To the Graduate Council:

I am submitting herewith a thesis written by William Warren Gill entitled "Nutrient Digestibility as Determined by the Lignin Ratio Technique and Its Relation to Body Parameters of Lactating Beef Cows." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

Karl M. Barth

Karl M. Barth, Major Professor

We have read this thesis
and recommend its acceptance:

Eric W. Swanson

J. B. McLaren

Will S. Gill Jr.

Accepted for the Council:

Hilton A. Smith

Vice Chancellor
Graduate Studies and Research

A

Ag-VetMed
Thesis
75
.G599
Cop.2

NUTRIENT DIGESTIBILITY AS DETERMINED BY THE LIGNIN RATIO TECHNIQUE AND ITS RELATION TO BODY PARAMETERS OF LACTATING BEEF COWS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

William Warren Gill

December 1975

1266383

ACKNOWLEDGEMENTS

The author is deeply indebted to all the people who have befriended and helped him in so many ways throughout his graduate career.

He is particularly grateful to his major professor, Dr. Karl M. Barth, whose patient encouragement, unfailing guidance and ready friendship have meant so much.

Appreciation is also expressed to Dr. Will T. Butts, Dr. James B. McLaren, and Dr. Eric W. Swanson, Department of Animal Science, who served as his graduate committee and who were invaluable in offering advice and assistance throughout the graduate course of study.

The author is grateful to his fellow graduate students for their friendship and help. He is especially indebted to James L. Thomas, whose cooperation and assistance in performing this experiment were of utmost importance, and to Dennis O. Onks, who aided in various technical aspects of the project.

Others whom the author wishes to thank for aiding in his research include: William A. Lyke and Marvis E. Fryer for their assistance in chemical analysis; Jackie E. Martin, John Hodges III, and Lyle Blair of Blount Farm for their assistance in managing the experimental animals; the staff of The University of Tennessee Computer Center; and especially Henderson M. Crowder for his friendship and encouragement.

The author is also grateful to those who helped him more than anyone else, his wife and his parents.

ABSTRACT

An indicator digestion trial was conducted using twenty-one mature Angus cows in late lactation in order to establish possible relationships between cow and calf body parameters and nutrient digestibility. The cow-calf pairs were selected to represent a wide range of body types and structures. They were individually fed timothy (Phleum pratense) orchardgrass (Dactylis glomerata) silage and alfalfa (Medicago sativa) pellets once each day.

Chromium sesquioxide (Cr_2O_3) was administered daily in 10 gram doses to each of the cows during a nine-day preliminary period and a seven-day collection period. Fecal samples were collected once a day over the collection period at a time established in a study by Thomas (1975) to find the optimal time for fecal collection to avoid error due to diurnal excretion of Cr_2O_3.

Feed and feces samples were analyzed for dry matter, crude protein, acid-detergent fiber, acid-detergent lignin, and gross energy. Fecal samples were also analyzed for Cr_2O_3. Digestion coefficients were calculated using both Cr_2O_3 and lignin as the indicator. Under the conditions of this experiment, the lignin method was preferable. Therefore, the digestion coefficients derived using lignin as the indicator were used to evaluate the relationships between cow-related variables and digestibility.

Differences in digestion coefficients between cows were quite marked (coefficients of variation were: dry matter; 5.40; gross energy, 4.77; acid-detergent fiber, 6.87; and crude protein, 8.52).

This variation was due to differences in relative ability of cows to digest the nutrients and by error due to lack of refinement in indicator technique. The average dry matter, gross energy, ADF and crude protein digestibilities were 49.7 percent, 48.3 percent, 41.6 percent, and 41.8 percent, respectively.

Dry matter, ADF and energy digestibilities were not correlated with cow weight or fat thickness, but there was a tendency for these variables to show a positive relationship with cow height and average daily gain.

Crude protein digestibility was highly correlated ($p<.01$) with cow weight ($r=-.71$). It was shown that as mature cow weight increased, crude protein digestibility decreased at an increasing rate.

The relationships between various cow-related variables and voluntary consumption were explored. Dry matter consumption was not related to cow weight, cow height or cow fat thickness, but the amount of dry matter consumption per unit of weight was found to be significantly affected by body weight, fat thickness and weight divided by height.

An indicator ratio method for estimating intake by cows was presented which might be of value in future nutrition research.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	REVIEW OF LITERATURE	2
	Using Chromic Oxide and Lignin as Indicators for Determining Digestion Coefficients	2
	Factors Known or Suspected to Influence Digestibility of Ration Constituents for Mature Lactating Cows . . .	6
III.	EXPERIMENTAL PROCEDURE	11
	Selection and Management of Cows	11
	Chromic Oxide Administration Procedure	15
	Procedure for Collection of Fecal Samples	16
	Sample Preparation	17
	Laboratory Analysis and Calculations	18
	Statistical Analysis	18
IV.	RESULTS AND DISCUSSION	20
	Dry Matter Intake by Cows	20
	Evaluation of Lignin and Cr_2O_3 as Indicators	26
	Factors Affecting Digestibility	28
V.	SUMMARY	43
BIBLIOGRAPHY		45
APPENDIX		50
VITA		52

LIST OF TABLES

TABLE

PAGE

1. Animal Observations 12
2. Individual Dry-Matter Consumption, kg/Day 21
3. Dry Matter Digestion Coefficients for Individual Cows Based on Either Cr_2O_3 or Lignin 27
4. Digestion Coefficients and Digestible Energy 29
5. Nutrient Composition of Ration Constituents 31
6. Composition of Ingested Rations by Individual Cows, Percent 33
7. Simple Correlation Coefficients, I 34
8. Estimated Total Digestible Nutrients 41
9. Simple Correlation Coefficients, II 51

CHAPTER I

INTRODUCTION

The difficulty of collecting digestibility data from statistically relevant numbers of animals while subjecting them to the stress of metabolism crates or bulky fecal collection collection harness has often led researchers to assume a necessarily over-wary approach to digestion studies. The use of indigestible indicators to indirectly derive digestion coefficients without a full fecal collection has, despite numerous problems encountered with their use, received marked attention in the animal nutrition field. This is due to the ease with which this method may be adapted to use with larger numbers of animals and the relatively lower labor requirements, while not subjecting the animals to undue stress.

The adaptibility of the indicator method for digestibility studies led to this experiment, which is an attempt to utilize relatively unique indicator methodology to evaluate the effects of factors other than those directly related to type and quality of feed on the digestibility of rations for mature, lactating beef cows. These variables include cow body weight, height, condition, and feed consumption, as well as various calf-related variables which may affect production of the cow, such as calf weight and average daily gain.

CHAPTER II

REVIEW OF LITERATURE

I. Using Chromic Oxide and Lignin as Indicators for Determining Digestion Coefficients

Ideally, the indicator, or inert reference substance, should be indigestible, unabsorbable, pharmocologically inactive, should pass through the tract at a uniform rate and be readily determined chemically (Maynard and Loosli, 1969). Two of the substances which most nearly meet these qualifications are chromic sesquioxide (Cr_2O_3), an external indicator, and lignin, an internal indicator.

The ratio of the concentration of the indicator to that of a given nutrient in the feed, and the same ratio in the feces are used to determine digestibility by the formula shown below (Kane et al., 1951; Schurch et al., 1952):

$$\text{Digestibility} = 100 - 100 \frac{\%\ \text{indicator in feed}}{\%\ \text{indicator in feces}} \times \frac{\%\ \text{nutrient in feces}}{\%\ \text{nutrient in feed}}$$

Chromic Oxide as An Indicator for Digestibility Studies

The use of Cr_2O_3 as an external indicator to determine digestion coefficients has received much attention by researchers interested in ruminant nutrition since its introduction by Edin in 1918 (Kane et al., 1951). Several problems have been encountered, however, and the resolution of some of these problems is incomplete at this time.

Most of the difficulty in Cr_2O_3 research is related to the diurnal excretion of the indicator (Elam et al., 1959). This phenomenon is apparently affected by frequency of administration of Cr_2O_3, time of administration, method of administration and level of feed intake.

Several researchers have found that increasing Cr_2O_3 dosing frequency from one to six times per day tends to reduce the amplitude of the Cr_2O_3 excretion curve (Brisson et al., 1957; Hardison et al., 1956; Smith and Reid, 1955). Increasing dosing frequency does not eliminate diurnal variation in the excretion of Cr_2O_3 completely, however (McGuire et al., 1966), and there is the disadvantage of increased labor with each additional dose.

The time of administering the Cr_2O_3 in relation to feeding has also been studied. Hardison et al. (1956) and Kane et al. (1951) found no relationship between indicator excretion and dosing time. Elam et al. (1959) found that feeding schedule affected the time-concentration variation in fecal Cr_2O_3. Others have since confirmed this (Putnam et al., 1967).

There are several methods for administering Cr_2O_3 including mixing directly with the ration, mixing with the ration and pelleting, gelatin capsule and using paper as a carrier. Crampton and Lloyd (1951) showed that the methods utilizing less concentrated doses of Cr_2O_3 have a recovery rate approaching 100 percent. Corbett et al. (1959) proved that gelatin capsules could lodge in the anterior rumen or reticulum.

Heifers fed at higher levels have been shown to excrete Cr_2O_3 at a more rapid rate (Putnam et al., 1967). Phar et al. (1970), in

studies with limit-fed steers, found that recovery rate was increased as level of feeding was decreased.

Another approach for overcoming the problem of diurnal variation in Cr_2O_3 excretion (rather than trying to decrease or eliminate the variation) is to assume a constancy in the diurnal excretion curve when variables which affect that curve are held constant. The percentage variation in Cr_2O_3 excretion from the mean excretion at any time is calculated from the diurnal excretion curve. Fecal samples may then be taken at pre-selected times corresponding to known points on the diurnal excretion curve, and the Cr_2O_3 percentages in these fecal samples can be mathematically corrected (unless the time selected happens to exactly correspond to the mean of the excretion curve) for error due to diurnal variation.

In spite of the various problems encountered with using Cr_2O_3 in digestion studies, many researchers have utilized this technique with varying degrees of success. Hatten and Owen (1969) compared the results of a total collection trial and a Cr_2O_3 indicator trial. Digestion coefficients determined by the Cr_2O_3 method were uniformly lower, without being significantly different in most cases. This was attributed to incomplete recovery of the Cr_2O_3. Phar et al. (1967) found similar results. Hardison et al. (1956) found that digestion coefficients varied more among animals than among days over a seven-day collection period.

Lignin as an Indicator for Digestibility Studies

Lignin is found in all forages, is highly indigestible and chemically inert. These are qualifications which make it potentially useful as an inert reference substance to determine digestibility. There are problems involved with the determination of the percentage of lignin in feeds and feces, however, and these problems have slowed the progress of lignin research (Crampton and Maynard, 1938; Ellis et al., 1946). There has also been some controversy over the possible digestibility of lignin (Bondi and Meyer, 1948; Davis et al., 1947), but this seems to be related to the chemical determination problem (Van Soest, 1964).

The problems involved with the chemical determination of lignin are largely due to the inclusion of various artifact substances in the lignin residue, and the loss of true lignin from this residue (Van Soest, 1964). This has complicated the procedure for digestibility determinations with lignin since the artifact substances (usually proteinaceious material) are often digestible to some degree. The old method of lignin determination (Ellis et al., 1946) is particularly vulnerable to these problems and has largely been discontinued in favor of the acid-detergent method developed by Van Soest (1963). Inaccuracies in lignin determination have also been traced to heat damage caused by the drying of samples over 50 degrees centigrade (Van Soest, 1962; Barth et al., 1970), and to loss of lignin by treatment of forage samples with solutions with a pH of greater than 7.0 (Van Soest, 1964).

Kellaway (1969) found the Van Soest method to be superior to other methods for determining lignin percentages with errors ranging from ± 0.2 percent to ± 0.4 percent. He also pointed out that the Van Soest method is simpler than other methods. Colburn et al. (1968) reported nearly 100 percent recovery of acid-detergent lignin.

Research utilizing acid-detergent lignin to determine digestion coefficients has not been extensive, but the results that have been reported are encouraging. Wilson et al. (1971) found that the use of acid-detergent lignin as an internal indicator was superior to other lignin methods for digestibility studies.

II. Factors Known or Suspected to Influence Digestibility of Ration Constituents for Mature Lactating Cows

It is recognized that the most influential factors affecting the digestibility of rations for cattle are directly related to the various feeds which make up that ration, the quality of these feeds, their preparation and the frequency with which they are fed (Church, 1969). These factors are not, however, of primary importance in this review but are mentioned since they cannot be wholly deleted from any discussion of digestibility.

Factors affecting digestibility other than those directly related to the type and quality of the feed have received less attention by animal nutritionists. These include level of intake in relation to maintenance and production needs, cow age and genetic variability.

Level of Intake or Plane of Nutrition

The amount of feed which a ruminant consumes in relation to various physical and productive parameters has a definite (but highly variable) effect on the degree to which that feed is digested (Anderson et al., 1959). Using the principle of diminishing returns, as developed by Liebig (cited by Brody, 1945), researchers have found that as food intake increases, productive processes increase at a decreasing rate (Jenson et al., 1942; Brody, 1945). These results have led to the logical assumption that digestibility decreases as intake increases above maintenance (Brody, 1945; Anderson et al., 1959).

Level of intake as a function of maintenance. The level of intake required to maintain the body of an animal at a constant weight and condition has been found to be a function of body weight to a power (W^b) (Brody, 1945). Several researchers have theorized that the relationship between dry matter (DM) consumption and nutrient digestibility is dependent upon the level of intake required for maintenance. As intake increases above maintenance, digestibility should theoretically be decreased (Lassiter et al., 1957; Anderson et al., 1959).

Forbes et al. (1928) fed alfalfa hay and corn meal to steers at five planes of nutrition: (1) fast, (2) half of the maintenance requirement, (3) maintenance, (4) half more than maintenance, and (5) twice the maintenance requirement. They found that dry matter digestibility was lower on the sub-maintenance level (0.5 x maintenance, 75.8 percent; maintenance, 76.4 percent), and also on the super-maintenance levels (1.5 x maintenance, 74.7 percent; 2.0 x maintenance,

72.5 percent). Individual nutrient and energy digestion coefficients tended to follow a similar pattern.

Anderson et al. (1959), using Brody's (1945) equation to determine the level of intake required to maintain body weight, fed both all-forage rations and mixed forage-concentrate rations to steers at different levels corresponding to multiples of the maintenance level. They found that, within the levels used (0.9 to 1.7 times the amount required for maintenance), there was no effect on digestibility with the all-forage ration. With a mixed ration, however, the results indicated that dry matter is 8.0 to 25.0 percent less digestible by steers at levels of intake 2.0 to 3.0 times the maintenance level.

In contrast, Blaxter (1962) showed that apparent dry matter digestibility of forages was usually depressed at higher levels of feeding. He also found that lower quality rations had a greater depression in digestibility at higher levels of feeding than did high quality rations. Finely ground feeds also exhibited a larger degree of depression in digestibility at higher levels of feeding. He related these phenomena to the rate of passage of ingesta through the rumen. High levels of intake and fine grinding of feeds cause increased rates of passage of ingesta through the rumen which causes decreased microbial digestion of particulate matter.

Level of intake per unit of production. In the beef cow, the production parameters of interest are those which are related to reproduction and calf growth. The secretion rate of milk parallels the demand for the milk by the calf until the point is reached where the cow

can no longer supply the milk needed. The intake of the cow must, therefore, be increased sufficiently to accommodate the various demands placed upon her in reproduction and lactation.

In recent work with beef cattle and beef cattle-Holstein crosses, Holloway (1973) explored the relationships between level of supplementation, winter weight loss, milk yield and calf gain. He found that as level of supplement intake increased, winter weight loss decreased, milk yield increased and calf gain increased.

Effect of Age on Disgestibility

The variation in digestibility due to age has been studied by several researchers, but little evidence has been found which indicates that age has any effect on digestibility (Maynard and Loosli, 1969). Blaxter (1962) arrived at a similar conclusion, except for possible declines in digestibility caused by loss of teeth at an advanced age or by the tendency to feed younger animals a greater amount of food relative to their size. Barth (1975) observed higher digestibility of dry matter, gross energy and crude protein by mature wether sheep weighing 85 kg than by wether lambs weighing 50 kg.

Effect of Breed on Digestibility

Comparative studies have been made exploring the differences in the degree to which cattle of the European (Bos taurus) breeds and those of the Brahman (Bos indicus) breeds digest various rations which differ in quality and nutrient make-up. Ashton (1962) found that the dry matter digestibility of hay was lower with Hereford steers than with Brahman steers. Vercoe (1967) reported that, with high

quality alfalfa hay, dry matter and nitrogen digestibility was higher in Brahman x Hereford steers than in Hereford steers.

Recent work by Moore et al. (1975) indicates that cattle of the European breeds have higher digestibilities with high energy rations than Brahman cattle, and lower digestibilities than Brahman cattle on low energy rations.

Biological Variation in Digestion Studies

Apparent digestibility is a biological measurement, and is subject to variation due to the differences between the animals and due to the error involved in measuring biological phenomena. Crampton and Harris (1956) pointed out that animal variation causes digestion coefficients to have a degree of error which prevents them from being constant for a given ration fed to a specific type of animal. This does not, however, keep these measurements from having a significant role in evaluating feeds.

Blaxter (1962) attributed most differences in the ability of animals within a group to digest food to internal parasitism, poor or changing dentition, and inherent digestion differences. He further stated that the heritability of digestive power has been found to be low in experiments with twins.

Other conditions which may cause variation in digestibility data are exercise and temperature. In experiments at the Hannah Institute (Blaxter, 1962) it was found that little, if any, effect was caused by exercise differences. He also dismissed the effects of temperature as being inconsequential.

CHAPTER III

EXPERIMENTAL PROCEDURE

Data for this study were obtained from 22 mature lactating Angus cows. These cows were concurrently being used in a "cow-size" experiment to study the effects of cow size and maternal ability on efficiency of beef production. The experiment was conducted at The University of Tennessee's Blount Farm.

I. Selection and Management of Cows

Cow Selection

The cows were selected from three University of Tennessee herds to give an adequate range of body weights and body types for evaluating the effects of these parameters on beef efficiency. They ranged in weight from 409 to 564 kilograms with a mean weight of 492 kilograms. The height at the shoulders ranged from 109 to 124 centimeters with a mean height of 118 centimeters.

All of the cows in this trial were nursing calves which ranged in weight from 167 to 290 kilograms with a mean weight of 234 kilograms. The cows had been exposed to the bull and were assumed to be in the second or third trimester of pregnancy. Variables describing body characteristics and gain of cows and calves are presented in Table 1.

TABLE 1. ANIMAL OBSERVATIONS

	COW						CALF				
Cow number	Body weight, kg[a]	Metabolic weight, $W_{kg}^{.75}$	Fat thickness, mm[a]	Height, cm[a]	Weight/ height, kg/cm	Weight change during experiment, kg[b]	Weight, kg[a]	Metabolic weight, $W_{kg}^{.75}$	ADG, kg[c]	Age, days	Sex[d]
1	450	97.7	5.0	115	3.91	2.0	252	63.3	0.87	322	F
2	506	106.7	6.0	123	4.11	6.8	288	69.9	1.14	308	M
3	484	103.2	6.0	119	4.07	-4.5	277	67.9	0.96	315	M
4	456	98.7	5.0	118	3.86	2.3	269	66.4	0.69	318	M
5	470	101.0	4.0	116	4.05	0.0	226	58.3	1.06	269	M
6	486	103.6	5.5	123	3.95	4.6	273	67.2	0.82	318	F
7	440	96.1	5.0	122	3.61	15.9	277	67.9	0.79	310	M
8	424	93.5	4.0	114	3.72	-2.3	202	53.6	0.94	227	M
9	523	109.3	10.0	114	4.59	0.0	269	66.4	0.80	317	F
10	506	106.7	5.5	114	4.44	11.4	185	50.2	0.91	237	M
11	484	103.2	7.5	115	4.21	0.0	183	49.8	0.74	246	F
12	530	110.4	8.0	124	4.27	4.5	174	47.9	0.91	237	F
13	484	103.2	5.0	124	3.90	0.0	236	60.2	0.50	314	F
14	470	101.0	5.5	117	4.02	4.5	193	51.8	0.89	246	M
15	409	91.0	3.5	110	3.72	0.0	193	51.8	0.85	237	M
16	511	107.5	19.0	121	4.22	22.7	220	57.1	0.91	306	M
17	522	113.9	7.0	109	5.06	40.9	260	64.8	0.67	373	M
18	488	103.8	3.0	123	3.97	-2.3	183	49.8	0.79	237	F

TABLE 1. (Continued)

	COW						CALF				
Cow number	Body weight, kg[a]	Metabolic weight, $W_{kg}^{.75}$	Fat thickness, mm[a]	Height, cm[a]	Weight/ height, kg/cm	Weight change during experiment, kg[b]	Weight, kg[a]	Metabolic weight, $W_{kg}^{.75}$	ADG, kg[c]	Age, days	Sex[d]
19	554	114.1	5.0	121	4.58	15.9	290	70.3	0.72	329	F
20	478	102.3	7.5	116	4.12	-6.8	250	62.9	0.91	288	F
21	564	115.7	4.5	112	5.04	0.0	286	69.6	1.05	322	M
22	545	112.7	7.0	123	4.43	6.8	167	46.5	0.99	214	M
Mean	492	104.3	6.3	118	4.18	5.6	234	59.7	.86	286	
C.V.%	8.57	6.41	51.97	3.98	9.27	191.5	18.17	13.75	16.89	15.24	

[a]Mean of observation recorded one week prior to start of experiment and one week following the end of experiment.

[b]Difference between body weights.

[c]Average daily gain from 9/11/74 to 12/3/74 (83 days).

[d]M = castrated male; F = female.

Facilities

The cow-calf pairs had previously been randomly assigned to 6.5 x 40 feet individual feeding and loafing pens. The pens had concrete floors and were located partially under an open shed. Each pen had an automatic waterer, a large feeding stall equipped with a gate at the rear for the cow and a small feeding stall accessible only to the calf. The cow-calf pairs were removed from the individual pens and placed in a common loafing area at night.

Feeding and Ort Collection Procedure

The experiment included a nine-day preliminary feeding period so that feed intake could be stabilized and a "steady state" of chromic sesquioxide excretion could be established. This was followed by a seven-day collection period.

The twenty-two lactating cows were separately fed a measured amount of timothy (Phleum pratense), orchardgrass (Dactylis glomerata), silage and alfalfa (Medicago sativa) pellets once a day. In order to achieve a uniform ratio between the silage and the pellets eaten by the cow, the pellets were fed at 10 percent of the previous day's silage intake (as fed basis).

The calves were fed a creep ration of alfalfa pellets. Some consumption by the calf of the silage intended for the cow could not be prevented. The amount of silage consumed by the calf is not known, although attempts were made to estimate it.

Feed refusals were weighed every morning before feeding and were assumed to consist entirely of silage (complete consumption of

pellets was assumed). If the amount of refusals was not too large, the entire sample was deposited in a plastic bag and sealed for transport to the nutrition laboratory. If the refusal was too great, a representative sample was taken, deposited in the bag, sealed and transported to the laboratory. The bags were identified by cow number and the date.

If the quantity of refusals was larger than desired (over 10 percent of the previous day's feed allotment) the amount of feed was decreased. If refusals were slight, feed quantity offered was increased the following day. This procedure was followed to obtain adequate intake with minimum refusal.

II. Chromic Oxide Administration Procedure

Each cow received a ten-gram dose of Cr_2O_3 (mol. wt. 151.99) powder per day during the entire experiment. The following procedure was developed to assure quantitative consumption of chromic oxide (Cr_2O_3--an external indicator) with minimal disruption of the normal feeding routine.

The Cr_2O_3 was weighed into a clean dry glass test tube, stoppered and transported to the farm each morning before feeding. Three pounds of alfalfa pellets for each cow were thoroughly moistened by sprinkling with warm water and approximately one-third of this was poured into rectangular plastic feeding pans. Approximately one-half of the 10g dose of Cr_2O_3 was poured over this. One-third more of the moist alfalfa pellets was added and the remainder of the Cr_2O_3 was sprinkled over this. The rest of the alfalfa pellets were then poured over the mixture.

The plastic pan containing the Cr_2O_3-alfalfa pellet mixture was placed in each cow's feeding trough and the cows were permitted to enter their pens without their calves. After the cows had consumed the mixture, the pans were removed and the individual allotments of silage and remaining pellets were fed. Any residue (Cr_2O_3, pellets or saliva) left in the plastic pans was wiped out with a handful of silage and added to the cow's ration. The calves were turned in with their dams after cows had eaten most of their alfalfa pellets.

III. Procedure for Collection of Fecal Samples

The following procedure for collection of fecal samples (grab samples) over the seven-day collection period was followed. The collection time had been previously established in a study conducted by Thomas (1975).

Each cow in succession was closed in her feeding compartment which curtailed movement by the cow enough for safe collection of feces by inserting the hand into the rectum and grasping the fecal material. A clean disposable plastic glove was used with each cow to prevent contamination of the sample. After obtaining a fecal sample of adequate proportion the collector deposited it in a clean, air-tight plastic jar previously marked with the cow's pen number and date. The time of collection was recorded on the jar and the jar was sealed. After all the fecal samples for that day were collected, they were removed to the nutrition laboratory and transferred to drying pans.

IV. Sample Preparation

Random samples of the timothy-orchardgrass silage and alfalfa pellets were taken during the seven-day collection period. The alfalfa pellet samples were mixed prior to drying to obtain one representative sample. Silage samples and refusals were individually placed in marked drying pans, weighed, dried at 60°C for three days and air-equilibrated for three days. They were then weighed again to determine air-equilibrated dry matter percentages, individually ground in the Wiley mill using a 20-mesh screen and stored in clean bottles. A composite silage sample was obtained by mixing equal portions of each of the several random silage samples together. A composite refusal sample was similarly obtained by mixing equal portions of each cow's daily orts into one representative sample for each cow. The composite alfalfa sample, silage sample and refusal samples were then ground in a Thomas-Wiley Intermediate Mill using a 40-mesh delivery tube.

Daily fecal samples for each cow were weighed, dried in individual marked drying pans for three days at 60°C, air-equilibrated for three days and weighed again to determine dry matter percentage. Each sample was then ground in the Wiley mill using a 20-mesh screen, and a representative sample for each cow was obtained by taking an equal portion from each day's collection for that cow and thoroughly mixing it. This sample was then ground in the Thomas-Wiley Intermediate Mill using a 40-mesh screen.

V. Laboratory Analysis and Calculations

The representative feed samples, refusals for each cow and fecal samples for each cow were analyzed for dry matter, crude protein, acid-detergent fiber (Van Soest, 1963), acid-detergent lignin (Van Soest, 1963) and gross energy (using the Parr Oxygen Calorimeter). In addition to the above, the fecal samples were analyzed for Cr_2O_3 percentage using the method of Stevenson and de Langen (1959). Density readings were made on a Beckman Spectrophotometer at a wave length of 400 millimicrons.

Dry matter, acid-detergent fiber, crude protein and energy digestion coefficients were calculated using lignin as the indicator by the formula (Kane et al., 1951; Schurch et al., 1952):

$$\text{Digestibility} = 100 - 100\frac{\%\text{ lignin in feed}}{\%\text{ lignin in feces}} \times \frac{\%\text{ nutrient in feces}}{\%\text{ nutrient in feed}}$$

VI. Statistical Analysis

Means, ranges, standard deviations and coefficients of variation were calculated for the following variables with each of the 22 cows in the experiment: dry matter consumption, digestible dry matter, digestible crude protein, digestible energy, estimated total digestible nutrients (ETDN from DE and digestible dry matter using equations developed by Heany and Pigden, 1963), cow weight, cow metabolic weight, cow height, cow weight divided by cow height, cow fat thickness, calf weight, calf metabolic weight, calf age, calf average daily gain and calf sex.

Correlation coefficients were calculated to estimate the relationships between the variables described in the preceding paragraph. Regression analysis was employed to assess the effects of various independent variables on such dependent variables as dry matter intake, digestible dry matter and digestible crude protein.

TABLE 2. INDIVIDUAL DRY-MATTER CONSUMPTION, KG/DAY

Cow Number	Timothy-orchardgrass silage[a]	Pellets[b]	Total ration, determined	Total ration, estimated[c]	Total ration/ body weight, percent
1	12.7	3.23	15.93	14.66	3.54
2	13.4	3.30	16.73	16.34	3.31
3	12.5	3.17	15.74	14.44	3.25
4	11.2	3.30	14.51	14.12	3.18
5	13.0	3.23	16.25	13.91	3.46
6	12.7	3.10	15.84	16.21	3.26
7	12.8	3.10	15.90	17.96	3.61
8	12.0	3.23	15.24	15.16	3.59
9	11.7	2.96	14.66	16.44	2.80
10	12.6	3.23	15.84	16.81	3.13
11	12.5	3.02	15.61	18.94	3.23
12	11.6	2.96	14.64	15.92	2.76
13	8.7	2.82	11.57	11.52	2.39
14	13.2	3.23	16.52	21.96	3.51
15	9.7	2.82	12.52	15.02	3.06
16	10.4	2.82	13.26	11.63	2.59
17	13.2	3.37	16.59	14.10	3.01
18	11.3	2.96	14.31	25.87	2.93

TABLE 2. (Continued)

Cow Number	Timothy-orchardgrass silage	Pellets[b]	Total ration, determined	Total ration, estimated[c]	Total ration/ body weight, percent
19	13.6	3.58	17.27	17.25	3.12
20	11.6	3.30	14.95	14.73	3.13
21	12.8	3.03	15.91	16.18	2.82
22	10.9	2.82	13.81	15.06	2.53
Mean	12.0	3.12	15.16	15.98	3.10
C.V. percent	10.41	6.60	9.35	21.14	11.18

[a]Dry matter 43.0 percent.

[b]Dry matter 90.8 percent.

[c]Dry-matter intake estimated by indicator (Cr_2O_3: Acid-detergent lignin) ratio procedure.

metabolizable energy (ME) basis. The ME supplied by the alfalfa pellets for each calf was similarly found using the tables by Crampton and Harris (1969). The total ME intake supplied by milk and pellets to the calves was then calculated.

Using the NRC (1974) nutrient requirement recommendations for beef cattle, the ME requirement for each calf according to its weight and gain was determined. Subtracting the ME supplied by milk and pellets from the NRC recommendation for ME for each calf yielded a value which represented the deficiency of energy which the calf was assumed to have corrected by eating silage.

In order to estimate the amount of silage eaten by each calf, an estimate of energy supplied per unit of silage was needed. An orchardgrass silage which was similar to the silage used in this experiment was found in the tables by Crampton and Harris (1969). From this, it was assumed that the silage would supply 1032 kcal of ME per kg of dry matter.

Dividing the calves' ME deficiency by the ME supplied per kg of silage resulted in the amount of silage the calves should have eaten to overcome the deficiency of energy in their diet. Subtracting this from the measured silage consumption by cows resulted in a corrected DM intake of the cows.

In evaluating the "NRC Method" for correcting cow intake figures, the accuracy of some of the following data is questionable: the nutritive values of feeds and milk, measurement of milk intake, measurement of the weights and the weight gain for the calves. Further, the application of general NRC requirement recommendations to a

specific research situation may not be justified. In addition, when the corrected intake figures were used to calculate digestion coefficients, the results were obviously erroneous, i.e., negative digestion coefficients were found in some cases. This led to the conclusion that the "NRC Method" altered the results too stringently. It was concluded that the measured intake figures were more correct than the figures derived by "NRC Method."

A Lignin-Cr_2O_3 Ratio Technique for Estimating Intake by Cows

Another method for estimating dry matter intake without measuring either the amount fed or the amount of feces voided utilizes the ratio between the indicators (lignin and Cr_2O_3) from the feed to the feces in the following manner.

Given the percentage of lignin in the feed and the feces and the percentage of Cr_2O_3 in the feces, it is possible to calculate the percentage of Cr_2O_3 in the feed. This is possible because the percentages of Cr_2O_3 and lignin increase (from feed to feces) at the same rate depending on the absorption of the digestible nutrients from the gastro-intestinal tract. Therefore the lignin:Cr_2O_3 ratio in the feed should be the same as the lignin:Cr_2O_3 ratio in the feces. In equation form this would be:

$$\frac{\% \text{ lignin in feed}}{\% \ Cr_2O_3 \text{ in feed}} = \frac{\% \text{ lignin in feces}}{\% \ Cr_2O_3 \text{ in feces}}$$

Solving for the unknown value:

$$\% \ Cr_2O_3 \text{ in feed} = \frac{\% \text{ lignin in feed} \times \% \ Cr_2O_3 \text{ in feces}}{\% \text{ lignin in feces}}$$

From the calculated percent Cr_2O_3 in the feed and from the amount of Cr_2O_3 fed per day (10g) the amount of dry matter consumed by the cow may be calculated as follows:

$$\% \ Cr_2O_3 = \frac{\text{amount of } Cr_2O_3 \text{ in feed} \times 100}{\text{amount of DM in feed}}$$

$$\frac{\text{amount of DM in feed}}{\text{amount of } Cr_2O_3 \times 100} = \frac{1}{\% \ Cr_2O_3 \text{ in feed}}$$

$$\text{DM intake} = \frac{\text{amount of } Cr_2O_3 \times 100}{\% \ Cr_2O_3 \text{ in feed}}$$

The results of the application of the lignin-Cr_2O_3 ratio technique are also given in Table 2, page 21. When these results are compared to the measured dry matter intake of the cows, it was readily apparent by visual inspection of the data that, while there was close agreement in several cases, there were also many instances of extreme disparity between the actual measured intake and the estimated intake. This error was related to the percentage of Cr_2O_3 in the feces. From this, one may conclude that the effect of diurnal variation on the excretion of Cr_2O_3 was not eliminated when the Thomas (1975) technique was employed.

If, however, one can assume that the error due to diurnal excretion was random (this may not be a totally valid assumption because of the number of animals involved and the possibility of error in establishing the mean of the diurnal excretion curve), one may conclude from the relatively small difference in the means of the measured DM intake versus the estimated DM intake (15.16kg versus 15.98kg) that

the measured DM intake for each cow was not an unreasonable figure to use in calculating digestion coefficients.

In assessing the value of the lignin-Cr_2O_3 technique for intake studies, one must concede the problems that must be overcome, especially those problems involved with the diurnal excretion of Cr_2O_3. If these problems can be resolved (and there is evidence that they can be) this technique may have some interesting possibilities in nutrition research.

II. Evaluation of Lignin and Cr_2O_3 as Indicators

Two indicators were used in this experiment, acid-detergent lignin (an internal indicator) and Cr_2O_3 (an external indicator). Dry matter digestion coefficients based on either acid-detergent lignin or Cr_2O_3 as the indicator are presented in Table 3. Differences between the results for individual cows with different indicators are readily apparent by visual inspection, and the simple correlation coefficient calculated to estimate the relationship between the two arrays of digestion coefficients was highly insignificant (correlation coefficient = 0.03). However, similarity of the means of the dry matter digestion coefficients derived by using acid-detergent lignin (49.7 percent) or Cr_2O_3 (46.5 percent) may indicate that the error which causes the extreme variation between the results of the two methods was random.

The fact that the coefficient of variation was much larger with the Cr_2O_3 method (19.6 percent with the Cr_2O_3 method compared to 5.4 percent with the acid-detergent lignin method) lead to the conclusion that the greatest amount of error was in the digestibility data derived

TABLE 3. DRY MATTER DIGESTION COEFFICIENTS FOR INDIVIDUAL COWS BASED ON EITHER Cr_2O_3 OR LIGNIN

Cow number	Based on acid-detergent lignin	Based on Cr_2O_3
1	50.9	56.0
2	55.3	55.0
3	48.5	52.3
4	48.6	49.3
5	52.1	53.7
6	51.5	46.8
7	46.8	39.2
8	49.2	47.6
9	47.5	40.0
10	43.8	40.9
11	50.0	39.7
12	47.2	45.1
13	47.3	61.1
14	51.3	31.3
15	49.0	37.4
16	50.5	56.1
17	45.0	53.8
18	52.3	22.1
19	52.3	52.0
20	51.2	49.5
21	51.6	48.9
22	50.7	44.5
Mean	49.7	46.5
C.V., percent[a]	5.40	19.64

[a]Coefficient of variation.

by the use of Cr_2O_3. Corroboration for this conclusion may also lie in the fact that certain of the DM digestion coefficients (especially those for cows 13, 14, and 18) derived using Cr_2O_3 did not fall within the logical range which one might expect from similar rations.

One possible reason for the large degree of error in digestion coefficients derived by using Cr_2O_3 as the indicator was pointed out by Thomas (1975). Since the animals consumed different amounts of feed with a constant amount of Cr_2O_3, the ratio of feed to Cr_2O_3 in the ration, and consequently in the feces, varied according to intake. Therefore, when fecal collection is carried out at the time the mean excretion curve intersects the mean excretion line there will be variation in feed Cr_2O_3 percentages due to variation in intake.

For the preceding reasons, the conclusion was reached that the digestion coefficients using acid-detergent lignin are more reliable and valid. Digestion coefficients derived by using acid-detergent lignin as the indicator will be used to evaluate relationships between the various animal observations and digestion coefficients.

III. Factors Affecting Digestibility

Digestion Coefficients

Digestion coefficients of energy, acid-detergent fiber and crude protein, and digestible energy from individual cows are presented in Table 4. Mean digestion coefficients for dry matter (49.7 percent, Table 3), crude protein (41.8 percent), acid-detergent fiber (41.6 percent) and energy (48.3 percent) were all somewhat lower than might normally be expected for an orchardgrass silage-alfalfa pellet ration.

TABLE 4. DIGESTION COEFFICIENTS AND DIGESTIBLE ENERGY[a]

Cow Number	Digestion Coefficients, Percent			Digestible energy, kcal/g
	Energy	ADF	CP	
1	48.3	44.3	45.9	2.14
2	53.0	48.6	43.5	2.37
3	46.5	41.8	42.9	2.07
4	46.9	39.3	48.6	2.09
5	50.2	43.1	44.5	2.24
6	48.1	40.9	40.6	2.15
7	46.9	40.8	39.8	2.09
8	48.7	42.3	45.6	2.18
9	46.0	38.8	43.1	2.04
10	43.5	39.8	40.2	1.94
11	49.3	43.7	43.2	2.21
12	46.3	38.7	37.4	2.07
13	46.6	40.3	40.5	2.08
14	51.0	44.5	45.7	2.28
15	46.8	38.3	43.6	2.08
16	49.9	44.9	44.0	2.22
17	44.5	35.9	34.6	1.99
18	50.9	40.5	42.9	2.27
19	50.4	40.7	38.6	2.25
20	49.9	40.6	40.6	2.22
21	49.6	42.3	35.8	2.21
22	48.4	45.4	37.3	2.15
Means	48.3	41.6	41.8	2.15
C.V., percent	4.77	6.87	8.52	4.84

[a]Using acid-detergent lignin as the indicator.

The higher than average percentages of lignin and acid-detergent fiber (Table 5) in the ration constituents might be responsible for this low digestibility.

A high degree of variation between the digestion coefficients and DE of individual cows was exhibited (coefficients of variation were: DDM, 5.40 percent; gross energy digestion coefficient, 4.77 percent; ADF digestion coefficient, 6.87 percent; CP digestion coefficient, 8.52 percent; DE, 4.84 percent). Several factors may have caused this variation, including differences in nutrient composition of the ingested ration, physical characteristics of the animals (such as body weight, height or fat thickness) and error due to biological variation or lack of refinement in indicator technique.

Possible Effect of Ration Composition on Variation in Digestibility

In order to assess the effects of various animal characteristics on digestibility of ration constituents, the nutrient make-up of the consumed ration for all the cows should not vary markedly. However, in the present experiment slight variations in the nutrient composition of the ingested ration could not be avoided, since the cows were able to select or avoid some portions of the silage.

The nutrient composition of the ingested ration was calculated by adding the product of each nutrient and amount offered of the two ration constituents and subtracting the product of amount and composition of the refusals. The quotient of the amount of nutrient ingested and total dry matter ingested yielded the percentage of the nutrient in the ingested ration.

TABLE 5. NUTRIENT COMPOSITION OF RATION CONSTITUENTS

	Orchardgrass-timothy silage	Alfalfa pellets
Day matter, percent	43.0	90.8
Crude protein, percent[a]	12.3	19.7
Acid-detergent fiber, percent[a]	50.4	37.3
Acid-detergent lignin, percent[a]	11.2	10.9
Gross energy, kcal/g[a]	4.49	4.34

[a]Dry matter basis.

The composition of the ingested ration for each cow is presented in Table 6. Visual inspection of the ingestion data led to the conclusion that the variation in nutrient composition of ration selected by individual cows was minimal. Therefore, variation found in the digestibility data apparently was not related to the percentages of nutrient intake.

Effect of Various Physical Parameters on Digestibility and Intake

Because of the high degree of variability in the digestibility data (Tables 3 and 4, pages 27 and 29, respectively), coefficients of simple correlation were calculated to establish possible relationships between digestibility and intake data with the pertinent animal observation data (Table 7).

Digestibility of dry matter, acid-detergent fiber and energy. A comparison of the simple correlation coefficients between the animal observation data and dry matter, ADF and energy digestion coefficients led to the logical conclusion that these three broad nutrient groups were highly inter-related and could be discussed together.

Neither dry matter, ADF nor energy digestibilities were significantly affected by cow weight, cow metabolic weight or cow fat thickness. Correlation coefficients between cow height and dry matter, ADF and energy digestibility were .30, .34, and .31, respectively, and approached significance ($p<.05$). Biological explanation of this phenomenon is difficult, however, due to the limited amount of available information on this subject. It is possible that the height

TABLE 6. COMPOSITION OF INGESTED RATIONS BY INDIVIDUAL COWS, PERCENT

Cow number	Dry matter	Crude protein[a]	Acid-detergent fiber[a]	Acid-detergent lignin[a]
1	48.7	13.9	48.2	11.2
2	48.6	13.8	47.6	11.1
3	48.7	13.7	48.3	11.1
4	49.8	14.0	46.9	10.9
5	48.7	13.8	47.6	11.0
6	48.6	13.7	47.8	11.1
7	48.5	13.7	47.7	11.1
8	48.8	13.9	47.2	10.9
9	48.8	13.6	47.7	11.0
10	49.1	13.8	46.7	11.1
11	48.7	13.5	48.0	11.0
12	48.8	14.0	48.0	11.3
13	50.4	13.9	47.0	11.3
14	48.7	13.7	47.9	11.0
15	49.6	13.8	47.8	11.0
16	49.2	13.7	48.2	11.2
17	48.9	13.8	47.6	11.2
18	48.9	14.1	47.4	11.2
19	48.9	13.8	47.3	10.8
20	49.6	14.0	47.2	10.8
21	48.4	13.7	47.7	10.9
22	48.8	13.8	47.4	10.9

[a]Dry matter basis.

TABLE 7. SIMPLE CORRELATION COEFFICIENTS, I

Digestion and consumption variables	Animal Observation						Consumption	
	COW				CALF			
	Body weight, kg	Body height, cm	Weight/ height, kg/cm	Fat thickness, mm	Body weight, kg	ADG, kg	Dry matter consumption, kg/day	Dry matter consumption per body weight, percent
Dry matter digestion coefficients, %	.02	.30	-.13	.07	.17	.46*	.22	.16
Acid-detergent fiber digestion coefficients, %	-.02	.34	-.18	.17	-.04	.60**	.18	.18
Digestible energy (DE) kcal/g	.00	.31	-.15	-.01	.07	.41	.24	.20
Crude protein digestion coefficiencts, %	-.71**	.03	-.67**	-.12	-.07	.05	-.10	.45*
Dry matter consumption, kg/day	.24	-.17	.31	-.23	.40	.34	1.00	.66**
Dry matter consumption per unit of weight, %	-.57**	-.25	-.43*	-.43*	.20	.25	.66**	1.00

*Coefficients of correlation are significant ($p < .05$).

**Coefficients of correlation are significant ($p < .01$).

of the animal is positively related to the length of the gastro-intestinal tract which may, in turn, be related to the degree to which the dry matter is digested. This is not in agreement with Blaxter (1962) who stated that ruminant digestive processes are independent of the absolute size of the digestive tract.

Average daily gains of calves were positively correlated with dry matter, ADF and energy digestibilities. The correlation coefficients were .46 (significant, $p < .05$), .60 (significant, $p < .01$), and .41 (approaching significance, $p < .05$), respectively. The relationship between ADF digestibility and average daily gains of the calves is presented in Figure 1. Shown also is the simple regression equation ($r^2 = 0.35$) which predicts ADF digestibility of the cows from rate of gain of their calves. Cow height was also positively correlated with their ADF digestibility, yet not highly correlated with average daily gains of the calves. A multiple regression equation was developed with ADF digestibility as the dependent variable and calf ADG and cow height as the independent variables. This equation is as follows:

$$y = 5.25 + 11.93\ X_1 + 0.222\ X_2 + e$$

where y = ADF digestibility

X_1 = calf average daily gain

X_2 = cow height at the withers

and e = error.

This equation accounted for 47.9 percent of the variability in ADF digestibility.

One possible explanation for the correlation of calf gains with DM, ADF and energy digestion coefficients is that faster-growing

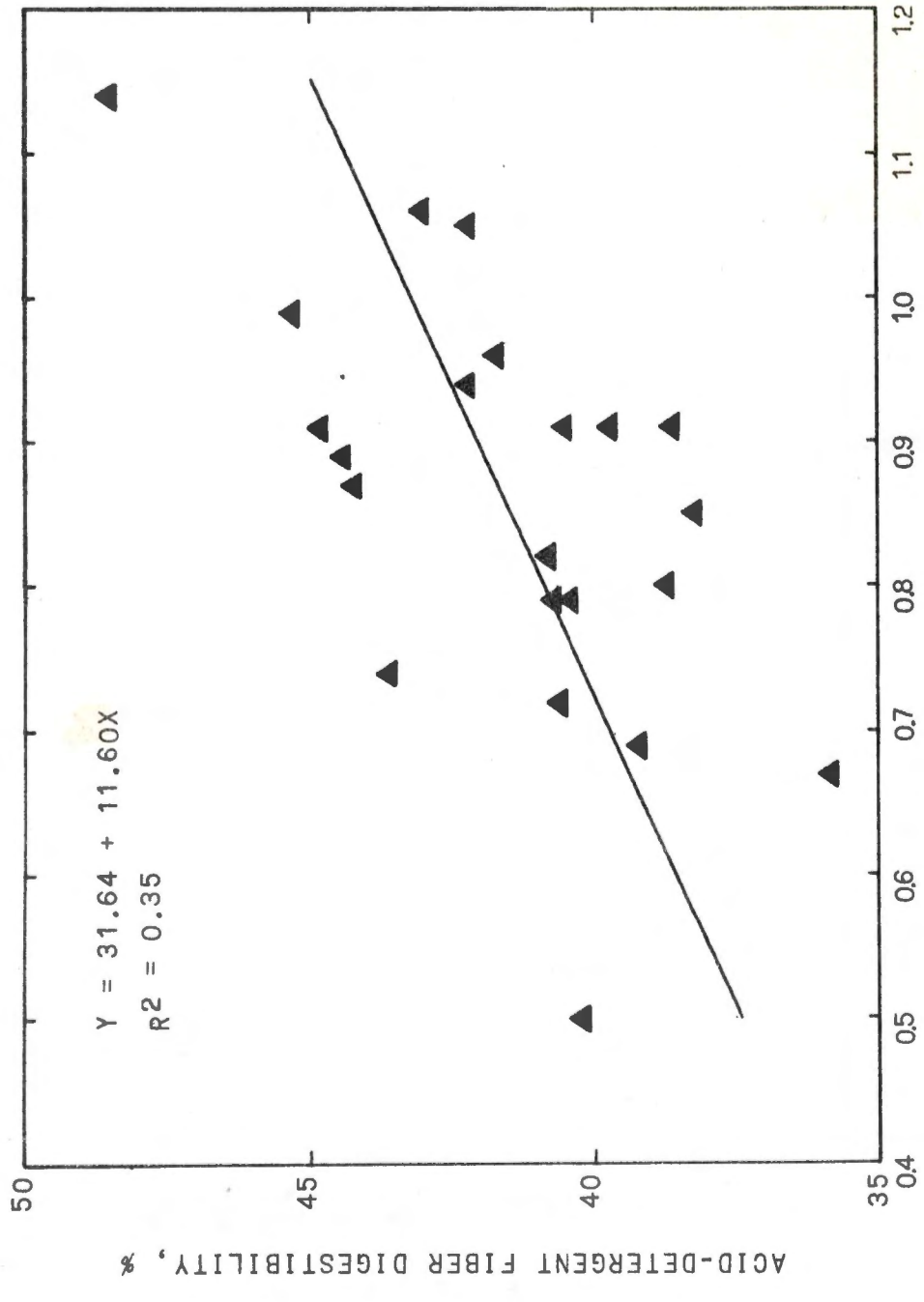

Figure 1. The relationship between ADF digestibility and calf gains.

calves cause increased demands on the cow resulting in increased digestive efficiency by the cow. Inheritance might also be a factor. The calves may gain more because they digest the ration better and they may digest better because they inherited the ability to digest better. This theory is in disagreement with the conclusions reached by Warwick and Cobb (1975) in a review examining the genetic relationships between nutritional phenomena. A more plausible explanation is that the relationship is caused by the previously discounted error in the calculation of digestion coefficients due to the observed consumption of silage by the calves. Faster-growing calves probably consumed more silage which resulted in an overestimation of the apparent digestion coefficients. Therefore, faster-growing calves cause a higher degree of overestimation of digestion coefficients for their dams, causing a positive correlation between the two variables. However, the same relationship could be hypothesized for heavier (thus older) calves, yet there was no correlation between digestibility by cows and the weight of their calves.

Dry matter, ADF and energy digestibility was not significantly ($p < .05$) correlated with the level of dry matter consumption ($r = .22$, .18 and .24, respectively). This is in agreement with Anderson et al. (1959) and Maynard and Loosli (1969) who found that the level of forage intake had little relationship with forage digestibility.

Crude Protein Digestibility

There were several cow-related observations which had a statistically significant ($p < .05$ or .01) relationship with apparent

crude protein digestibility. These include cow body weight (r = - .71), weight divided by height (-.67) (an estimate of physiological body mass, Klosterman et al., 1968) and dry matter consumption per unit of weight (.45).

The relationship between apparent CP digestibility and cow weight is shown in Figure 2. It is noted that the decrease in crude protein digestibility with increasing cow weight is best expressed by a curvilinear (quadratic) function. This indicates that as cows increase in mature weight crude protein digestibility decreases at an increasing rate.

Holter and Reid (1959) found that crude protein digestibility increased as the percentage of crude protein in the feed was increased. However, while there was slight variation in the percentage crude protein of the ingested ration (Table 6, page 33), the crude protein percentages of the ingested rations were not related to crude protein digestibility. This does not, therefore, explain the relationship between crude protein digestibility and cow body weight.

Warwick and Cobb (1975), in a review article exploring genetic variation in nutrition, compared the digestive ability of Bos taurus species with that of Bos indicus (Zebu types). They stated that the Zebu species were superior in apparent crude protein digestibility. This was attributed to higher true nitrogen digestibility by Zebus and lower metabolic fecal protein level. It is quite possible that the differences between the aforementioned species and the differences between animals of different body type within the same species are of similar origin.

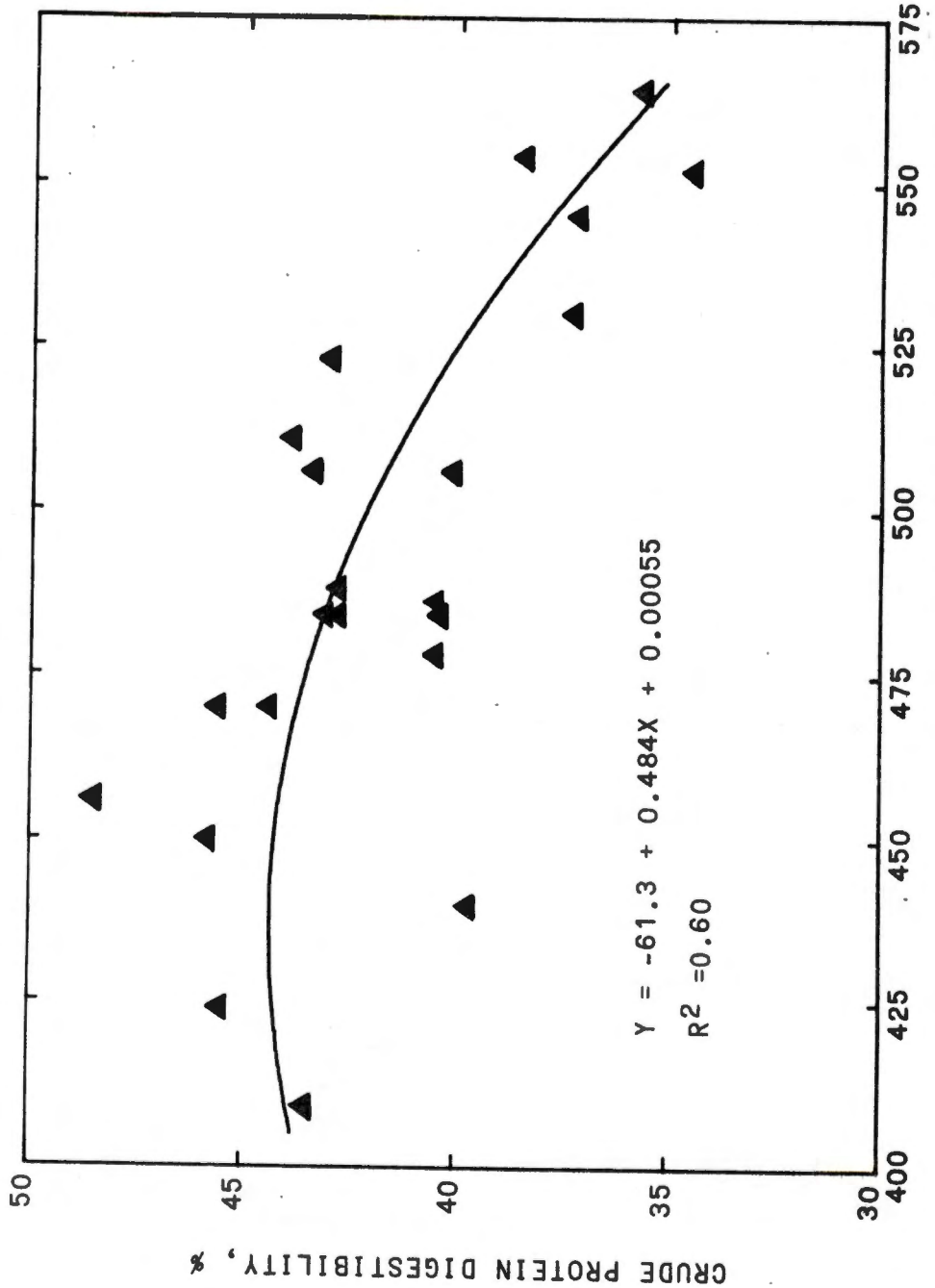

Figure 2. The relationship between crude protein digestibility and cow weight.

Estimated Total Digestible Nutrients

Total digestible nutrients (ETDN) were estimated from DE and DDM (Table 8) by the equations by Heany and Pigden (1963). Since these were calculated variables it was not felt that the ETDN figures for the individual cows would be any more relevant than the DE or DDM data from which they were derived, so they were not statistically related to any of the cow measurement variables. The high correlation between the ETDN from DE with the ETDN from DDM (correlation coefficient = 0.94) provides proof of the validity of the equations.

A comparison of the mean ETDN figures from Table 3, page 27 (49.0 percent when estimated from DDM; 49.1 percent when estimated from DE) with the NRC (1970) TDN requirements for beef cows (50.0 - 57.0 percent) shows that the cows in this experiment were receiving a ration of the quality recommended by NRC.

Variation in Digestibility Due to Error

Of the factors which may normally affect digestibility, it is obvious that those previously discussed (nutrient composition and animal characteristics) only account for a small portion of the variation found in the digestibility data (Table 3, page 27).

It is probable, therefore, that much of the variation in the digestibility is due to error caused by the lack of refinement in indicator technique.

Factors Affecting Level of Consumption Voluntary Intake

Although none of the animal related variables presented were significantly correlated ($p < .05$) with dry matter consumption, there was

TABLE 8. ESTIMATED TOTAL DIGESTIBLE NUTRIENTS[a]

Cow Number	Estimated Total Digestible nutrients, percent[b]	
	From DDM	From DE
1	50.0	48.8
2	53.9	53.0
3	48.0	47.9
4	48.0	47.9
5	51.1	50.7
6	50.6	49.0
7	46.5	47.9
8	48.6	49.6
9	47.1	47.0
10	43.9	45.2
11	49.3	50.1
12	46.8	47.6
13	46.9	47.7
14	50.4	51.4
15	48.4	47.7
16	49.7	50.3
17	44.9	46.1
18	51.3	51.2
19	51.3	50.8
20	50.3	50.3
21	50.7	50.1
22	49.9	49.0
Mean	49.0	49.1
C.V., percent[c]	4.78	3.84

[a]Using acid-detergent lignin as indicator.

[b]Total digestible nutrients estimated from either DDM or DE using equations by Heany and Pigden (1963).

[c]Coefficient of variation.

a noticeable tendency for the calf measurement variables to have a greater effect than the cow measurement variables. This is possibly because of the consumption by the calves of the silage fed to the cows.

The fact that dry matter consumption was not significantly correlated ($p < .05$) with weight, height or condition of the animal does not agree with the results of experiments from other researchers (Garret et al., 1959; Klostermann et al., 1968), who have found that feed requirements are a function of cow weight and condition. The failure of these data to establish significant relationships between consumption and body parameters was probably due to the lack of adequate numbers of cows over a more extensive experimental period.

The amount of dry matter consumption per unit of weight was found to be significantly affected by body weight (correlation coefficient = 0.57), body fat (correlation coefficient = - 0.43), and weight divided by height (an estimate of condition, Klosterman et al., 1968) (correlation coefficient = - 0.43). This indicates that the heavier and fatter animals consumed less per unit of weight. This agrees with the results of Brody (1945).

CHAPTER V

SUMMARY

An indicator digestion trial was conducted using twenty-two mature Angus cows in late lactation in order to establish possible relationships between cow and calf body parameters and nutrient digestibilty. The cow-calf pairs were selected to represent a wide range of body types and structures. They were individually fed timothy (Phleum pratense) orchardgrass (Dactylis glomerata) silage and alfalfa (Medicago sativa) pellets once each day.

Chromium sesquioxide (Cr_2O_3) was administered daily in 10 gram doses to each of the cows during a nine-day preliminary period and a seven-day collection period. Fecal samples were collected once a day over the collection period at a time established in a study by Thomas (1975) to find the optimal time for fecal collection to avoid error due to diurnal excretion of Cr_2O_3.

Feed and feces samples were analyzed for dry matter, crude protein, acid-detergent fiber, acid-detergent lignin, and gross energy. Fecal samples were also analyzed for Cr_2O_3. Digestion coefficients were calculated using both Cr_2O_3 and lignin as the indicator. Under the conditions of this experiment, the lignin method was preferable. Therefore, the digestion coefficients derived using lignin as the indicator were used to evaluate the relationships between cow-related variables and digestibility.

Differences in digestion coefficients between cows were quite marked (coefficients of variation were: dry matter, 5.40; gross energy, 4.77; acid-detergent fiber, 6.87; and crude protein, 8.52). This variation was due to differences in relative ability of cows to digest the nutrients and by error due to lack of refinement in indicator technique. The average dry matter, gross energy, ADF and crude protein digestibilities were 49.7 percent, 48.3 percent, 41.6 percent, and 41.8 percent, respectively.

Dry matter, ADF and energy digestibilities were not correlated with cow weight or fat thickness, but there was a tendency for these variables to show a positive relationship with cow height and average daily gain.

Crude protein digestibility was highly correlated ($p < .01$) with cow weight ($r = -.71$). It was shown that as mature cow weight increased, crude protein digestibility decreased at an increasing rate.

The relationships between various cow-related variables and voluntary consumption were explored. Dry matter consumption was not related to cow weight, cow height or cow fat thickness, but the amount of dry matter consumption per unit of weight was found to be significantly affected by body weight, fat thickness and weight divided by height.

An indicator ratio method for estimating intake by cows was presented which might be of value in future nutrition research.

BIBLIOGRAPHY

BIBLIOGRAPHY

Anderson, P. E., J. T. Reid, M. J. Anderson, and J. W. Stroud. 1959. Influence of level of intake upon the apparent digestibility of forages and mixed diets by ruminants. J. Anim. Sci. 18:1299.

Ashton, G. C. 1962. Comparative nitrogen digestibility in Brahman, Brahman X Shorthorn, Africander X Hereford, and Hereford steers. J. Agric. Sci. 58:333.

Barth, K. M. 1975. Unpublished data.

Barth, K. M., J. E. Chandler, M. E. Fryer, and H. C. Wang. 1970. Effects of saliva and drying temperature on composition and digestibility of forage samples collected through esophogeal fistulas. J. Anim. Sci. 31:794.

Blaxter, K. L. 1962. The Energy Metabolism of Ruminants. Charles C. Thomas Publishers, Springfield, Illinois.

Bondi, A., and H. Meyer. 1948. Lignin in young plants. Biochem. Journ. 43:248.

Brisson, G. J., W. J. Pigden, and P. E. Sylvestore. 1957. Effect of frequency of administration of chromic oxide on its fecal excretion patterns by grazing cattle. J. Anim. Sci. 37:90.

Brody, S. 1945. Bioenergetics and Growth. Reinhold Publishing Corp., New York.

Church, D. C. 1969. Digestive Physiology and Nutrition of Ruminants. Oregon State University, Dept. of Animal Science.

Colburn, M. W., J. L. Evans, and C. H. Ramage. 1968. Ingestion control in growing ruminant animals by the components of cell-wall constituents. J. Dairy Sci. 51:1458.

Corbett, J. L., J. F. D. Greenbalgh, and A. P. McDonald. 1959. Paper as a carrier of chromium sesquioxide. Nature, London 182:1014.

Crampton, E. W., and L. E. Harris. 1956. Applied Animal Nutrition. W. H. Freeman and Company, San Francisco.

Crampton, E. W., and L. E. Lloyd. 1951. Studies with sheep on the use of chromium oxide as an index of digestibility of ruminant rations. Journal of Nutrition 45:319.

Crampton, E. W., and L. A. Maynard. 1938. The relation of cellulose and lignin content to the nutritive value of animal feeds. J. Nutri. 15:383.

Davis, R. E., C. O. Miller, and I. L. Lindahl. 1947. Apparent digestibility by sheep of lignin in pea and lima bean vines. J. Agr. Res. 74:285.

Elam, C. J., P. A. Putnam, and R. E. Davis. 1959. Fecal excretion pattern of chromic oxide administered to Hereford heifers in a completely pelleted ration. J. Anim. Sci. 18:718.

Elliot, J. M., and J. K. Loosli. 1959. Relationship of milk production efficiency to the relative of the rumen fatty acids. J. Dairy Sci. 46:753.

Ellis, G. H., G. Matrone, and L. A. Maynard. 1946. A 72 percent H_2SO_4 method for the determination of lignin and its use in animal nutrition studies. J. Anim. Sci 5:285.

Forbes, E. B., W. W. Braman, M. Kriss, C. D. Jeffries, R. W. Swift, R. B. French, R. C. Miller, and C. W. Smythe. 1928. The energy metabolism of cattle in relation to the plane of nutrition. J. Agr. Res. 37:253.

Garrett, W. N., J. H. Meyer, and G. P. Lofgreen. 1959. The comparative energy requirement of sheep and cattle for maintenance and gain. J. Anim. Sci. 18:127.

Hardison, W. A., R. W. Engel, W. N. Linkane, H. C. Sweeney, and G. C. Graf. 1956. Fecal chromic oxide concentration in 12 dairy cows as related to time and frequency of administration and to feeding schedule. J. Nutri. 58:11.

Hatten, G. L., and F. G. Owen. 1969. Efficiency of total collection and chromic oxide techniques in short-term digestion trials. J. Dairy Sci. 53:325.

Heany, D. P., and W. J. Pigden. 1963. Interrelationships and conversion factors between expressions of digestible energy value of forage. J. Anim. Sci. 22:956.

Holloway, J. W. 1973. Efficiency on range and in dry lot of Hereford, Hereford X Holstein and Holstein females as influenced by level of winter supplementation. Unpublished Doctoral dissertation, Oklahoma State University, Stillwater.

Holter, J. A., and J. T. Reid. 1959. Relationship between the concentration of crude protein and apparently digestible protein in forages. J. Anim. Sci. 18:1339.

Jensen, E., J. W. Klein, E. Rauchenstein, T. E. Woodward, and R. H. Smith. 1942. Input-output relationships in milk production. U.S.D.A. Tech. Bull. 815.

Kane, E. A., W. C. Jacobson, and L. A. Moore. 1951. Diurnal variation in the excretion of chromium oxide and lignin. J. Nutri. 47:263.

Kelloway, R. C. 1969. The estimation of digestible energy intake from forages by ruminants. Aus. J. of Exp. Agric. and Anim. Husb. 9:578.

Klosterman, E. W., L. G. Sanford, and C. F. Parker. 1968. Effect of cow size and condition and ration protein content upon maintenance requirements of mature beef cattle. J. Anim. Sci. 27:242.

Lassiter, C. A., C. F. Huffman, and C. W. Duncan. 1957. The effect of varying hay-grain ratios and levels of feed intake on feed utilization of dairy cows. J. Dairy Sci. 40:611.

Maynard, L. A., and J. K. Loosli. 1969. Animal Nutrition. McGraw-Hill Book Company, New York.

McGuire, R. L., N. W. Bradley, and C. O. Little. 1966. Effects of frequency of feeding on excretion of chromic oxide, crude protein and gross energy and on nutrient digestion by steer. J. Anim. Sci. 25:105.

Moore, R. L., H. W. Essig, and L. J. Smithson. 1975. Influence of breeds of beef cattle on ration utilization. J. Anim. Sci. 41:203.

Nutrient Requirements of Beef Cattle. 1970. National Academy of Sciences, Washington, D. C.

Phar, R. A., N. W. Bradley, C. O. Little, and L. V. Cundiff. 1970. Effects of confinement and level of feed intake on digestibility of nutrients and excretion of chromic oxide, curde protein and gross energy in the bovine. J. Anim. Sci. 30:589.

Putnam, P. A., J. Bond, and R. Lehmann. 1967. Gestation and feed intake effects on rate of passage of chromic oxide in beef heifers. J. Anim. Sci. 26:1428.

Schurch, A. F., E. W. Crampton, P. R. Haskell, and L. E. Lloyd. 1952. The use of chromic oxide in digestibility studies with pigs fed ad libitum in the barn. J. Anim. Sci. 11:261.

Smith, A. M., and J. T. Reid. 1955. Use of chromic oxide as an indicator of fecal output for the purpose of determining the intake of pasture herbage by grazing cows. J. Dairy Sci. 38:515.

Stevenson, A. E., and H. de Langen. 1959. Measurement of feed intake by grazing cattle and sheep. VII. Modified wet digestion method for determination of chromic oxide in feces. N. Z. J. Agric. Res. 3:314.

Thomas, J. L. 1975. Determination of optimal collection time of fecal grab samples in a chromium sesquioxide indicator digestion trail. Unpublished Masters thesis, The University of Tennessee, Knoxville.

Van Soest, P. J. 1962. The estimation of forage protein digestibility and determination of the effects of heat-drying upon forage by means of the nitrogen of acid-detergent fiber. J. Dairy Sci. 45:664.

Van Soest, P. J. 1963. The use of detergents in the analysis of fibrous feeds: II. A rapid method for the determination of fiber and lignin. J. Assn. Official Agric. Chem. 46:829.

Van Soest, P. J. 1967. Breed and nutritional effects on the composition of faeces, urine, and plasma from Hereford and Brahman X Hereford steers fed on high and low quality diets. Aust. J. Agric. Res. 18:1003.

Vercoe, J. E. 1967. Breed and nutritional effects on the composition of faeces, urine, and plasma from Hereford and Brahman X Hereford steers fed on high and low quality diets. Aust. J. Agric. Res. 18:1003.

Warwick, E. J., and E. H. Cobb. 1975. Genetic variation in nutrition of cattle for meat production in the effect of genetic variance on nutritional requirements of animals. National Academy of Sciences.

Wilson, A. D., W. C. Weir, and D. T. Torell. 1971. Comparison of methods of estimating the digestibility of range forage and browse. J. Anim. Sci. 32:1046.

APPENDIX

TABLE 9. SIMPLE CORRELATION COEFFICIENTS, II

	Animal Observation						
	Cow				Calf		
Animal Observation	Body weight, kg	Body height, cm	Weight/ height, kg/cm	Fat thickness, mm	Body weight, kg	Age, days	ADG, kg
COW Body weight kg	1.00	.12	.90	.31	.16	.29	.07
COW Body height cm	.12	1.00	-.32	.12	-.01	-.08	-.04
COW Weight/height kg/cm	.90**	-.33	1.00	.23	.17	.32	.07
COW Fat thickness mm	.31	.13	.23	1.00	-.04	.16	.04
CALF Body weight kg	.16	-.01	.17	.04	1.00	.88**	-.05
CALF Age, days	.29	-.08	.32	.16	.88**	1.00	-.30
CALF ADG, kg	.07	-.04	.07	.04	-.05	-.30	1.00

*Coefficients of correlation are significant ($p < .05$).

**Coefficients of correlation are significant ($p < .05$).

VITA

William Warren Gill, son of William W. and Carolyn Collier Gill, was born December 20, 1950, in Fayetteville, Tennessee. He was raised on a farm near Petersburg, Tennessee, where he attended elementary school. He graduated from Fayetteville Central High School in 1969.

He entered The University of Tennessee at Knoxville in September, 1969 and graduated with the Bachelor of Science degree in Animal Husbandry in August, 1973.

In September, 1973, he began graduate studies at The University of Tennessee at Knoxville, with emphasis of study in ruminant nutrition. He was granted the Master of Science degree in Animal Science in December, 1975.

He married the former Melissa Clark of Fayetteville, Tennessee, on September 20, 1975.