein	Acid Detergent Fiber	Acid Insoluble Lignin	Cellulose	Lignin-Fiber Ratio	Soluble Carbohydrates	Digestible Organic Matter
			%						
3	FES	Random	17.77	46.40	6.76	39.63	14.59	7.25	70.58
3	FES	Fescue	15.19	44.33	6.04	37.98	13.71	9.88	69.94
3	FES	Orch.	21.35	42.35	7.02	35.33	16.53	8.63	73.24
3	OC	Random	17.42	44.80	8.18	36.62	18.26	9.89	75.27
3	OC	Fescue	12.28	44.77	7.77	37.00	17.36	8.71	66.87
3	OC	Orch.	17.36	44.87	7.17	37.69	15.98	8.79	67.88
3	OC	Clover	27.00	26.68	5.57	21.11	23.42	8.03	82.00
3	FOC	Random	13.43	45.46	7.26	38.19	16.05	6.86	63.66
3	FOC	Fescue	11.71	43.74	5.42	38.31	12.40	10.75	63.99
3	FOC	Orch.	17.30	46.57	10.65	35.93	22.89	4.93	63.42
3	FOC	Clover	28.51	34.45	7.46	26.99	21.51	9.77	90.43

TABLE 32 (continued)

Collection Period	Pasture Type	Sample Type	Protein	Acid Detergent Fiber	Acid Insoluble Lignin	Cellulose	Lignin-Fiber Ratio	Soluble Carbohydrates	Digestible Organic Matter
			%						
4	FES	Random	11.53	46.09	6.31	39.78	13.68	5.96	62.07
4	FES	Fescue	10.31	48.90	8.09	40.80	16.56	1.76	62.61
4	FES	Orch.	13.27	49.65	9.18	40.46	18.46	5.73	56.14
4	OC	Random	9.91	44.23	7.38	36.85	16.69	5.74	58.66
4	OC	Fescue	11.38	47.39	5.97	41.42	12.54	8.86	63.92
4	OC	Orch.	10.41	50.04	8.49	41.55	16.96	3.56	50.67
4	OC	Clover	31.93	23.20	5.18	18.02	22.26	10.95	81.43
4	FOC	Random	9.03	45.39	7.40	37.99	16.36	5.65	56.67
4	FOC	Fescue	9.56	49.20	5.61	43.59	11.41	6.49	59.66
4	FOC	Orch.	13.63	47.26	8.17	39.09	17.33	4.54	58.83
4	FOC	Clover	33.99	24.57	6.40	18.16	26.13	12.38	85.40

[1] Organic-matter basis.

TABLE 33

COMPARISON OF IN VITRO VFA PRODUCTION OF FOUR DIFFERENT TYPES OF SAMPLES

Item	Pasture Type			
	FES	OC	FOC	Av.
	mmoles/liter/gm. OM			
Acetic				
Random	87.35	74.56	86.11	82.67
Fescue	78.28	77.72	83.16	79.72
Orchardgrass	74.76	66.30	76.46	72.51
Clover	-----	99.27	117.02	108.14
Propionic				
Random	26.68	22.86	26.01	25.22
Fescue	25.18	27.52	27.68	26.79
Orchardgrass	21.84	24.53	23.02	23.13
Clover	-----	33.08	32.52	32.80
Butyric				
Random	11.40	9.28	8.52	9.73
Fescue	9.14	9.74	9.52	9.47
Orchardgrass	9.54	9.32	8.18	9.01
Clover	-----	12.70	12.67	12.68
Isovaleric				
Random	2.44	3.70	3.40	3.18
Fescue	2.19	3.60	2.44	2.74
Orchardgrass	2.18	2.67	1.58	2.14
Clover	-----	4.30	3.60	3.95
Valeric				
Random	2.42	2.17	1.22	1.94
Fescue	1.67	2.28	2.15	2.03
Orchardgrass	1.48	1.66	0.69	1.28
Clover	-----	2.73	2.58	2.66
Total VFA				
Random	127.00	112.13	125.12	121.42
Fescue	116.44	120.86	126.66	121.32
Orchardgrass	109.79	103.49	105.56	106.28
Clover	-----	152.08	168.40	160.24
Acetic/Propionic				
Random	3.25	3.08	3.30	3.21
Fescue	3.09	2.82	3.00	2.97
Orchardgrass	3.52	2.70	3.40	3.21
Clover	-----	3.01	3.59	3.30

TABLE 34

IN VITRO VFA PRODUCTION[1] FROM FORAGE SAMPLES[2] CLIPPED FROM THREE PASTURE TYPES

Collection Period	Pasture Type	Sample Type	C_2	C_3	C_4	$i\text{-}C_5$	$n\text{-}C_5$	C_2/C_3	Total
			mmole/liter/gm. OM.						
1	FES	Random	76.08	24.83	6.45	2.62	3.50	3.03	110.33
1	FES	Fescue	56.83	22.75	4.66	2.09	1.30	2.60	86.47
1	FES	Orch.	63.22	17.88	6.57	1.64	1.02	3.63	90.34
1	OC	Random	86.00	23.58	11.02	4.25	3.29	3.69	128.91
1	OC	Fescue	96.23	26.46	10.79	4.43	2.92	3.64	140.84
1	OC	Orch.	72.11	21.36	8.34	2.45	1.58	3.38	105.85
1	OC	Clover	116.71	32.35	12.40	3.94	1.73	3.61	167.14
1	FOC	Random	110.71	31.44	11.51	2.87	1.55	3.53	158.08
1	FOC	Fescue	103.44	34.72	11.98	3.05	3.56	2.98	156.72
1	FOC	Orch.	89.24	25.82	8.19	1.68	0.10	3.48	124.99
1	FOC	Clover	128.97	32.89	11.89	2.88	2.47	3.92	179.10

TABLE 34 (continued)

Collection Period	Pasture Type	Sample Type	C_2	C_3	C_4	i-C_5	n-C_5	C_2/C_3	Total
			mmole/liter/gm. OM.						
2	FES	Random	88.06	26.73	12.62	2.07	0.70	3.29	130.19
2	FES	Fescue	67.06	20.22	5.64	1.86	0.07	3.31	94.86
2	FES	Orch.	88.89	22.77	9.57	2.54	0.93	3.90	124.70
2	OC	Random	89.69	25.00	11.10	4.10	3.32	3.60	133.22
2	OC	Fescue	92.41	31.48	12.54	5.25	3.42	2.95	145.05
2	OC	Orch.	82.88	29.92	13.40	4.13	2.28	2.77	129.12
2	OC	Clover	112.82	34.86	13.76	4.98	2.30	3.23	168.72
2	FOC	Random	93.71	27.18	9.45	2.48	0.82	3.44	133.63
2	FOC	Fescue	92.34	29.89	11.66	3.05	2.40	3.10	139.32
2	FOC	Orch.	95.83	28.44	9.72	1.69	0.54	3.36	136.21
2	FOC	Clover	138.31	35.77	11.68	2.19	1.82	3.87	189.76

TABLE 34 (continued)

Collection Period	Pasture Type	Sample Type	C_2	C_3	C_4	$i-C_5$	$n-C_5$	C_2/C_3	Total
			mmole/liter/gm. OM.						
3	FES	Random	102.13	29.67	15.09	2.90	2.79	3.44	144.78
3	FES	Fescue	97.02	28.58	13.47	2.66	2.64	3.39	144.39
3	FES	Orch.	99.71	28.64	13.88	3.34	2.45	3.94	148.02
3	OC	Random	77.22	26.03	10.28	2.71	1.51	2.96	117.76
3	OC	Fescue	55.26	26.72	7.38	2.43	1.10	2.06	92.90
3	OC	Orch.	61.72	24.42	9.17	2.66	1.94	2.50	99.41
3	OC	Clover	85.41	35.99	11.95	4.34	3.35	2.37	141.05
3	FOC	Random	73.50	23.50	4.96	4.59	1.43	3.19	107.47
3	FOC	Fescue	81.08	26.80	7.26	1.81	1.50	3.02	122.95
3	FOC	Orch.	54.56	15.50	6.64	1.06	0.70	3.52	78.46
3	FOC	Clover	85.69	25.56	11.34	3.44	1.82	3.35	127.84

TABLE 34 (continued)

Collection Period	Pasture Type	Sample Type	C_2	C_3	C_4	$i\text{-}C_5$	$n\text{-}C_5$	C_2/C_3	Total
			mmole/liter/gm. OM.						
4	FES	Random	83.15	25.51	11.45	2.18	2.28	3.26	124.57
4	FES	Fescue	92.23	29.17	12.81	2.16	2.66	3.06	140.03
4	FES	Orch.	47.23	18.07	8.15	1.14	1.51	2.61	76.10
4	OC	Random	45.31	16.84	4.70	1.21	0.56	2.68	68.62
4	OC	Fescue	66.98	25.45	8.26	2.27	1.68	2.62	104.64
4	OC	Orch.	48.50	22.41	6.35	1.45	0.85	2.16	79.57
4	OC	Clover	82.13	29.14	12.68	3.92	3.54	2.84	131.42
4	FOC	Random	66.53	21.92	8.14	3.65	1.07	3.04	101.32
4	FOC	Fescue	55.78	19.30	7.17	1.87	1.13	2.89	85.25
4	FOC	Orch.	66.22	22.33	8.15	1.87	1.42	2.96	82.60
4	FOC	Clover	115.10	35.88	15.78	5.58	4.23	3.21	176.88

[1]Expressed on organic-matter basis.

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

TABLE 35

IN VITRO VFA PRODUCTION[1] FROM FORAGE SAMPLES[2] CLIPPED FROM THREE PASTURE TYPES

Collection Period	Pasture Type	Sample Type	C_2	C_3	C_4	$i-C_5$	$n-C_5$
			molar %				
1	FES	Random	68.54	22.74	6.11	2.36	2.45
1	FES	Fescue	66.03	25.98	5.36	2.45	1.65
1	FES	Orch.	70.05	19.78	7.27	1.82	1.13
1	OC	Random	67.39	18.33	8.57	3.14	2.55
1	OC	Fescue	68.34	18.45	7.65	3.13	2.07
1	OC	Orch.	68.18	20.17	7.88	2.31	1.49
1	OC	Clover	69.78	19.38	7.43	2.36	1.04
1	FOC	Random	70.07	19.87	7.27	1.81	0.97
1	FOC	Fescue	66.00	22.18	7.60	1.91	2.30
1	FOC	Orch.	71.36	20.58	6.62	1.38	0.08
1	FOC	Clover	71.97	18.37	6.64	1.60	1.40
2	FES	Random	69.50	20.48	9.81	1.61	0.58
2	FES	Fescue	70.67	21.13	5.95	1.91	0.07
2	FES	Orch.	71.28	18.26	7.67	2.04	0.75
2	OC	Random	67.33	18.76	8.34	3.08	2.50
2	OC	Fescue	63.68	21.68	8.67	3.62	2.36
2	OC	Orch.	64.71	23.30	10.27	3.12	1.72
2	OC	Clover	66.85	20.67	8.16	2.95	1.37
2	FOC	Random	70.12	20.35	7.07	1.81	0.61
2	FOC	Fescue	66.28	21.45	8.36	2.19	1.72
2	FOC	Orch.	70.36	20.91	7.12	1.23	0.37
2	FOC	Clover	72.89	18.84	6.14	1.16	0.96

TABLE 35 (continued)

Collection Period	Pasture Type	Sample Type	C_2	C_3	C_4	$i\text{-}C_5$	$n\text{-}C_5$
			molar %				
3	FES	Random	70.56	20.50	10.43	2.01	1.93
3	FES	Fescue	67.18	19.80	9.33	1.84	1.83
3	FES	Orch.	67.36	19.34	9.38	2.26	1.66
3	OC	Random	65.55	22.11	8.72	2.31	1.30
3	OC	Fescue	59.46	28.77	7.95	2.62	1.19
3	OC	Orch.	61.56	24.61	9.23	2.66	1.94
3	OC	Clover	60.55	25.53	8.48	3.08	2.37
3	FOC	Random	68.37	21.41	4.64	4.25	1.33
3	FOC	Fescue	66.24	21.97	5.70	1.19	1.23
3	FOC	Orch.	69.54	19.76	8.46	1.35	0.90
3	FOC	Clover	67.00	20.02	8.90	2.68	1.41
4	FES	Random	66.78	20.47	9.20	1.73	1.82
4	FES	Fescue	66.58	20.81	9.15	1.55	1.92
4	FES	Orch.	62.07	23.74	10.71	1.50	1.98
4	OC	Random	66.07	24.66	6.75	1.75	0.75
4	OC	Fescue	63.96	24.43	7.85	2.15	1.59
4	OC	Orch.	60.98	28.25	7.87	1.79	1.11
4	OC	Clover	62.58	22.09	9.65	2.99	2.69
4	FOC	Random	65.66	21.63	8.03	3.61	1.06
4	FOC	Fescue	65.42	22.65	8.41	2.20	1.33
4	FOC	Orch.	66.22	22.33	8.15	1.88	1.42
4	FOC	Clover	65.06	20.30	8.92	3.16	2.39

[1]Expressed on organic-matter basis.

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

VITA

Delmer Irvin Davis, Jr., was born in Riverside, California, on December 9, 1943. He attended elementary schools in Coleman and Taylor counties of Texas and was graduated from Merkel High School, Merkel, Texas, in 1962. The following September he entered Abilene Christian College, Abilene, Texas, and in May, 1966, he received a Bachelor of Science degree in Animal Husbandry.

In the fall of 1966, he accepted a National Defense Education Act Fellowship, Title IV, and began study toward a Doctor of Philosophy degree at the University of Tennessee. He received the Doctor of Philosophy degree with a major in Animal Nutrition in December, 1969. He is a member of the Block and Bridle Club, the American Society of Animal Science, American Society of Range Management, Delta Tau Alpha, Alpha Chi, and Gamma Sigma Delta.

He is married to the former Cynthia Faye Johnson of Fort Worth, Texas.