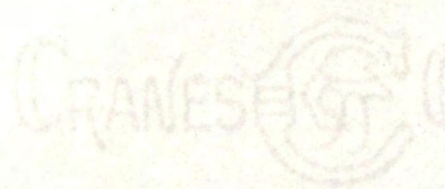
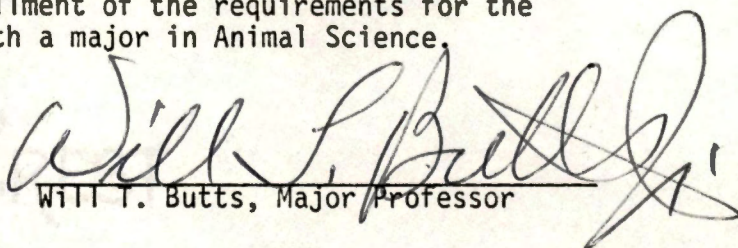
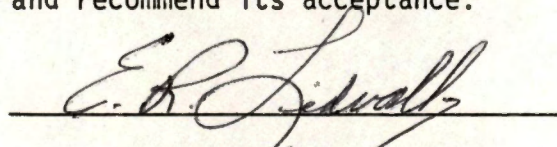
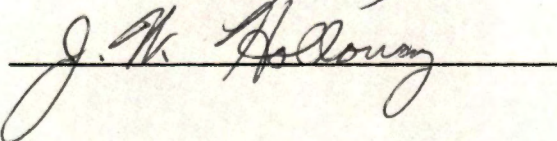


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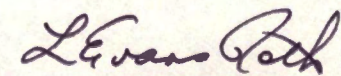
I am submitting herewith a thesis written by Joe Young entitled "The Relationship Among Initial Linear Body Measurements, Characteristics of Feedlot Cattle and Subsequent Performance." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.



Will T. Butts, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:


Vice Chancellor
Graduate Studies and Research

THE RELATIONSHIP AMONG INITIAL LINEAR BODY
MEASUREMENTS, CHARACTERISTICS OF FEEDLOT
CATTLE AND SUBSEQUENT PERFORMANCE

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

Joe Young
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ABSTRACT

Data from 630 Angus, Hereford and Charolais-cross feeder calves were utilized to study the relationship between initial calf measurements, selected performance variables and feedlot performance.

Calves were fed either a silage plus limited concentrate diet (medium-energy) or a growing-finishing grain diet (high-energy) and were serially slaughtered at a predetermined date to give a range in carcass quality from standard to high choice.

The steers were photographed, weighed and sonorayed for subcutaneous fat thickness upon arrival at the farm. This, along with weight of the calves at time of purchase, made up the objective initial measurements. Initial subjective scores were obtained from the evaluation of the animals by a single grader before the initiation of the trial. During the trial, animals were weighed and sonorayed for subcutaneous fat at biweekly intervals. These measurements and variables calculated from them along with average daily feed consumption records were used for performance variables in the analyses.

Means for each diet indicated that cattle on the grain diet were heavier, fatter cattle that gained weight more rapidly and consumed more feed.

Residual correlation within year and within year-breed groups were used to determine simple relationships that existed among the variables used in this study. Initial weight was related to initial depth, weight, weight^{.75} ($P < .001$) and fat ($P < .01$) for cattle on the grain diet while on the silage diet, initial weight was related to these

variables along with DE efficiency and feed efficiency ($P < .01$).

Initial height was highly correlated with initial depth, frame, subjective and objective carcass weight and days on feed ($P < .001$) for both diets, and negatively related to initial fat, subjective fat and fat measured at biweekly weigh dates for both diets, ($P < .001$). Initial fat was negatively related to frame, initial height, objective and subjective carcass weight and days on feed, gain, relative gain and consumption ($P < .001$) while being positively related to subjective fat and fat measured during the trial. Coefficients for frame were the same as for initial height. Subjective fat described the same relations as initial fat and objective and subjective carcass weight and days on feed followed the same patterns as initial height and frame. Correlation coefficients for gain and relative gain showed strong negative correlations with efficiency variables ($P < .001$).

Factor analyses were conducted within year-breed groups for both diets to test for redundancies among variables and to describe the sample of calves. Five factors were used to explain variation among calves with factor 1 being a shape or rate of maturing factor and explaining 49 and 43% of the correlation structure for the grain and silage diets, respectively. Factor 2 explained an additional 17 and 22% of the variation for cattle on the grain or silage diet, respectively and was considered a factor that explained differences in feed efficiency. Factors 3, 4 and 5, for cattle on the grain diet, explained an additional 25% of the correlation structure with factor 3 explaining fat and fat change variation, factor 4 explaining differences in consumption and factor 5 explaining variation caused by size differences.

Factors 3, 4 and 5, for cattle on the silage diet, explained an additional 22% of the variance with factor 3 being a consumption factor, factor 4 explaining shape variation and factor 5 explaining variation in weight.

Canonical correlation analyses, for cattle on each diet, were calculated correlating objective and subjective initial measurements with selected performance variables. Two major relationships were described using canonical correlations. First, initially taller, thinner or initially larger framed, thinner cattle were related to heavier, thinner cattle that consumed more feed, gained more weight and converted feed to gain slightly more efficiently than the average. Secondly, initially heavier, deeper bodied feeder calves were heavier, fatter cattle that gained relatively little weight and converted feed to gain less efficiently than other types of cattle described.

Multiple regression analyses were utilized to develop prediction equations for selected performance variables for cattle on both diets. Prediction equations regressing initial measurements on performance traits were found to be an accurate method in predicting performance with R^2 values ranging from .43 for consumption on the grain diet to .73 for relative gain on the silage diet. Regressing selected performance variables on other variables of feedlot performance calculated R^2 values ranging from .47 for consumption of feed on the grain diet to .93 for feed efficiency on the grain diet. Initial height and initial fat were found to be initial measurements of mature size and rates of maturing with each being significant in most of the models used in predicting performance of cattle on the grain and silage diets,

respectively. Fat measured at biweekly intervals was also significant in every model used in the analyses. Fatter cattle deposited fat more rapidly, gained less weight, consumed less feed and were less efficient on the silage diet while being more efficient on the grain diet. Average daily gain and relative average daily gain were found to be highly related to feed efficiency ($P < .001$) with faster gaining cattle being more efficient. It was also concluded that later maturing, growthier cattle were more efficient in producing edible protein than were earlier maturing cattle when fed a high-energy diet.

Questions were also raised concerning the broad generalizations that the California Net Energy System (CNES) makes concerning energy requirements for feedlot cattle. Charolais-cross steers, which were considered the late-maturing group of steers gained more weight and consumed less feed being more efficient than earlier maturing Angus steers on the grain diet. These results indicate that protein deposition is more efficient than fat deposition and adjustments in the CNES should be made for the differences in rate of maturing and mature size.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
II. LITERATURE REVIEW	3
The California Net Energy System in Review	3
Feed Efficiency and Its Relation to Rate of Gain and Carcass Composition	6
The Relationship Between Feed Efficiency, Rate of Maturing and Maintenance Requirements	7
Feed Intake, Energy Density of the Diet and Interactions	11
III. EXPERIMENTAL PROCEDURE	15
Experimental Animals	15
Management Upon Arrival	15
Allotment System	18
Feeding and Management	19
Methods of Analysis	23
IV. RESULTS	28
Description of Steers	28
Factor Analysis	35
Canonical Correlation Analyses	40
Multiple Regression Analysis	46
V. DISCUSSION	61
VI. CONCLUSIONS	65
VII. SUMMARY	66

CHAPTER	PAGE
BIBLIOGRAPHY	70
APPENDIX	75
VITA	84

LIST OF TABLES

TABLE	PAGE
1. Composition and Energy Level of the Grain Diet and the Concentrate Mixture Fed with the Silage Diet	21
2. Means and Standard Deviations of Objective and Subjective Measurements	29
3. Means and Standard Deviations of Response Variables . . .	30
4. Coefficients of Correlation Among Various Traits for Grain Diet	31
5. Coefficients of Correlation Among Various Traits for Silage Diet	32
6. Rotated Factor Pattern of Measurements, Within Year-Breed Groups for Grain Diet	36
7. Rotated Factor Pattern of Measurements, Within Year-Breed Groups for Silage Diet	37
8. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variable of Group 1 and Group 2 for Objective Measurements for Grain Diet	41
9. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variable of Group 1 and Group 2 for Objective Measurements for Silage Diet	42
10. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variables of Group 1 and Group 2 for Subjective Measurements for Grain Diet	43
11. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variables of Group 1 and Group 2 for Subjective Measurements for Silage Diet	44
12. Analyses of Variance for Initial Measurements Predicting Performance Traits for Grain Diet	48
13. Analyses of Variance for Initial Measurements Predicting Performance Traits for Silage Diet	49

TABLE	PAGE
14. Coefficients of Partial Regression and Least-Square Means	50
15. Analyses of Variance for Performance Traits for Grain Diet	55
16. Analyses of Variance for Performance Traits for Silage Diet	56
17. Coefficients of Partial Regresssion and Least-Squares Means	57
A-1. Rotated Factor Pattern for Measurements Within Year Groups for Grain Diet	76
A-2. Rotated Factor Pattern for Measurements Within Year Groups for Silage Diet	77
A-3. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variables of Group 1 and Group 2 for Objective Measurements for Grain Diet	78
A-4. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variables of Group 1 and Group 2 for Objective Measurements for Silage Diet	79
A-5. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variables of Group 1 and Group 2 for Subjective Measurements for Grain Diet	80
A-6. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variables of Group 1 and Group 2 for Subjective Measurements for Silage Diet	81
A-7. Coefficients of Partial Regression and Least-Squares Means (Weight)	82
A-8. Coefficients of Partial Regression and Least-Squares Means (Fat Change)	83

CHAPTER I

INTRODUCTION

Postweaning growth and feed efficiency of beef steers are important components in the overall net efficiency of beef production. In today's finished cattle market, where production costs are high and margin for profit small, the feedlot manager must be able to determine the type of animal that can produce a desirable quality carcass most efficiently on the type of diet being fed. Although this would seem to be a relatively simple procedure, many variables can enter and enhance the problem. Much research has been conducted concerning the problem of efficiency of gain with differences being related to breed characteristics. Most researchers agree that for a time-or-weight-constant feeding period, larger framed, later maturing cattle will produce more edible products than will earlier maturing breeds. This assumption is based on the differences in energy required for muscle growth and fat deposition with fat deposition requiring a greater amount of energy than muscle growth. This allows the later maturing cattle, that are synthesizing protein tissue, to gain more weight more efficiently than earlier maturing cattle, that are accumulating fat tissue, on a time- or weight-constant basis. Other research has also shown that cattle fed to a constant maturity or subcutaneous fat level will be no different in efficiency of gain.

With these ideas in mind, the feedlot manager must decide, on the basis of initial characteristics and the feedyards management practices, on which type of animal to feed.

Along with being able to relate initial calf characteristics to feedlot performance, the feedlot manager or consulting nutritionist must be able to formulate diets that allow the cattle to maximize gain or attain a predetermined goal. The California Net Energy System (CNES) has become a management tool that has allowed for improvement in diet formulation. In fact, the CNES has become the most widely used energy system for diet formulation and gain projection in the United States. Although the CNES is the most widely used energy system today, it does not take into account different rates of maturing. The CNES assumes that all heifers, steers, and bulls at a constant weight, have the same energy requirements for gain. This would seem to be a fault of the system, because all animals weighing the same are not all depositing fat or protein but are accumulating one or the other based on their physiological maturity at that constant weight.

With these problems concerning which type of animal is more efficient and questions arising from the generalizations of the CNES, it was the objective of this research herein to:

1. Compare feedlot performance of Angus, Hereford and Charolais-cross steers on two diets of differing levels of energy and to relate differences in performance to initial calf measurements and selected performance criterion.
2. To review the generalizations made in the CNES with reference to rate of maturing and mature size.

CHAPTER II

LITERATURE REVIEW

I. The California Net Energy System in Review

Determining the amount of energy that is needed for cattle to grow at a given daily gain has become more accurate through the use of the California Net Energy System (CNES, Lofgreen and Garrett, 1968). The CNES has become the most widely used energy system for ration formulation and maintenance and gain projections for feedlot cattle today.

This system separates the requirements for maintenance from that of body weight gain and expresses a net energy value for feed ingredients for these two functions (Lofgreen and Garrett, 1968). The need for separation of net energy for maintenance and body gain came about from the fact that the net energy of a feed will vary with the level of feeding, being higher at low levels of feeding and decreasing as feed intake increases. It was then apparent that if a net energy system was to be functional, it must take into consideration separate net energy values for different physiological functions. Moe et al. (1971) reported that the efficiency in which ME was utilized was dependent on the physiological function. The authors reported that ME was converted to energy for maintenance, gain, and milk production with coefficients of efficiency being .80, .54 and .75, respectively.

It was reported that the partial net energy of a feed when utilized for weight gain above maintenance could be considered constant (Lofgreen et al., 1963; Garrett et al., 1964). It was also suggested

that the energy needed for maintenance was equal to the heat produced by a fasting animal which depends largely upon the relatively constant basal heat production (Kleiber, 1961). It was therefore realized that using MEm and NEg were more nearly constant and accurate than using NE for maintenance and growth combined because the latter depended on the level of feeding.

The net energy required for maintenance came primarily from the idea that to keep an animal in energy equilibrium, one would have to supply enough energy to replenish the energy that was lost through basal metabolism and heat of activity. Classically, the heat production of a fasting animal has been considered to be equal to its basal metabolism which is expressed as $70W^{.75}$ with heat production expressed in Kcal and W being bodyweight in kg. Lofgreen and Garrett (1968) suggested that heat production of a fasting animal could be calculated by deducting the amount of energy an animal gained over a period of time (energy balance) from the metabolizable energy intake (MEI) of that animal. Determination of energy balance was by comparative slaughter method (Lofgreen, 1964). Once energy balance was deducted from the (MEI) the metabolizable energy that was not used for energy balance was assumed to have been used by the animal for basal metabolism, heat of activity and heat increment. These three functions constitute heat production in a feeding animal, but at zero intake or fasting the heat production of an animal is from basal metabolism and heat of activity only. The authors considered this amount of energy as the amount of energy needed for maintenance. To determine the heat production of a fasting animal, the authors collected data from five comparative

slaughter trials which used 208 feeder cattle varying in weight from 230 to 300 kg (Garrett, 1960; Lofgreen and Otagaki, 1960; Lofgreen et al. 1962; Lofgreen et al. 1963). The cattle were fed five diets varying from 2 to 100% roughage and fed at 3 levels of intake from maintenance to ad libitum. In each case energy retention was measured by comparative slaughter technique (Lofgreen, 1964) and heat production calculated by subtracting energy retained from MEI. A logarithmic equation was used to describe the relationship between ME intake and daily heat production. It was found that when the equation was extrapolated back to zero feed intake, the antilogs of the limits determined by the equation were 72 and 83 Mcal per $W^{.75}$ kg, which gave a mean value of 77 Kcal per $W^{.75}$ kg. Therefore the MEm requirement for cattle can be considered to be 77 Kcal per $W^{.75}$ kg. The authors also compared steers and heifers to see if any differences in NEm would be shown between sexes (Garrett et al., 1964). The results showed that there was no significant difference between sexes in NE required for maintenance.

A second vital part in the CNES is the amount of energy needed for production or gain. Lofgreen and Garrett (1968) stated that the net energy for gain (NEg) requirement was simply equal to the amount of energy deposited in the gain. To determine this, the authors compared the energy deposited in 264 steers with that deposited by an equal number of heifers. The correlation coefficients between empty weight gain and energy gain were .97 and .98 for the steers and heifers, respectively. The authors also reported that by expressing energy gain as (Kcal/unit of $W^{.75}$ kg), one would eliminate variation caused by

the effect of different body sizes. The authors therefore, determined that the NEg for steers was equal to $(52.72g + 6.84g^2) (W^{.75})$ and the NEg for heifers equal to $(56.30g + 12.65g^2) (W^{.75})$ with g equal to average daily gain and W equal to body weight.

II. Feed Efficiency and Its Relation to Rate of Gain and Carcass Composition

Rate of gain and efficiency of gain are important traits in feedlot cattle (Klosterman et al., 1976a). Even though Kleiber (1961) suggested that feed efficiency is independent of absolute rate of gain, except for animals of the same size, there has been a great deal of research that suggests that as the rate of gain increases, feed efficiency is also increased (Brungardt, 1971; Klosterman et al., 1976b; Lipsey et al., 1978; Loveday et al., 1980). When cattle are fed over a constant time or to a constant weight, the relationship between rate of gain and feed efficiency is increased because of the leaner composition of the weight gained and the decreased days of maintenance, respectively (Klosterman et al., 1976a; Smith et al., 1976). Smith (1979) determined that the correlation between feed efficiency and rate of gain in the age and weight constant intervals was high ($r = .94$). Faster gaining cattle also tend to produce a leaner and larger carcass as compared to slower gaining cattle when fed to a constant weight or age (Ferrell et al., 1978; Young et al., 1978; Loveday et al., 1980; Mario et al., 1980). Although this is true when comparing different types of cattle, Klosterman (1972) and Jesse et al. (1976b) found that when cattle within a breed or type are fed for a constant time, the faster gaining cattle produced fatter higher grading carcasses.

Though much research has been based on comparing cattle fed to a constant weight or age, Brundgardt (1971) concluded that when cattle of various breeds are evaluated at constant weights or ages, the results are comparing cattle at different points on their growth curves, which fails to recognize differences in composition, quality grade and market value. Crickenberger et al. (1976) also suggested that to make valid comparisons of the energetic efficiency among cattle types, all cattle should be at the same physiological maturity or body composition. There have been studies conducted that reported when cattle of diverse sizes or type are fed to a similar carcass composition, differences in ADG, feed efficiency, marbeling and carcass grade are insignificant (Brungradt, 1971; Adams et al., 1973; Crickenberger et al., 1976; Klosterman et al., 1976b). Although these studies reported no significant differences in feed efficiency when fed to a similar composition, Lipsey et al. (1978) and Loveday et al. (1980) concluded that faster gaining cattle were more efficient when fed to a similar physiological maturity compared to slower gaining cattle because they spent less energy on maintenance. It would seem that from these studies that feed efficiency is not only related to rate of gain but to other important traits such as rate of maturing, mature size and energy required for maintenance by cattle of different weights and ages.

III. The Relationship Between Feed Efficiency, Rate of Maturing and Maintenance Requirements

Rate of maturing and mature size are essential factors that influence the ability of animals to be efficient utilizors of energy.

Butts et al. (1980) described rate of maturing and mature size as fundamental traits of cattle which underlie variation in specific responses such as rate and efficiency of gain and carcass composition. There has been a considerable amount of research done concerning the relationship between rate of maturing and mature size with rate and efficiency of gain (Brody, 1945; Kleiber, 1947; Fitzhugh and Taylor, 1971; Klosterman et al., 1976b; Crickenberger et al., 1976; Smith, 1976). Klosterman et al. (1976b) suggested that the selection for rate of gain would increase mature size as well as feed efficiency. Even though selection for mature size would be expected to increase rate of gain, it would not substantially improve feed efficiency. Thus, the authors suggested that in comparing different types of cattle, the faster gaining cattle are more efficient, have a slower rate of maturing and have larger mature weights over a constant feeding period. However, when comparing cattle of similar type or slaughter weight potential, the faster gaining cattle would be the more efficient utilizers of feed, but they would also be the earlier maturing (Kleiber, 1945).

It was been well documented that selection for early maturity would lead to smaller mature weights (Fitzhugh and Taylor, 1971; Brown et al., 1972). It has also been reported that a strong relationship exists between partial efficiency or energy above maintenance and physiological maturity as expressed by carcass composition (Blaxter, 1962b; Lipsey et al., 1978). It has been thought that initial subcutaneous fat measurements, taken before entering the feedlot, provide an estimate of initial degree of maturity and some information on subsequent maturing rate (Butts et al., 1980). If subcutaneous fat

is an adequate indication of maturity then it would seem that as the animal becomes older and approaches its mature weight, it would require more energy for gain (Lofgreen and Garrett, 1968). Taylor and Young (1966) and Klosterman et al. (1976b) concluded in their studies that in early life, animals were more efficient in utilizing energy for gain than when they became more mature. Jesse et al. (1976b) determined that feed efficiency favored the lightest slaughter weight group (341 kg) in a study which involved feeding Hereford steers four diet combinations of corn-silage and corn grain to three slaughter weights (341, 454, and 545 kg). However, when efficiency is defined as Mcal energy consumed/Mcal energy gain or as energetic efficiency, cattle that are mature and are putting on weight in the form of fat will be more efficient than younger later maturing cattle that are putting on protein. Garrett (1965, 1971) suggested that Herefords were more efficient in converting feed energy into body energy than Brahmans or Holsteins, and Herefords were 12% more efficient in converting feed energy consumed above maintenance into stored energy than Holsteins, respectively. Jesse et al. (1976b) also found that as slaughter weight increased net energetic efficiency increased.

There is disagreement in the literature concerning which type of animal is most efficient. Part of the disagreement evolves from the different definitions given to efficiency. When efficiency is defined as kg feed consumed/kg gain the later maturing larger framed cattle are more efficient, over a weight or time constant interval, because they produce more lean/unit of feed intake (Ferrell et al., 1978; Loveday et al., 1980; Marion et al., 1980). If efficiency is defined as

energetic efficiency or Mcal energy consumed/Mcal energy gain, then the earlier maturing small framed cattle are more efficient because they accumulate fat at an earlier age or weight and fat has almost twice the energy value of protein. In general, the cattle which will produce the most carcass weight of the desired grade at the youngest age will be the most efficient utilizers of feed (Klosterman et al., 1976a).

Maintenance requirements have a large influence on productive efficiency. There seems to be some disagreement in the literature about the amount of energy needed for cattle to meet their maintenance needs. The California Net Energy System assumes that maintenance requirements are a constant function of metabolic weight (Lofgreen and Garrett, 1968). Also Webster et al. (1974) predicted that basal metabolism was constant throughout growth and independent of rate of growth, and that basal metabolism is a constant function of metabolic weight. But because of the complexity of maintenance needs and how it is influenced by factors such as age, environment, ration and these interactions; it has been suggested that maintenance requirement standards can not be considered absolute or constant (Blaxter, 1962b, Luitingh, 1966). If maintenance is defined as the state where a nonproductive animal is at tissue equilibrium, then there is research to indicate that the amount of energy required for maintenance by young rapidly growing cattle is greater than that required by mature animals. Graham et al. (1974) and Webster et al. (1974) have demonstrated that age was associated with a significant decrease in fasting metabolic rate, whereas energy intake

and growth rate were both associated with an increase in fasting metabolic rate. Trowbridge et al. (1915) and Hogan et al. (1922) both suggested that maintenance requirements were significantly higher following a high plane of nutrition than that determined subsequent to the imposition of a low plane of nutrition. Webster et al. (1974) also reported that Freisians had greater basal metabolism than Angus steers and that it was also greater on high energy diets compared to medium energy diets. Tyrrell and Moe (1979) determined in yearling heifers that apparent maintenance requirements increased $.21 \text{ Kcal/W}^{.75}$ for each increase in metabolizable energy intake of $1 \text{ Kcal/W}^{.75}$ above that required for energy equilibrium. These studies seem to conclude that maintenance requirements are higher for faster growing young animals that have a higher rate of metabolism, or animals that are consuming a great deal of energy over maintenance needs, which increases the heat increment and thus, the energy used for maintenance.

IV. Feed Intake, Energy Density of the Diet and Interactions

Voluntary feed intake is an important factor that influences efficiency of gain, mature size and rates of maturing (Fitzhugh and Taylor, 1971; Lipsey et al., 1978; Song et al., 1978). It has been thought that feed intake is regulated by physical demand for energy, and that feed intake for production varies with degree of maturity and energy density of the diet (Song et al., 1978). The authors found that energy intake/weight at ad libitum feeding levels, decreased linearly ($r^2 = .987$) with the advance in degree of maturity. This agrees with research reported by Reid et al. (1971) who suggested that

increasing degrees of body fatness in ruminants, which is associated with increasing maturity, was associated with decreasing intake of feed. Kleiber (1961) discussed the significance of feed intake by defining relative feed capacity as $\text{feed intake}/W^{.75}$. He, along with Klosterman et al. (1976a), related higher relative feed capacity to higher total efficiency of feed utilization and suggested that relative feed capacity is closely related to feed efficiency, relative gain, and rate of maturing, respectively. If feed efficiency is related to relative feed capacity then there is disagreement in the literature concerning which type of animal has the highest relative feed capacity. Ferrell et al. (1978) determined from his study that dry matter intake or metabolizable energy intake did not differ between cattle when expressed on a $W^{.75}$ basis. However, Klosterman et al. (1976a) and Lipsey et al. (1978) found that early maturing breeds of cattle consume more $\text{feed}/W^{.75}$ daily than late maturing breeds; although, Lipsey et al. (1978) concluded that animals with higher consumptions of $\text{feed}/W^{.75}$ maintained were slower gaining and less efficient. Klosterman et al. (1976a) suggested in the same study that daily $\text{feed intake}/W^{.75}$ was negatively and closely related to the number of days required to reach low choice grade. In contrast to these findings, Bath et al. (1966), Garrett (1971) and Prior et al. (1977) concluded that late maturing breeds of cattle consume more $\text{feed}/W^{.75}$ daily than do earlier maturing breeds.

The results concerning relationships among feed intake, feed efficiency and mature size vary in the literature. The contrasts found could possibly be explained by the type of ration being fed. Klosterman

et al. (1976b); Prior et al. (1977); Byers et al. (1980); Danner et al. (1980) concluded that smaller, earlier maturing cattle were more efficient (ME/unit of retail product) on low energy diets as compared to medium or high energy diets. This agrees with Klosterman et al. (1976a) and Tipley et al. (1978) in that earlier maturing, smaller cattle have a higher feed intake than do larger, later maturing breeds, and that if fed a low energy ration could finish at a desired fat composition at an earlier age. It has also been stated that high energy or grain diets allowed larger framed cattle to express their full potential for protein growth (Byers and Parker, 1980). The authors found that larger size cattle gained 8.3% faster and 6.3% more efficiently than small type cattle on a shelled corn high energy diet. The high energy diets allowed the late maturing large cattle to minimize time on feed and produce a carcass at the desired weight and fatness. These findings seem to indicate a breed type x nutrition interaction which would agree with the findings of Smith et al. (1977) and Prior et al. (1977) who reported altered composition due to nutritional regime. In contrast, Gunther et al. (1965); Reid et al. (1968); Jesse et al. (1976a); Ferrell et al. (1978) and Loveday et al. (1980) concluded that interaction between breed types and dietary treatment and between energy density and protein content were not significant and had little effect especially on carcass composition.

In reviewing the literature there seems to be differences in the maintenance and gain requirements for cattle that weigh the same, because of the differences in rate of gain and feed intake. These differences seem to be primarily due to the difference in their rate

of maturing and mature size. It therefore seems to be a need for further generalization of the California Net Energy System which was developed using a homogenous group of British breed cattle which were assumed to have the same requirements for maintenance and gain.

CHAPTER III

EXPERIMENTAL PROCEDURE^{*}

I. Experimental Animals

Angus, Hereford and Charlois feeder calves of early and late maturing types were purchased from Tennessee Graded Feeder Calf sales and auction markets. Charolais calves were largely crossbred calves sired by Charlois bulls and out of mostly Angus and Hereford dams. Weights of the breed groups purchased were in a 22.5 kg range centered near the mean weights of the respective breeds from previous years of the study. Weights ranged from 172.8 kg to 278.5 kg and averaged 223.5 kg. The animals purchased were considered to be a representative sample of feeder calves of this weight range available in East Tennessee.

II. Management Upon Arrival

Objective and Subjective Measurements

Body measurements and estimates of subcutaneous fat were obtained after arrival at the Tennessee Agricultural Experiment Station. All live animal fat estimates were made over the 12th rib by the same operator with a Branson Model 12 Sonoray. Point of the shoulder and

^{*}Data for this study were collected from September 1977 through August of 1980 from experiments conducted at the University of Tennessee Blount Farm, Knoxville, Tennessee.

a surface point directly posterior to the pin were located by palpation and marked with paint prior to entering a specially prepared grid chute for photographing. Linear body measurements were obtained from life-size projections of 35-mm slides of the animals photographed in the grid chute. Purchase weight and initial measurements of wither height, subcutaneous fat, length from point of shoulder to rear of pin bone and body depth were measurements taken upon arrival at the experiment station. Body depth was measured from the floor of the chest vertically to the back of the animal at the point of least depth. Wither height was measured from the base of the grid chute to the dorsal top line of the withers. Body length was measured from the painted areas at the point of the shoulder to the area posterior to the pin bone. Visible long erect hair over the withers and under the floor of the chest was not included in the respective measurements. Cattle were also wormed, treated for grubs, identified and sorted to respective pens ($n = 7$) for a 28-day stabilization period in which they received a diet of corn silage fed ad libitum and limited grain.

After the 28-day stabilization period, in which the calves recovered from the stresses of shipping, the animals were subjectively scored by a live animal evaluator with about 30 years of experience in animal evaluation. The subjective scores reflected differences between animals in frame size (frame), condition (fat) and muscle expression (muscle). Fat estimates were expressed as millimeters of subcutaneous fat. Frame and muscle were on a scale of 1 to 15, with greater manifestation of a trait receiving a high score.

Scores for frame were estimates of structural dimension associated with expected slaughter weights. For example, a score of 4, 5 or 6 indicated relative structural sizes associated with expected slaughter weights between 408 and 454 kilograms. Scores of 7, 8 and 9 denoted sizes associated with slaughter weights between 454 and 499 kilograms.

Muscle was a measure of natural thickness and body shape. Factors influencing muscle score were thickness and shape of quarter, "expression" down the top, prominence of muscle in the stifle and forearm and width of walk. Flat-quartered, narrow fronted calves received low scores while thick-quartered, wide fronted calves received high scores.

By using purchase weight, initial height, initial depth and initial subcutaneous fat measurements, carcass weight and days on feed were predicted for both diets (Butts et al., 1980a,b).

The models and R^2 values for objective and subjective carcass weight and days on feed are as follows:

Objective carcass weight for grain = $-181 + .66 * \text{Initial weight} + 5.27 * \text{Initial height} - 15.65 * \text{Initial fat} - 3.76 * \text{Initial depth}$ $R^2 = .56$

Objective carcass weight for silage = $82 + .66 * \text{Initial weight} + 5.27 * \text{Initial height} - 15.65 * \text{Initial fat} - 3.76 * \text{Initial depth}$ $R^2 = .56$

Objective days on feed for grain = $-177 + .32 * \text{Initial weight} + 5.84 * \text{Initial height} - 17.56 * \text{Initial fat} - 5.16 * \text{Initial depth}$ $R^2 = .45$

Objective days on feed for silage = $390 + .32 * \text{Initial weight} + .77 * \text{Initial height} - 17.56 * \text{Initial fat} - 5.16 * \text{Initial depth}$ $R^2 = .45$

Subjective carcass weight for grain = $156 + .30 * \text{Initial weight} + 7.55 * \text{Frame} + 1.69 * \text{Muscle} - 2.57 * \text{Subjective fat}$ $R^2 = .40$

Subjective carcass weight for silage = $163 + .30 * \text{Initial weight} + 7.55 * \text{Frame} + 1.69 * \text{Muscle} - 2.57 * \text{Subjective fat}$ $R^2 = .40$

Subjective days on feed for grain = $167 - .19 * \text{Initial weight} + 8.78 * \text{Frame} + 2.25 * \text{Muscle} - 5.34 * \text{Subjective fat}$ $R^2 = .41$

Subjective days on feed for silage = $238 - .19 * \text{Initial weight} + 4.78 * \text{Frame} + 2.25 * \text{Muscle} - 5.34 * \text{Subjective fat}$ $R^2 = .41$

III. Allotment System

During the three years of the experiment, animals were assigned to maturity, dietary treatment, feeding pen and slaughter groups. By using initial fat thickness, which was assumed to be a measure of initial maturity, purchase weight, initial height and initial depth, and initial fat in a prediction equation, animals within breed were ranked from earliest to latest maturing. The order in which the animals were listed and assigned to maturity groups was dependent upon the predicted number of days needed to reach 12 mm of fat with animals needing fewer days to reach 12 mm being earlier maturing. The maturity groups contained animals within breed that were of similar maturity and were projected to reach 12 mm of fat at approximately the same time. Once grouped by stage of maturity, the animals were randomly assigned to one of two dietary treatments, blocked into feeding groups of 7 or 8 animals of similar maturity and randomly assigned to predicted slaughter groups with 1 animal from each maturity group being assigned to each slaughter group. This gave a range in carcass quality that coincided with the range in the maturity groups.

IV. Feeding and Management

Diet Treatments represented high-and medium-levels of energy. The high-level or constant energy diet was fed ad libitum and was composed of: 50% shelled corn, 10% cottonseed meal, 20% cottonseed hulls, 5% molasses, 3% dehydrated alfalfa meal, 2% animal fat, .5% ground limestone and .5% salt. The medium-level or variable energy diet was composed of corn silage, offered ad libitum, and a concentrate mixture composed of 86% corn and 14% cottonseed meal. The concentrate mixture was initially fed at the rate of 1.25% of body weight (pen mean) daily and increased to 1.4% and 1.55% when animals in the pen reached an average of 8 and 10 mm of fat, respectively. The mixture was fed daily in 2 feedings. A salt and dicalcium phosphate mixture was offered free choice.

Complete records of feed consumed were maintained and summarized for each pen in the time intervals that coincided with the weigh periods. Therefore, the amount consumed per weigh period was known throughout the experiment. The amount received and the amount refused (orts) was recorded every day and Proximate analysis of the two diets were performed every 28 days in year 1979-80. In years 1977-78 and 1978-79 Proximate analysis was performed 3 times each year and these values were combined to give an average analysis of the feed for those years, respectively. Dry matter (DM air dry basis), crude protein (CP), crude fiber (CF), ether extract (EE), ash and nitrogen free extract (NFE) were recorded and used to determine total digestible nutrients (TDN) and digestible energy (DE).

After reviewing the analysis of the feedstuffs, it was decided that because of the homogeneity of the grain diet and concentrate mixture fed with the silage over the three years of the trial, that accepted book values for the ingredients of these feedstuffs would give an accurate description of the feeds.

To estimate the TDN and DE of the grain diet and the concentrate fed with the silage diet, values for each ingredient that made up the grain diet and concentrate mixture were taken from the National Research Councils (NRC) Nutrient Requirements of Beef Cattle (1976). The ingredients and their energy values for the grain diet and concentrate mixture can be found in Table 1.

In determining the TDN and DE of the corn silage, values from the Proximate Analysis were used in 2 equations that predicted TDN and DE of the corn silage. Using McCulloughs (1973) equation that utilized crude protein and crude fiber content of corn silage, TDN was calculated.

The equation used for calculating TDN for corn silage was as follows:

$$\text{TDN} = .9093 + .39(\text{CP}) - 1.1(\text{CF}) * 100$$

Where TDN for corn silage was in a percentage form. The values for TDN were very acceptable compared to accepted book values (NRC, 1976) for corn silage with a maximum of 30% dry matter.

Once TDN was calculated, it was determined that by using the equation of Heaney and Pigden (1963) that DE could be calculated accurately from known TDN values.

The equation used for calculating DE of corn silage was as follows:

Table 1. Composition and Energy Level of the Grain Diet and the Concentrate Mixture Fed with the Silage Diet

Ingredient	IFN	Grain diet				
		% of diet(%)	DM (%)	% on DM basis	DE DM (Mcal/kg)	DE of diet (Mcal/kg)
Corn	4-02-994	59	87	58.96	4.01	2.36
Cottonseed meal	5-01-621	10	91.5	10.51	3.31	.35
Cottonseed hulls	1-01-599	20	90.3	20.74	1.85	.38
Molasses	4-04-696	5	75	4.31	3.35	.14
Dehy. alfalfa meal	6-02-632	3	92.7	3.19	2.73	.09
Animal fat	4-00-409	2	99.5	2.29	5.68	.13
Limestone	6-02-632	.5	-	-	-	-
Salt		.5				
Sum		100		100		3.45
Ingredient	IFN	Concentrate diet				
		% of diet(%)	DM (%)	% on DM basis	DE DM (Mcal/kg)	DE of diet (Mcal/kg)
Corn	4-02-994	86	87	86.23	4.01	3.46
Cottonseed meal	5-01-621	14	91.5	14.76	3.31	.49
Sum		100		100		3.95

$$DE = -.546 + .055 (TDN) * 1000$$

Where DE was Kcal DE/kg TDN of corn silage. After DE for both diets was calculated, maintenance requirements (.077 Mcal/W^{.75}) were subtracted and the amount of DE remaining was assumed to be DE used for gain.

As noted earlier, the grain and silage-concentrate diets were fed twice daily. The concentrate was fed on top of the silage and it was assumed that the steers ate an equal proportion of the silage and concentrate. This assumption, if not completely true, was accepted because the amount of refusal never exceeded more than 10% of the amount fed. Therefore, the steers on the silage diet probably ate the concentrate mixture first but eventually ate all or most of the silage.

Animals were weighed and fat thickness was estimated (ultrasonic measurement) at 28-day intervals until about February 1st of each year and 14-day intervals thereafter. Steers were then slaughtered at their assigned dates with weight, fat thickness and body measurements, taken from a projected life-size transparency of a 35-mm photograph in the grid chute, being recorded. In each year as cattle were slaughtered, it became necessary to move animals from their original pen into other pens. This allowed for easier feeding and decreased the number of pens used by the experiment. When animals moved, they were combined with animals of the same breed, diet group and average fat thickness (pen means). This allowed for continuous feeding of a homogenous group of animals. After slaughter, carcass data were collected after a constant 48-hour chilling period. Animals

were slaughtered from February 4th through August 25th in 1978, January 4th through August 16th in 1979 and January 31st through August 14th in 1980.

V. Methods of Analysis

Using the Statistical Analysis System developed by Barr and Goodnight (1976), non-linear regression analysis, canonical correlation analyses, factor analyses and multiple regression analyses were performed on criterion variables of feedlot steers. The analyses were used to adjust selected variables, predict performance traits using initial trials and predict feed consumption and feed efficiency from selected performance traits.

Non-Linear Regression

Non-linear regression procedure produces least-squares or weighted least-squares estimates of the parameters of a non-linear model. This analysis uses 1 of 3 iterative methods and regresses the residuals on the partial derivatives of the model, with respect to the parameters, until the iterations converge and minimize the error-sums-of-squares. By using a quadratic model, that regressed date (bi-weekly weigh date in Julian days) and date-squared on the actual weight and subcutaneous fat measurement of each steer, predicted weight and fat measurements were calculated for each steer for each weigh date. The predicted weight and fat estimates were used in place of the actual values of each variable to minimize weighing and sonoscopy errors and gut fill variation.

Factor Analysis

Factor analysis is a branch of multivariate analysis of which the principle concern is the resolution of a set of variables linearly in terms of a small number of categories or "factors." In general, factor analysis can be used to reduce a large number of variables into a fewer, more usable number of factors. This allows the researcher to identify and possibly eliminate 1 or more variables that are redundant to one another.

In factor analysis, the first factor explains the largest portion of variance in the variance-covariance structure. Each succeeding factor is orthogonal to the first and other factors and explains a decreasing amount of the variance.

Factors with positive and negative weighting factor coefficients are contrasting those variables with large positive loadings against those with large negative loadings. This differential weighting of variance variables provides an objective means of identifying animals of different sizes, shapes and fatness.

In this study, factor analysis, on a within-year and within year and breed basis, was performed to test for redundancies between objective and subjective initial measurements and performance characteristics. At the same time, factor analysis was used to describe the sample of steers through objective and subjective initial measurements and performance variables.

Rotation of the factors was utilized to obtain the maximum differences in the factor loadings of the original variables.

Canonical Correlation Analysis

Canonical correlation analysis is a method of multivariate analysis capable of determining the simultaneous relationship of two groups of criterion variables. "The object of canonical correlation is to construct from the set of predictor variables and the set of criterion variables that pair of linear composites which are maximally correlated between the 2 sets of variables" (Mulaik, 1972). This analysis makes no distinction between the 2 sets of variables being studied. In addition, it is not necessary for the number of variables in 1 set to be equal to the number of variables in the second set, but the maximum number of canonical variables can only be as great as the fewest criterion variables in a set. Canonical variables are composed of the sums of the products of the criterion variables called standard scores. A normalized characteristic vector is a set of regression weights which, when applied to the standard score, produces a canonical variate.

The first canonical variate from each set of variables are calculated so as to maximally correlate with each other. The second set of canonical variates are also calculated for maximum correlation and is independent and orthogonal to other variates which are calculated in the same manner.

The canonical correlation analysis used the chi-square test for determining significance.

In this study, canonical correlation was used to identify and correlate selected initial measurements (objective and subjective) with performance characteristics of the steer. This was done using residual

values of the variables on a within-year and within-year and breed basis, and gave some idea of how steers, that differed initially in size, shape and weight, performed later in the trial.

Multiple Regression Analysis

Multiple regression analysis uses the principle of least-squares to fit linear models. In multiple regression analysis, the values of a dependent variable are described or predicted in terms of one or more independent or explanatory variables.

In this study, there were two basic areas of concentration. The first portion of the study dealt with predicting or describing performance during the trial from initial measurements taken before the start of the trial.

The basic form of the model for this part of the study was as follows:

$$Y_{ijklmn} = + \text{initial weight}_i + \text{initial height}_j + \text{initial fat}_k + (\text{initial fat})^2_l + \text{year}_m + \text{breed}_n + \text{error}_{ijklk}$$

where Y is weight, fat daily fat change, percent fat in the gain, average daily gain (gain), relative average daily gain (rel. gain), daily consumption of grain or silage and feed efficiency on the grain and silage diets.

The second area of study was to predict certain performance characteristics using other selected performance variables.

In this segment of the study, the basic model was as follows:

$$Y_{ijklmnopq} = + \text{weight}_i^{.75} + \text{relative average daily gain}_j + (\text{relative average daily gain})_k^2 + \text{fat}_l + (\text{fat})_m^2 + \text{daily consumption of grain or silage}_n + (\text{daily consumption of grain or silage})_o^2 + \text{year}_p + \text{breed}_q + \text{error}_{ijklmnopq}$$

Where Y is daily fat change, percent fat in the gain, average daily gain, relative average daily gain, daily consumption of grain or silage and feed efficiency on the grain or silage diets.

Because feed consumption was based on a pen basis over the entire period of the trial, therefore, final analysis was conducted with one set of initial measurements for each pen and one set of performance variables for each pen.

CHAPTER IV

RESULTS

I. Description of Steers

Table 2 contains means and standard deviations of objective and subjective measurements of initial traits, predicted carcass weight and days on feed for both diets. All variables for both diets were extremely similar, which would be expected from the way in which the steers were allotted to diet groups. There was some variation between the objective and subjective carcass weights and days on feed, with the subjective measurements predicting heavier carcasses and more days on feed. However, when the objective and subjective measurements were compared as a ratio of carcass weights/days on feed the differences between the two measurements were minimal.

Table 3 contains the means and standard deviations of response variables by weigh date for each diet. Steers on the grain (high energy) diet gained more rapidly and were heavier than those on the silage diet. This was attributed to the steers consuming more feed on the grain diet.

Residual correlations within year and within year-breed for both diets are presented in Tables 4 and 5. Residual correlations allowed a simple overview of relationships among initial calf measurements and performance variables.

Within year breed groups, initial weight of calves on the grain diet was correlated with initial depth ($P < .001$) and initial height

Table 2. Means and Standard Deviations of Objective and Subjective Measurements

Traits ^a	Grain		Silage	
Initial weight (kg)	223	± 5	224	± 5
Initial height (cm)	101.4	± 2.2	101.4	± 2.2
Initial fat (mm)	2.1	± .95	2.1	± .95
Initial depth (cm)	52.3	± .89	52.5	± 1.1
Frame ^b	7.0	± 1.7	7.0	± 1.6
Pfat ^c (mm)	3.0	± .73	3.0	± .75
Muscle ^b	8.3	± .63	8.4	± .61
Obj. cwt for grain (kg) ^d	270	± 22	271	± 22
Obj. cwt for silage (kg) ^d	277	± 18	277	± 17
Obj. days on feed for grain (days) ^d	179	± 24	179	± 24
Obj. days on feed for silage (days) ^d	232	± 17	232	± 17
Sub. cwt for grain (kg) ^d	282	± 14	282	± 13
Sub. cwt for silage (kg)	289	± 14	290	± 13
Sub. days on feed for grain (days) ^d	189	± 17	189	± 17
Sub. days on feed for silage (days) ^d	232	± 11	232	± 11

^aMean and standard deviations are calculated within year and breed.

^bFrame and muscle scores = subjective estimated assigned on a scale of 1 to 15, with higher scores reflecting greater manifestations of the trait.

^cPfat scores = subjective estimates of initial fat (condition) in millimeters.

^dPredicted carcass weight (cwt), and days on feed were calculated using equations from Butts et al. (1980a,b). See Procedures section for equations used.

Table 3. Means and Standard Deviations of Response Variables

Traits ^a	Grain						Silage					
	3 ^b	4	5	6	3	4	5	6	3	4	5	6
Weight (kg)	302 ± 9	328 ± 10	345 ± 11	361 ± 12	291 ± 9	312 ± 9	325 ± 10	338 ± 10				
Weight ^c (kg)	73 ± 2	77 ± 2	80 ± 2	83 ± 2	70 ± 2	74 ± 2	77 ± 2	79 ± 2				
Fat (mm)	4.3 ± .91	5.2 ± .97	5.6 ± 1.0	5.9 ± 1.1	3.8 ± .83	4.3 ± .78	4.5 ± .74	4.8 ± .74				
Fat change (mm/day)	.04 ± .01	.04 ± .01	.04 ± .01	.04 ± .01	.02 ± .01	.03 ± .01	.03 ± .01	.03 ± .01				
Gain (ADG) (kg/day)	1.1 ± .09	.99 ± .11	.96 ± .11	.99 ± .10	.86 ± .08	.82 ± .07	.81 ± .07	.80 ± .08				
Rel. Gain (kg/day/M ^{.75})	1.5 ± .12	1.3 ± .14	1.2 ± .14	1.2 ± .11	1.2 ± .11	1.1 ± .09	1.1 ± .09	1.0 ± .10				
Consumption (kg/DW/day)	8.3 ± .50	9.0 ± .65	8.7 ± .77	8.7 ± .95	7.0 ± .41	7.4 ± .44	7.3 ± .39	7.4 ± .71				
Rel. consumption (kg/kgM ^{.75})	1.1 ± .06	1.2 ± .07	1.1 ± .10	1.1 ± .12	1.0 ± .04	1.0 ± .05	.96 ± .05	.94 ± .10				
DE consumed for ^c gain (Mcal/day)	23.1 ± 1.6	25.1 ± 2.1	24.0 ± 2.6	23.8 ± 3.3	19.1 ± 1.3	20.5 ± 1.4	20.1 ± 1.3	20.0 ± 2.5				
DE consumed (Mcal/day)	28.7 ± 1.7	31.1 ± 2.2	30.1 ± 2.7	30.1 ± 3.3	24.5 ± 1.4	26.2 ± 1.5	26.0 ± 1.3	26.0 ± 2.5				
DE efficiency for gain ^d (Mcal/kg)	21.4 ± 1.8	25.9 ± 3.2	25.7 ± 4.2	24.2 ± 3.6	22.6 ± 2.2	25.3 ± 2.2	25.1 ± 2.5	25.2 ± 3.4				
DE efficiency (Mcal/kg)	26.6 ± 2.1	32.1 ± 3.9	32.3 ± 4.9	30.8 ± 3.8	29.1 ± 2.7	32.4 ± 2.6	32.5 ± 3.0	33.0 ± 3.6				
Feed efficiency (Mcal/kg)	7.7 ± .61	9.3 ± 1.1	9.4 ± 1.4	± 1.1	8.3 ± .77	9.2 ± .74	9.2 ± .84	9.4 ± 1.0				

^a Means and standard deviation calculated within year and breed.^b Bi-weekly weigh periods.^c DE consumed for gain = DE consumed - (.077* wt^{.75}).^d DE efficiency for gain = DE consumed for gain/ADG.

Table 4. Coefficients of Correlation Among Various Traits for Grain Diet

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1. Initial weight		.31	.25	.55	.04	.23	.07	.08	.01	-.04	-.27	.12	.12	-.08	-.14	.47	.47	.35	.06	-.12	-.24	.05	-.17	.01	.05	.13	.16	.16
2. Initial height	.59		-.59	.56	.84	-.60	-.37	.86	.78	.83	.56	.87	.86	.81	.78	.33	.33	.33	.56	-.22	.49	.42	.53	.46	.52	.53	-.12	-.18
3. Initial fat	-.07	-.66		-.20	-.66	.78	.45	-.90	-.95	-.93	-.98	-.65	-.64	-.72	.74	.19	.19	.19	.77	.06	-.52	-.50	-.48	-.49	-.49	-.48	.25	.31
4. Initial depth	.46	.42	-.17		.30	-.04	-.18	.36	.28	.28	.03	.33	.36	.21	.16	.37	.37	.37	.03	-.02	.14	.06	.39	.28	.38	.39	.06	.03
5. Frame	.52	.88	-.66	.11		-.73	-.47	.83	.78	.83	.66	.99	.93	.98	.96	.18	.17	.74	-.28	.46	.43	.60	.62	.61	.60	.03	-.11	.11
6. Pfat	-.24	-.73	.78	.06	-.84		.49	-.78	-.79	-.81	-.80	-.75	.75	-.83	-.87	.03	.03	.86	.34	-.44	-.46	-.30	-.39	-.32	-.30	.20	.25	.25
7. Muscle	.47	.16	.11	.04	.22	.02		-.45	-.45	-.46	-.43	-.41	-.41	-.44	-.41	-.04	-.04	.47	.07	-.14	-.11	-.29	-.32	-.30	-.30	.03	.01	.01
8. Obj. cwt. grain ^d	.46	.91	.88	.25	.89	-.86	.09		.99	.99	.89	.85	.85	.85	.84	.32	.32	.73	.14	.56	.50	.53	.49	.53	.54	.22	.28	.28
9. Obj. cwt. silage ^d	.39	.86	.92	.18	.86	-.87	.07	.99		.99	.95	.80	.80	.81	.82	.30	.30	.75	.10	.55	.50	.51	.47	.51	.51	.24	.30	.30
10. Obj. days on feed grain ^d	.36	.88	.91	.17	.87	-.88	.05	.99	.99		.93	.83	.83	.86	.86	.27	.27	.78	.14	.58	.53	.53	.50	.53	.53	.24	.30	.30
11. Obj. days on feed silage ^d	.13	.67	-.97	-.04	.74	-.86	-.04	.91	.95	.94		.66	.66	.73	.76	.17	.17	.78	.07	.52	.50	.43	.44	.43	.43	.27	.32	.32
12. Sub. cwt. grain ^d	.58	.88	.64	.13	.99	-.84	.29	.89	.86	.87	.73	1.00		.98	.95	.21	.21	.72	.29	.46	.42	.58	.58	.59	.58	.04	.11	.12
13. Sub. cwt. silage ^d	.58	.88	.64	.13	.99	-.84	.29	.89	.86	.87	.73	1.00	.98		.95	.21	.21	.72	.29	.46	.42	.58	.58	.59	.58	.04	.11	.12
14. Sub. days on feed grain ^d	.47	.86	.69	.07	.99	-.89	.24	.89	.87	.89	.78	.99	.99	.99		.95	.11	.11	.81	.31	.49	.48	.56	.60	.57	.56	.08	.16
15. Sub. days on feed silage ^d	.43	.85	.71	.04	.98	-.91	.24	.89	.88	.89	.80	.98	.98	.99	.07		.07	.84	.33	.50	.50	.52	.58	.54	.52	.11	.19	.19
16. Weight	.60	.48	-.28	.46	.34	-.14	.27	.44	.41	.38	.25	.38	.38	.31	.28	.99	.99	.19	-.34	.31	.09	.51	.15	.45	.51	.04	.03	.03
17. Weight ⁷⁵	.60	.48	-.28	.46	.34	-.14	.27	.43	.41	.38	.25	.37	.37	.30	.28	.99	.99	.19	-.34	.31	.09	.51	.15	.45	.51	.04	.03	.03
18. Fat	-.22	-.73	.77	.03	-.87	.91	-.09	-.84	-.85	-.86	-.83	-.86	-.86	-.90	-.91	-.07	-.07	-.07	.50	-.42	-.48	-.26	-.41	-.29	-.26	.23	.29	.29
19. Fat change	-.42	-.52	.28	-.20	-.58	.50	-.42	-.46	-.43	-.44	-.31	-.61	-.61	-.59	-.60	-.12	-.12	.64	.24	.18	.10	-.05	.07	.10	-.27	-.27	-.27	-.27
20. Gain	.10	.53	.55	-.11	.57	-.59	.05	.61	.61	.63	.61	.56	.56	.59	.60	.23	.23	.56	.02	.97	.97	.37	.40	.37	.37	.77	.83	.83
21. Rel. gain	-.04	.42	-.49	-.22	.50	-.56	-.01	.51	.53	.55	.57	.48	.48	.53	.54	.01	.01	.55	.06	.97	.97	.92	.99	1.00	.20	.10	.10	.10
22. Consumption	.05	.40	-.43	.45	.30	-.17	-.19	.39	.37	.39	.32	.26	.26	.27	.25	.49	.49	.14	.02	.27	.16	.90	.94	.95	.92	.20	.09	.09
23. Rel. consumption	-.23	.22	-.37	.29	.18	-.14	-.34	.24	.24	.27	.26	.13	.13	.17	.16	.08	.08	.14	.06	.20	.19	.90	.94	.95	.92	.20	.10	.10
24. DE consumed for gain	.01	.37	-.42	.43	.28	-.16	-.22	.36	.35	.37	.31	.24	.24	.25	.24	.42	.42	.14	.03	.26	.17	.99	.94	.95	.92	.20	.10	.10
25. DE consumed	.05	.40	-.43	.45	.30	-.17	-.19	.39	.37	.39	.32	.26	.26	.27	.25	.49	.49	.14	.02	.27	.16	1.00	.90	.94	.95	.92	.20	.10
26. DE for gain efficiency	-.09	-.28	.32	.31	-.39	.46	-.14	-.33	-.40	-.40	-.43	-.39	-.39	-.42	-.43	.06	.06	.46	-.04	-.82	-.86	.29	.29	.29	.29	.29	.99	.99
27. DE efficiency	-.07	-.31	.36	.29	-.42	.48	-.11	-.41	-.43	-.44	-.47	-.41	-.41	-.44	-.46	.05	.06	.48	-.06	-.86	-.89	.21	.21	.21	.21	.21	.99	1.00
28. Feed efficiency	-.07	-.31	.36	.29	-.42	.48	-.11	-.41	-.43	-.44	-.47	-.41	-.41	-.44	-.46	.05	.06	.48	-.06	-.86	-.89	.21	.21	.21	.21	.21	.99	1.00

^aCoefficients above the diagonal were calculated on a within year-breed basis.^b $r \leq .25$, $P \leq .10$, $26 \leq r \leq .31$, $P \leq .05$, $32 \leq r \leq .39$, $P \leq .10$, $P < .001$.^cSubcutaneous fat subjectively estimated in millimeters.^dPredicted carcass weight (cwt) and days on food were calculated using equations from Butts et al. (1980 a,b). See Materials and Methods section for equations used.

Table 5. Coefficients of Correlation Among Various Traits for Silage Diet

Variables	Traits ^{a,b}																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1. Initial weight		-.05	.27	.39	-.24	.30	.13	-.12	-.14	-.23	-.29	-.14	-.14	-.32	-.36	.51	.51	.36	.08	-.28	-.39	.03	-.27	.01	.06	.24	.27	.27
2. Initial height	.46		-.52	.60	.70	-.52	-.52	.79	.65	.76	.41	.69	.69	.66	.63	.14	.14	.50	-.20	.28	.23	.28	.26	.28	.28	-.08	-.12	-.12
3. Initial fat	-.11	-.62		-.10	-.65	.76	.42	-.92	-.96	-.93	-.97	-.66	-.66	-.69	-.72	-.13	-.13	.82	.16	-.53	.49	-.36	-.37	-.35	.34	.30	.36	.34
4. Initial depth	.40	.52	-.13		.22	.01	-.30	.28	.15	.19	-.12	.23	.23	.13	.08	.36	.36	-.12	-.08	.04	-.05	.30	.16	.29	.32	.15	.14	.13
5. Frame	.48	.86	-.66	.21		-.74	-.43	.75	.70	.76	.60	.99	.99	.98	.95	.05	.05	.73	.24	.36	.33	.30	.39	.34	.32	.14	-.20	.18
6. Pfat	-.28	-.75	.81	-.11	-.84		.36	-.76	-.77	-.78	-.76	-.78	-.78	-.84	-.88	.07	.09	.78	.08	-.49	-.51	-.21	-.32	-.21	-.19	-.34	.39	.37
7. Muscle	.50	.13	.07	-.07	.29	-.14		-.49	-.44	-.49	-.34	.36	.36	.36	.32	.13	.13	.48	.27	-.15	-.17	-.25	-.39	-.25	-.22	.01	.05	.04
8. Obj. cwt. grain	.42	.88	-.88	.27	.88	-.88	.13		.99	.98	.95	.72	.72	.73	.14	.20	.20	-.77	-.17	.48	.42	.35	.31	.33	.33	.27	-.32	-.30
9. Obj. cwt. silage	.39	.80	-.93	.18	.84	-.88	.13	.99		.99	.90	.76	.76	.79	.79	.14	.14	-.77	-.19	.49	.44	.34	.33	.33	.32	-.27	-.32	.31
10. Obj. days on feed grain	.33	.86	-.91	.21	.87	-.89	.09	.99	.99		.92	.62	.61	.65	.69	.10	.10	-.76	-.13	.50	.47	.29	.30	.28	.27	-.32	-.37	.35
11. Obj. days on feed silage	.16	.59	-.96	-.07	.71	-.83	.04	.89	.95	.92		.69	.69	.69	.11	.11	.11	-.71	-.20	.36	.33	.34	.35	.34	.33	.15	-.20	.19
12. Sub. cwt. grain	.55	.85	-.65	.22	.99	-.85	.36	.88	.35	.86	.69		1.00	.98	.96	.11	.11	-.71	-.20	.36	.33	.34	.35	.34	.33	.15	-.20	.19
13. Sub. cwt. silage	.55	.85	-.65	.22	.99	-.85	.36	.88	.35	.86	.69	1.00		.76	.62	.11	.11	-.71	-.20	.36	.33	.34	.35	.34	.33	.15	-.20	.19
14. Sub. days on feed grain	.44	.85	-.70	.17	.99	-.88	.31	.90	.86	.88	.74	.99	.99		.99	.01	-.01	-.77	-.19	.41	.40	.31	.38	.31	.29	-.20	-.27	.26
15. Sub. days on feed silage	.42	.84	-.72	.15	.99	-.91	.32	.90	.86	.88	.76	.98	.98	.99		-.03	-.03	-.78	-.17	.44	.44	.29	.37	.29	.27	-.24	-.29	.30
16. Weight	.53	.29	-.20	.45	.21	-.09	.30	.30	.29	.24	.16	.25	.25	.19	.18		.99	.23	.26	.13	-.13	.58	.11	.53	.61	.18	.17	.17
17. Weight-75	.53	.29	-.20	.45	.21	-.09	.30	.30	.29	.24	.16	.25	.25	.19	.18	.99		.23	.26	.13	-.13	.58	.11	.53	.61	.18	.17	.17
18. Fat	-.27	-.72	.80	-.13	-.86	.85	-.10	-.85	-.86	-.86	-.81	-.85	-.85	-.88	-.89	.03	.04		.31	-.48	-.54	-.17	-.35	-.17	-.14	.36	.42	.40
19. Fat change	-.39	-.51	.36	-.09	-.68	.50	-.24	-.53	-.51	-.51	-.41	-.68	-.68	-.67	-.66	.07	.08	.66		.13	.05	.10	-.04	.09	.11	-.03	-.03	-.03
20. Gain	-.01	.39	-.55	.03	.44	-.53	.07	.51	.52	.53	.54	.43	.43	.47	.49	.13	.13	.55	.15		.96	.08	.18	.09	.07	-.82	-.88	-.87
21. Rel. gain	-.13	.30	-.49	-.09	.37	-.49	-.01	.42	.43	.45	.48	.35	.35	.41	.43	.13	.13	.55	.17	.96		.89	.87	.99	.99	.40	.30	.32
22. Consumption	.28	.46	-.44	.36	.47	-.38	.06	.49	.47	.47	.40	.46	.46	.46	.44	.63	.63	.34	-.17	.28	.10		.89	.91	.99	.41	.30	.32
23. Rel. consumption	-.05	.41	-.45	.19	.47	-.43	-.11	.45	.44	.46	.40	.45	.45	.47	.47	.47	.47	.46	-.27	.29	.22	.89		.99	.99	.40	.30	.32
24. DE consumed for gain	.27	.46	-.43	.35	.47	-.38	.05	.48	.47	.46	.38	.47	.47	.46	.45	.59	.59	.35	-.18	.28	.11	.99	.91		.99	.41	.30	.32
25. DE consumed	.31	.46	-.42	.37	.46	-.36	.08	.48	.46	.46	.37	.46	.46	.45	.44	.65	.65	.32	-.16	.28	.09	.99	.87	.99		.40	.30	.32
26. DE for gain efficiency	.19	-.06	.25	.21	.10	.25	-.01	.16	-.19	-.19	-.26	-.09	-.09	-.14	-.16	.25	.26	.29	.04	-.74	-.80	.41	.35	.41		.41	.99	.99
27. DE efficiency	.18	-.11	.30	.19	.16	.30	-.01	-.21	-.24	-.25	-.31	-.15	-.15	-.20	-.22	.24	.24	.35	.07	-.81	-.87	.32	.26	.33		.33	.99	.99
28. Feed efficiency	.19	-.12	.32	.19	.18	.32	-.01	-.23	-.26	-.27	-.33	-.16	-.16	-.21	-.24	.23	.24	.37	.08	-.79	-.86	.30	.23	.30		.33	.99	1.00

^aCoefficients above the diagonal were calculated on a within-year, breed and sequence basis and those below on a within year-sequence basis.

^b $r \leq .14$, $P \leq .10$; $14 < r \leq .21$, $P \leq .05$; $.21 < r \leq .26$, $P < .01$; $r > .26$, $P < .001$.

^cSubcutaneous fat subjectively estimated in millimeters.

^dPredicted carcass weight (cwt) and days on food were calculated using equations from Butts et al. (1980 a,b). See Materials and Methods section for equations used.

($P < .05$), while on the silage diet, initial weight was positively related to initial depth, initial fat, and subjective fat ($P < .001$) and negatively related to frame ($P < .01$) and subjective and objective days on feed ($P < .001$). On a within-year basis for both diets, initial weight was positively related to initial height, initial depth, frame and muscle ($P < .001$) while being negatively related to subjective fat ($P < .001$) on the silage diet only. Initial height was highly correlated with initial depth, frame, subjective and objective carcass weight and days on feed ($P < .001$) and negatively related to initial and subjective fat measurements ($P < .001$). Correlation coefficients for initial fat were reversed from those of initial height with initial fat being negatively related to frame, objective and subjective carcass weight and days on feed ($P < .001$) and positively related to muscle ($P < .001$) on a within year-breed basis. From the coefficients of variables of initial fat it was assume that initially fatter calves were heavier muscled, slower gaining, smaller-framed steers that required fewer days to reach 12mm of fat and produced lighter carcasses. This follows the assumption of Butts et al. (1980a) that initial subcutaneous fat is a reliable predictor of rate of maturity. Coefficients for frame were, in general, the same as coefficients for initial height. Objective and subjective carcass weight and days on feed for both diets were again highly correlated ($P < .001$) with variables that indicated large framed, tall, thin growthy cattle.

When initial weight was related to performance during the test period, it was related to weight, weight^{.75} ($P < .001$) and fat ($P < .01$) for cattle on the grain diet. While for cattle on the silage diet,

initial weight was related to these variables and also to DE efficiency and feed efficiency ($P < .01$). With these correlations it was hypothesized that calves within breed that were initially heavier would be heavier and fatter in the feedlot if fed a grain diet and would be heavier, fatter and less efficient if fed a silage base diet. Within year-breed groups, initial height was negatively related to bi-weekly fat measurements ($P < .001$) and positively related to daily gain and consumption ($P < .001$). Within year, initial height was negatively correlated with daily fat change ($P < .01$), feed efficiency, DE efficiency ($P < .05$) and also positively related to gain and consumption ($P < .001$). Initial fat was negatively related to gain, relative gain, and consumption ($P < .001$).

When relating performance variables to other performance variables, weight and weight^{.75} were synonymous with each other with both being positively related to all consumption of DE consumed for gain and DE consumed ($P < .001$) and negatively related to daily fat change and daily gain on the grain diet ($P < .01$). For cattle on the silage diet, initial weight was positively related to fat and fat change ($P < .01$), subcutaneous fat measured during the trial was negatively related to daily gain, relative daily gain and all variables of consumption and positively related to efficiency variables on both diets. Daily gain and relative daily gain were similar--their coefficients with both being positively related to consumption ($P < .001$) on the grain diet and negatively related to all variables of efficiency ($P < .001$) for cattle on either diet.

II. Factor Analysis

Factor analyses were performed on all variables in the data set. This analysis produced linear combinations of the original variables within a data set to explain the greatest amount of variation and covariation among those variables. Factor analyses performed on within year and within year-breed basis for each diet group were used to test for redundancies among descriptive measurements and to describe the sample of calves. Results from factor analyses, within year-breed basis, can be found in Tables 6 and 7.

Table 6 is the rotated factor pattern, within year-breed, for the grain diet. The first factor of the 5 factor analysis explained 49% of the correlation structure and may be largely considered a frame size and rate of maturing factor. Initial height, frame, objective and subjective predicted carcass weight and days on feed, received high positive loadings, while initial fat, subjective fat and fat received high negative loadings.

The second factor explaining an additional 17% of the correlation structure may be considered a unique factor associated with efficiency of gain, with gain and relative gain favorably related to efficiency of gain. Factor 3 explained an additional 11% of the correlation structure and can be described as another unique factor with high positive loadings for fat change and fat. Factor 4 described mainly consumption with high positive factor loadings for consumption, relative consumption, DE consumed and DE consumed for gain. Factor 4 explained an additional 8% of the variation. Factor 5 explained an additional 6% of the variation

Table 6. Rotated Factor Pattern of Measurements, Within Year-Breed Groups for Grain Diet

Variables	Factor loadings ^a				
	1	2	3	4	5
Initial weight	-.05	.14	.08	-.13	.78
Initial height	.78	-.07	-.07	.19	.45
Initial fat	-.78	.09	-.09	-.19	.09
Initial depth	.17	.04	-.03	.23	.88
Frame	.90	-.03	-.06	.32	.14
Pfat	-.86	.06	.17	-.05	.20
Muscle	-.39	-.05	-.02	-.11	-.03
Obj. cwt. grain	.88	-.08	.04	.17	.16
Obj. cwt. silage	.87	-.08	.07	.16	.07
Obj. days on feed grain	.90	-.09	.04	.18	.06
Obj. days on feed silage	.82	-.09	.10	.14	-.21
Sub. cwt. grain	.91	-.02	-.07	.29	.19
Sub. cwt. silage	.91	-.02	-.07	.29	.19
Sub. days on feed grain	.94	-.05	-.09	.28	.03
Sub. days on feed silage	.95	-.06	-.11	.26	-.04
Weight	.37	.05	.14	.21	.26
Weight ^{.75}	.37	.05	.15	.21	.26
Fat	-.75	.18	.41	-.07	.25
Fat change	-.24	-.29	.89	.08	.01
Gain	.26	-.87	.04	.37	-.02
Rel. gain	.12	-.91	.01	.31	-.11
Consumption	.36	.06	.05	.88	.10
Rel. consumption	.22	.04	-.04	.95	-.06
DE consumed	.34	.06	.04	.88	.07
DE consumed for gain	.36	.06	.05	.90	.10
DE for gain efficiency	-.01	.95	-.07	.30	.01
DE efficiency	-.04	.97	-.07	.19	.02
Feed efficiency	-.04	.97	-.07	.19	.02
Cumulative portion	.49	.66	.77	.85	.91

^aPrincipal axis method, varimax rotation.

Table 7. Rotated Factor Pattern of Measurements, Within Year-Breed Groups for Silage Diet

Variables	Factor loadings ^a				
	1	2	3	4	5
Initial weight	-.16	.24	-.03	-.07	.10
Initial height	.48	.04	-.08	.37	-.18
Initial fat	-.47	.13	-.18	-.82	.13
Initial depth	.07	.11	.19	.05	-.07
Frame	.93	-.06	.17	.19	-.04
Pfat	-.79	.20	-.08	-.39	.15
Muscle	-.15	-.01	-.15	-.29	.76
Obj. cwt. grain	.54	-.05	.13	.76	-.15
Obj. cwt. silage	.51	-.07	.13	.82	-.12
Obj. days on feed grain	.55	-.07	.12	.76	-.15
Obj. days on feed silage	.46	-.13	.12	.84	-.09
Sub. cwt. grain	.95	-.06	.16	.21	.02
Sub. cwt. silage	.95	-.06	.16	.21	.02
Sub. days on feed grain	.94	-.11	.15	.23	-.01
Sub. days on feed silage	.94	-.14	.13	.25	.01
Weight	.04	.09	.44	.64	.42
Weight ^{.75}	.04	.09	.44	.64	.43
Fat	-.68	.30	-.05	-.31	.38
Fat change	-.01	-.10	.16	-.03	.14
Gain	.20	-.91	.26	.19	.03
Rel. gain	.18	-.95	.08	-.06	-.13
Consumption	.19	.15	.91	.28	.04
Rel. consumption	.24	.12	.87	-.15	-.32
DE consumed	.19	.15	.90	.22	.07
DE consumed for gain	.18	.15	.92	.29	.01
DE for gain efficiency	-.05	.91	.38	-.05	-.04
DE efficiency	-.08	.94	.29	-.04	.01
Feed efficiency	-.08	.94	.31	-.04	.01
Cumulative portion	.43	.65	.74	.82	.87

^aPrincipal axis method, varimax rotation.

and could be considered an initial size factor largely independent of variation in weight during the test period.

Table 7 is the rotated factor pattern, within year and breed for the silage diet. The first factor of the 5 factor analysis explained 43% of the correlation structure. As in the factor analysis for the gain diet, factor 1 may be considered a factor that described frame size and different rates of maturing with high positive loadings for initial height, frame, objective and subjective carcass weights and days on feed and high negative loadings for initial fat, subjective fat and fat measured during the feedlot phase. When compared to factor 1 in the factor analysis for the grain diet, initial height, initial fat, objective carcass weights, days on feed and weight in the feedlot receive smaller positive loadings. This would seem to indicate a slightly different type of feeder steer on the silage diet compared to the feeder steers on grain. This could also point out, especially looking at the loadings for weight and weight^{.75}, that taller, thinner, later maturing cattle did not perform as well on silage as they did on grain. This would agree with work done by Byers and Parker (1980), which indicated that late maturing cattle could more nearly reach their full potential for protein growth on a concentrate diet as compared to a silage diet. On a silage diet, tall, thin, late maturing cattle are probably restricted on energy intake for gain. Factor 2 explained an additional 22 % of the variation and again, like factor 2 on the grain diet, described differences related to efficiency. Daily gain and relative gain both received high negative loadings while DE consumed for gain, DE consumed and feed efficiency all received high positive loadings. Factor 3

explained an additional 9% of the variation and, in general, is a factor related to consumption and weight, with consumption, relative consumption, DE consumption and DE consumed for gain receiving heavy positive loadings. Factor 4 is similar to factor 1 in that it, too, is a factor that described frame size and rate of maturing. The essential difference being that factor 4 loaded heavier on objective initial measurements and weight in the feedlot as compared to factor 1. Factor 4 explained an additional 8% of the correlation structure with objective carcass weights and days on feed, weight, weight^{.75} receiving heavy positive loadings and initial fat receiving the heaviest negative loading. Factor 5 explained an additional 5% in the correlation structure with muscle score, weight, weight^{.75} and fat receiving heavy positive loadings while relative consumption received a moderate negative loading.

After inspection of the factor patterns for the 2 diets, it was decided that redundancy between variables existed. Objective carcass weights and days on feed were generally loaded in the same direction and magnitude as height and frame so these variables were deleted from further analysis. Initial height and frame also moved in the same manner but both variables were used in further analysis. This was also true on all fat measurements and all measures of fat remained in further analysis along with weight and weight^{.75}. Digestible energy consumed, DE consumed for gain, DE for gain efficiency and DE efficiency were found to be redundant with other variables and were removed from further analysis.

III. Canonical Correlation Analyses

Canonical correlation analysis on all sources in the data set were conducted correlating objective and subjective measurements with selected performance variables. Canonical correlation is similar to factor analysis with the exception that the criterion of selection has been altered. Though both techniques produce linear combinations of the original variables, canonical correlation does so not with the objective of accounting for as much variance as possible within one set of variables, but with the aim of accounting for a maximum amount of the relationship between 2 sets of variables. The first canonical variable will always be the combination which explains the greatest amount of correlation between the 2 data sets. Canonical correlation variables were calculated on a within year-breed basis for each diet. Four canonical variables are presented in each table, but only significant variables will be discussed. Results for the canonical correlation analyses are found in Tables 8, 9, 10 and 11. Table 8 describes the relationship between initial objective measurements and performance variables for cattle on the grain diet. Variable 1 with a canonical correlation of .93 described initially taller, thinner, slightly deeper bodied calves with heavier, thinner cattle that gained slightly more weight, consumed a greater amount of feed with a neutral effect on efficiency. Canonical variable 2 with a canonical correlation of .61 associated initially heavier, deeper bodied, slightly taller calves, with heavier, fatter feedlot cattle that gained considerably less weight, consumed slightly more feed and converted feed to gain less

Table 8. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variable of Group 1 and Group 2 for Objective Measurements for Grain Diet

	Canonical variables ^{a,b}			
	1	2	3	4
Group 1				
Initial weight	-.1358	.8801	-.4539	-.0312
Initial height	.7785	.3767	-.2137	.4542
Initial fat	-.9718	.0742	-.0938	.2030
Initial depth	.3249	.8522	.3662	.1849
Group 2				
Weight	.6413	.6999	-.2068	-.1692
Fat	-.7152	.5701	.0275	-.3047
Fat change	-.0612	.1246	.1447	-.6901
Rel. gain	.2168	-.3905	.0376	.3652
Consumption	.6207	.2859	.2374	.2500
Feed efficiency	-.1055	.2508	-.0388	-.0837
Canonical correlations	.9285	.6084	.4892	.4433
Chi-square				
Degrees of freedom	24	15	8	3
Probability chi-square	.0001	.0014	.0151	.0380

^aCanonical variables are the sums of the products of the criterion variables and its normalized characteristic vector.

^bCanonical variables are on a within year and breed basis.

Table 9. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Valuable of Group 1 and Group 2 for Objective Measurements for Silage Diet

	Canonical variables ^{a,b}			
	1	2	3	4
Group 1				
Initial weight	.0976	.9643	-.1822	-.1656
Initial height	-.6465	.0558	.6669	-.3663
Initial fat	.9660	.2214	.1152	.0680
Initial depth	-.3942	.5907	.6484	.2743
Group 2				
Weight	-.6955	.6065	.0494	.3214
Fat	.7193	.6387	.0496	.2027
Fat change	.0410	.0976	-.7468	.6389
Rel. gain	-.1200	-.7624	-.1703	.2535
Consumption	-.5574	.1709	.3680	.6889
Feed efficiency	.0652	.5928	.3218	.0859
Canonical correlations	.9183	.4978	.2640	.1459
Chi-square				
Degrees of freedom	24	15	8	3
Probability chi-square	.0001	.4584	.8829	.8376

^aCanonical variables are the sums of the products of the criterion variables and its normalized characteristic vector.

^bCanonical variables are on a within year and breed basis.

Table 10. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variables of Group 1 and Group 2 for Subjective Measurements for Grain Diet

	Canonical variables ^{a,b}			
	1	2	3	4
Group 1				
Initial weight	-.3162	.8357	.0556	-.4455
Frame	.8912	.3127	.3125	-.1006
Pfat	-.9123	-.1585	.3682	-.0832
Muscle	-.5876	.2703	.1450	.7486
Group 2				
Weight	.3306	.7843	.0872	-.3784
Fat	-.9043	.1831	.1842	-.2948
Fat change	-.2739	-.1488	.1111	-.4016
Rel. gain	.2743	-.2079	.3176	.6655
Consumption	.5529	.2608	.7348	-.2779
Feed efficiency	-.0528	.1333	.1318	-.6529
Canonical correlations	.9248	.6029	.4517	.2456
Chi-square				
Degrees of freedom	24	15	8	3
Probability chi-square	.0001	.0182	.1917	.4946

^aCanonical variables are the sums of the products of the criterion variables and its normalized characteristic vector.

^bCanonical variables are on a within year and breed basis.

Table 11. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variables of Group 1 and Group 2 for Subjective Measurements for Silage Diet

	Canonical variables ^{a,b}			
	1	2	3	4
Group 1				
Initial weight	-.3633	-.0803	.8962	-.2417
Frame	.9050	.1220	.2136	.3469
Pfat	-.9326	.3517	-.0250	.0762
Muscle	-.5208	-.6758	.0457	.5196
Group 2				
Weight	.2583	-.0362	.7938	.2974
Fat	-.9550	-.0321	.1861	.1762
Fat change	-.0150	-.8027	.1109	.5046
Rel. gain	.3810	-.3341	-.7081	.0960
Consumption	.4325	.2613	.3970	.5793
Feed efficiency	-.2106	.4124	.5931	.0539
Canonical correlations	.8492	.5006	.4239	.0657
Chi-square				
Degrees of freedom	24	15	8	3
Probability chi-square	.0001	.1965	.4339	.9822

^aCanonical variables are the sums of the products of the criterion variables and its normalized characteristic vector.

^bCanonical variables are on a within year and breed basis.

efficiently. Canonical variable 3 with a correlation of .49 related initially lighter, deeper bodied calves with slightly lighter cattle that consumed slightly more feed. Canonical variable 4 with a correlation of .44 described initially taller calves with thinner cattle that fattened slowly and gained more weight.

Canonical variables of objective initial scores and performance variables for cattle on the silage diet are described in Table 9. Variable 1 with a canonical correlation of .92 described initially shorter, fatter, shallow bodied calves with lighter, fatter cattle that consumed considerably less feed. Variable 2, even though insignificant, had a canonical correlation of .50 which merits discussion. Variable 2 described initially heavier, deeper bodied calves with heavier, fatter slower gaining cattle that were less efficient.

Table 10 related subjective initial measurements with performance variables for cattle on the grain diet. Variable 1 with a canonical correlation of .92 described initially larger framed, thinner, lighter muscled feeder calves with thinner cattle that consumed more feed. Variable 2, with a correlation of .60, described initially heavier, slightly bigger framed, calves with heavier cattle. Variables 3 and 4 were insignificant, but variable 4 correlated initially lighter, heavier muscled calves with slightly lighter cattle that fattened slowly, gained a greater amount of weight and converted feed to gain very efficiently.

Table 11 related subjective initial traits to performance variables for cattle on the silage diet. Variable 1, with a canonical correlation of .89, described initially bigger framed, thinner, lighter muscled

calves with thinner cattle that gained more weight, consumed more feed and converted feed to gain relatively more efficiently. Variable 2, even though insignificant, had a canonical correlation of .50 and related initially lighter muscled calves with cattle that fattened more slowly and converted feed to gain less efficiently.

From the canonical correlation analyses, 2 major relationships between initial calf measurements and performance measurements were determined. First, calves that were initially taller or larger framed and thinner, were heavier, thinner cattle that consumed more feed, gained more weight and converted feed into gain slightly more efficiently in the feedlot. The second relationship that was generally consistent among the canonical correlations was that initially heavier, deeper bodied cattle were heavier, fatter cattle that gained little weight relative to metabolic body weight and converted feed to gain most inefficiently.

IV. Multiple Regression Analysis

Initial Calf Traits Predicting Performance in the Feedlot

Initial calf measurements along with selected performance variables were utilized to develop prediction equations for daily fat change, fat in the gain, daily gain (ADG), relative daily gain ($\text{ADG}/\text{weight}^{.75}$), daily feed consumption and feed efficiency for cattle on both the grain and silage diets. Prediction equations included year and breed as initial measurements explained less variation than did the objective initial measurements in predicting feedlot performance. Therefore, only objective initial measurements were used in final prediction

equations. Also, all two-way interactions were tested and found to be negligible sources of variation in the variables studied.

Final models regressing performance variables on initial measurements for both diets can be found in Tables 12 and 13. Coefficients of partial regression and least-squares means for discrete variables can be found in Table 14.

Breed, year, initial weight and initial fat contributed to the prediction of feedlot weight, accounting for .65 and .61 of the variation in weight of cattle on the grain and silage diets, respectively. The positive relationship between initial weight and weight ($P < .01$) and the negative relationship between initial fat and weight ($P < .001$) did not differ importantly between diets. Variation accounted for by year for both diets was significant ($P < .01$), but analysis of mean squares showed a much stronger relationship between year and weight of cattle on the silage diet. Breed differences accounted for a significant amount of variation (grain diet, $P < .01$ and silage diet, $P < .05$), with the greatest difference being between the Charolais-cross and Angus steers on both diets. Initial weight ($P < .001$) and initial height ($P < .01$) accounted for 82% of the variation in subcutaneous fat among cattle on grain. Initial weight was positively related and initial height negatively related to fat while greatest breed differences were between the British breeds and the Charolais-cross steers. On the silage diet, initial weight ($P < .10$), initial fat ($P < .01$), initial fat-squared ($P < .10$), year ($P < .01$) and breed ($P < .001$) accounted for 83% of the variation in fat with initial weight and initial fat being positively related and initial fat-squared being negatively related.

Table 12. Analyses of Variance for Initial Measurements Predicting Performance Traits for Grain Diet

Source	Weight (kg)		Fat (mm)		Fat change (mm/day)		Percent fat in gain (fat change/gain)		Gain (kg/day)		Rel. gain (kg/day/ wt.75)		Consumption (kg/day)		Feed efficiency (consumption/gain)	
	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS
Initial weight (kg)	1	1004.85**	1	3.69**	1	.00006	1	.0002 [†]	1	.02	1	.07*	1	.002	1	.56
Initial height (cm)	1	41.73	1	2.05*	1	.00001	1	.00033**	1	.031*	1	.044 [†]	1	.58 [†]		
Initial fat (cm)	1	1202.03**	1	.89	1	.00004			1	.013	1	.033	1	.50	1	.28
(Initial fat) ² (mm)					1	.00009			1	.016	1	.031			1	.39
Year	2	570.85**	2	1.88**	2	.00002	2	.0003**	2	.18***	2	.37***	2	.78*	2	18.58***
Breed	2	482.28**	2	6.86***	2	.0005***	2	.0006***	2	.05**	2	.13***	2	.86*	2	10.16***
Residual	37	101.38	37	.35	36	.00005	38	.00004	36	.008	36	.014	37	.205	37	.743

[†]P<.10.

*P<.05.

**P<.01.

***P<.001.

Table 13. Analyses of Variance for Initial Measurements Predicting Performance Traits for Silage Diet

Source	Weight (kg)		Fat (mm)		Fat change (mm/day)		Percent fat in gain (fat change/gain)		Gain (kg/day)		Rel. gain (kg/day/ wt./5)		Consumption (kg/day)		Feed efficiency (consumption/gain)	
	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS
Initial weight (kg)	1	1079.73**	1	.67 [†]	1	.000003	1	.00006	1	.007	1	.035	1	.07	1	1.28
Initial height (cm)	1	39.97	1	.03	1	.000002	1	.00003	1	.001	1	.006	1	.14		
Initial fat (cm)	1	1688.89***	1	1.78**					1	.03**	1	.05**	1	.58*	1	2.27*
(Initial fat) ² (mm)			1	.69 [†]					1	.03**	1	.05**			1	2.17*
Year	2	1629.87***	2	1.83**	2	.00003	2	.0002*	2	.09***	2	.27***	2	.60*	2	14.84***
Breed	2	370.68*	2	3.69***	2	.00035**	2	.0004***	2	.009 [†]	2	.03*	2	.14	2	1.29 [†]
Residual	37	111.77	36	.2304	38	.000027	38	.000043	36	.0033	36	.0069	37	.13	37	.5033

[†]p<.10.

*p<.05.

**p<.01.

***p<.001.

Table 14. Coefficients of Partial Regression and Least-Square Means

	Weight (kg)		Fat (mm)		Fat change (mm/day)		Percent fat in gain (fat change/gain)		Gain (kg/day)		Rel. gain (kg/day/wt. ⁷⁵)		Consumption (kg/day)		Feed efficiency (consumption/gain)	
	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage
Intercept	-2.25	22.43	4.22	-2.15	.08	.018	.08	.01	-.05	1.95	.93	3.47	.39	2.21	3.07	-.41
Initial weight (kg)	1.21**	1.06**	.07**	.03 [†]	.0003	.00005	.0004 [†]	.0002	-.005	-.003	-.01*	-.006*	-.002	.009	.02	.04
Initial height (cm)	.74	.58	-.16*	-.02	-.001	-.00004	-.001**	-.0004	.02*	-.003	.03 [†]	-.007	.09 [†]	.03		
Initial fat (mm)	-8.90***	-8.62***	.24	1.16**	.006				.11	-.16**	.17	-.20**	-.18	-.16*	-.42	1.20*
(Initial fat) ² (mm) ²									-.02	.03**	-.03	.04**			.10	-.23*
Year																
1977	327 ^a	322 ^a	5.22 ^a	4.52 ^a	.040	.029	.045 ^a	.038 ^b	.86 ^a	.76 ^a	1.15 ^a	1.01 ^a	8.69 ^a	7.35 ^a	9.86 ^a	9.65 ^a
1978	319 ^b	300 ^b	4.78 ^b	3.91 ^b	.039	.028	.036 ^b	.031 ^a	1.11 ^b	.92 ^b	1.48 ^b	1.27 ^b	8.36 ^b	6.98 ^b	7.56 ^b	7.73 ^b
1979	331 ^a	309 ^c	5.54 ^a	4.56 ^a	.042	.026	.041 ^a	.033 ^a	1.05 ^c	.80 ^a	1.36 ^c	1.08 ^c	8.82 ^a	7.34 ^a	8.61 ^c	9.20 ^b
Breed ^d																
(A)	333 ^a	317 ^a	5.87 ^a	4.95 ^a	.041 ^a	.032 ^a	.044 ^a	.040 ^a	.94 ^b	.79 ^a	1.22 ^b	1.06 ^a	8.91 ^a	7.33	9.70 ^b	9.23 ^b
(H)	326 ^b	313 ^a	5.58 ^a	4.56 ^b	.048 ^b	.030 ^a	.047 ^a	.037 ^a	1.04 ^a	.82 ^a	1.36 ^a	1.11 ^a	8.64 ^a	7.15	8.40 ^a	8.73 ^a
(CX)	319 ^c	302 ^b	4.10 ^b	3.48 ^c	.032 ^c	.021 ^b	.031 ^b	.025 ^b	1.06 ^a	.86 ^b	1.42 ^a	1.19 ^b	8.32 ^b	7.19	7.93 ^a	8.62 ^a
R ²	.65	.61	.82	.83	.58	.46	.68	.57	.70	.70	.69	.73	.43	.44	.70	.65

a, b, c Least-squares means with different letters identify significant differences at $P < .10$.

[†] $P < .10$.

** $P < .05$.

*** $P < .01$.

*** $P < .001$.

d A = Angus; H = Hereford; CX = Charolais and Charolais cross.

There were differences in fat thickness among all 3 breeds with Angus steers being fattest, followed by Hereford and Charolais-cross calves (Angus = 4.95, Hereford = 4.56 and Charolais-cross = 3.48), respectively. Variation in daily fat change was explained mostly by differences among breeds ($R^2 = .58$) for the grain diet and $R^2 = .46$ for cattle on the silage diet). Herefords fattened more rapidly (.045 mm/day) on the grain diet compared to the Angus (.041 mm/day) and Charolais-cross steers (.032 mm/day). While on the silage diet Hereford and Angus steers fattened faster (0.03 mm/day and 0.32 mm/day, respectively) than Charlois-cross steers (.021 mm/day). Year ($P < .05$) and breed ($P < .001$) differences explained .57 of the variation in percent of fat in the gain for cattle on the silage diet. Cattle on the silage diet in 1977 had a higher proportion of fat in their gain (.038 mm/kg gain) than did cattle on the silage diet in 1978 (.031 mm/kg gain) and 1979 (.033 mm/kg gain). Differences in breed showed the Charolais-cross calves put on less fat/kg gain (.025 mm/kg gain) compared to the Angus (.040 mm/kg gain) and Hereford steers (.037 mm/kg gain). Variation in degree of fat in the gain for cattle on grain was explained by differences in initial weight ($P < .10$), initial height ($P < .01$), year ($P < .01$) and breed ($P < .01$). These variables explained 68% of the variation in degree of fat in the gain with initial weight being positively related and initial height being negatively related to percent fat in the gain. Year differences resulted in cattle on grain in 1978 having less fat in their gain (.036 mm/kg gain) compared to .045 and .041 mm/kg gain for cattle in 1977 and 1978, respectively. Variation among breeds resulted in the Charolais-cross calves putting on less fat in their gain (.031 mm/kg gain) compared to the Angus and Herefords (.044 and

.047 mm/kg gain), respectively. Initial height ($P < .01$), year ($P < .001$) and breed ($P < .01$) were important sources of variation in daily gain of cattle on the grain diet with a R^2 of .70. Initial height was positively related to daily gain and all three years showed significant differences (1977 = .86 kg/day; 1978 = 1.11 kg/day; 1979 = 1.05 kg/day). Variation among breed resulted in the Angus gaining less (.94 kg/day) than the Hereford (1.04 kg/day) or Charolais-cross steers (1.06 kg/day). On the silage diet, initial fat ($P < .01$), initial fat-squared ($P < .01$), year ($P < .001$) and breed ($P < .10$) explained .70 of the variation in daily gain. Initial fat was negatively related and initial fat-squared was positively related to daily gain with cattle in 1978 gaining more daily (.92 kg/day) compared to cattle in 1977 (.76 kg/day) or 1979 (.80 kg/day). Charolais-cross cattle gained more/day (.86 kg/day) than did the Hereford (.82 kg/day) or Angus steers (.79 kg/day). Relative daily gain on the grain diet was related to initial weight ($P < .05$), initial height ($P < .10$), year and breed ($P < .001$). These variables explained .69 of the variation with initial weight being negatively related and initial height being positively related. There were significant differences between each year with cattle in 1978 gaining the most relative to body weight (.48 kg/day/wt^{.75}). Also, Angus cattle gained less weight (1.22 kg/day/wt^{.75}) compared to Hereford and Charolais-cross steers (1.36 and 1.42 kg/day/wt^{.75}), respectively. Consumption of the grain diet was positively related to initial height ($P < .10$) and associated with year ($P < .01$) and breed ($P < .01$) with these variables accounting for .43 of the variation. Cattle in 1978 consumed less feed (8.36 kg/day) compared to year 1977 (8.69 kg/day) and 1979 (8.82 kg/day). The British breeds consumed more than

did the Charolais-crosses with Angus consuming 8.91 kg/day, Hereford 8.64 kg/day and Charolais-cross steers consuming 8.32 kg/day. Consumption of the silage diet was negatively related to initial fat ($P < .05$) and differed among years ($P < .05$). These 2 variables along with other insignificant variables accounted for .44 of the variation with cattle in the other years (1977 = 7.35 kg/day and 1979 = 7.34 kg/day). Feed efficiency on the grain diet was related only to year ($P < .001$) and breed ($P < .001$) with these 2 discrete variables accounting for all .70 of the variation. There were significant differences between all 3 years of the study with cattle in 1977 requiring 9.86 kg feed/kg gain, cattle in 1978 requiring 7.56 kg feed/kg gain and cattle in 1979 requiring 8.61 kg feed/kg gain. Variation among breeds reflected differences between the Angus (9.70 kg feed/kg gain) compared to the Hereford and Charolais-cross steers (8.40 and 7.93 kg feed/kg gain), respectively. Feed efficiency of cattle on silage was positively related to initial fat, initial fat-squared ($P < .05$), year ($P < .001$) and breed ($P < .10$) with these variables and initial weight accounting for 65% of the variation. Year variation again showed that cattle on silage in 1978 were more efficient (7.73 kg feed/kg gain), compared to cattle in 1977 and 1979 (9.65 and 9.20 kg feed/kg gain), respectively. Differences among breeds resulted in Angus cattle being less efficient (9.23 kg feed/kg gain) compared to Hereford (8.75 kg feed/kg gain) and Charolais-cross steers (8.62 kg feed/kg gain).

Selected Animal Traits Predicting Performance in the Feedlot

Analyses of variance for models regressing selected performance variables on selected animal traits in the feedlot for both diets can

be found in Tables 15 and 16. Coefficients of partial regression and least-squares means are presented in Table 17.

Metabolic weight ($\text{weight}^{.75}$) ($P < .10$), relative daily gain ($P < .10$), subcutaneous fat ($P < .05$) and breed ($P < .01$) accounted for 77% of the variation in daily fat change for cattle on the grain diet. All variables were positively related to daily fat change. Variation among breeds showed that Hereford steers fattened more rapidly (.045 mm/day) than Angus (.039 mm/day) or Charolais-cross steers (.036 mm/day). Daily fat change for cattle on the silage diet was positively related to $\text{weight}^{.75}$ ($P < .05$), fat ($P < .05$) and breed ($P < .05$) with 56% of the variation accounted for in this model. Least-squares means for the breeds showed that Charolais-cross steers fattened slower (.025 mm/day) than Hereford or Angus steers (.029 mm/day and .030 mm/day, respectively). Percent fat in the gain was positively related to fat ($P < .001$) and breed ($P < .05$) for cattle on the grain diet with the model used for accounting for .70 of the variation. Hereford steers had a higher percentage of fat in their gain (.046 mm/kg gain) compared to Angus and Charolais-cross steers (.040 mm/kg gain and .036 mm/kg gain), respectively. Two models were used to relate performance trials to daily fat change for cattle on the silage diet. The first model used relative gain and relative gain-squared and accounted for .68 of the variation with fat ($P < .05$) and breed ($P < .05$) being related to percent fat. The second model replaced relative gain and relative gain-squared with consumption and consumption-squared and accounted for .69 of the variation with fat ($P < .01$), consumption ($P < .10$), consumption-squared ($P < .10$) and breed ($P < .05$) being related to percent fat in

Table 15. Analyses of Variance for Performance Traits for Grain Diet

Source	Fat change (mm/day)		Percent fat in gain (fat change/gain)		Gain (kg/day)		Rel. gain (kg/day/wt. ⁷⁵)		Consumption (kg/day)		Feed efficiency (consumption/gain)	
	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS
Weight ^{.75}	1	.0001†	1	.00002	1	.02†	1	.006	1	4.2***	1	.17
Rel. gain ² (ADG/wt. ^{.75})	1	.0001†	1	.000008							1	4.02***
Rel. gain ² (ADG/wt. ^{.75}) ²	1	.00007									1	2.20***
Fat (mm)	1	.00014*	1	.0008***	1	.04*	1	.07*	1	.67†	1	.75*
Fat ² (mm) ²	1	.00003									1	.55†
Consumption (kg) (Consumption) ² (kg) ²											1	1.98†
Year	2	.00006	2	.00006	2	.18***	2	.65***	2	.22	2	.60*
Breed	2	.0002**	2	.0002*	2	.04**	2	.15**	2	.64*	2	1.15**
Residual	38	.000029	38	.00003	36	.008	38	.014	38	.185	38	.169
											37	.695

†P<.10.

*P<.05.

**P<.01.

***P<.001.

Table 16. Analyses of Variance for Performance Traits for Silage Diet

Source	Fat change (mm/day)			Percent fat in gain (fat change/gain)			Gain (kg/day)			Rel. gain (kg/day/wt. ⁷⁵)			Consumption (kg/day)			Feed efficiency (consumption/gain)		
	df	MS		df	MS		df	MS		df	MS		df	MS		df	MS	
Weight ⁷⁵ (kg)	1	.0001*		1	.00006		1	.000002		1	.014		1	3.51***		1	.028	
Rel. gain (ADG/wt. ⁷⁵)				1	.00008											1	14.27***	
Rel. gain ² (ADG/wt. ⁷⁵) ²	1	.00007																
Fat (mm)	1	.00009*		1	.0002*		1	.0002**		1	.07**		1	.33*		1	.05	
Fat ² (mm) ²																		
Consumption (kg)				1	.0001 [†]											1	4.66***	
{Consumption} ² (kg) ²				1	.0001 [†]													
Year	2	.00004		2	.00002		2	.00005		2	.10***		2	.16		2	.113	
Breed	2	.0001*		2	.00014*		2	.00013*		2	.004		2	.004		2	.127	
Residual	58	.00002		36	.00003		36	.00003		38	.007		40	.079		37	.133	

[†]P<.10.

*P<.05.

**P<.01.

***P<.001.

Table 17. Coefficients of Partial Regression and Least-Squares Means

	Fat change (mm/day)		Percent fat in gain (fat change/gain)		Gain (kg/day)		Rel. gain (kg/day/wt.75)		Consumption (kg/day)		Feed efficiency (consumption/gain)		
	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage	Silage
Intercept	-.15	-.03	-.007	.07	.52	.57	1.99	1.87	-.66	-.86	26.32	5.37	16.50
Weight ¹ .75(kg)	.0007 [†]	.0006*	.0002	.0005	.01 [†]	.005	-.005	-.008	.13***	.12***	.03	-.04	.01
Rel. gain (ADG/wt.75)	.11 [†]		-.004	-.15							-.21.15***		-.7.15***
Rel. gain ² (ADG/wt.75) ²	-.03			.06							5.81***		
Fat (mm)	.01*	.002*	.006***	.003*	-.04*	-.04**	-.05 [†]	-.06**	-.15 [†]	-.09*	-.82 [†]	.25	-.06
Fat ² (mm) ²	-.0005										.07		.44**
Consumption (kg)												.53 [†]	1.24***
(Consumption) ² (kg) ²													
Year													
1977	.044 ^b	.027 ^a	.044 ^b	.035	.036	.77 ^a	1.17 ^a	1.04 ^a	8.71	7.16	8.94 ^a	9.81 ^a	8.38
1978	.039 ^a	.030 ^a	.038 ^a	.034	.033	.91 ^b	1.46 ^b	1.23 ^b	8.47	7.16	8.35 ^b	7.76 ^b	8.07 ^b
1979	.039 ^a	.026 ^b	.039 ^a	.033	.033	.80 ^a	1.36 ^c	1.09 ^a	8.69	7.34	8.74 ^a	8.46 ^c	8.97
Breed ^d													
(A)	.039 ^a	.030 ^a	.040 ^a	.037 ^a	.037 ^a	.83	1.25 ^a	1.12	8.87 ^a	7.26	9.05 ^a	9.42 ^b	8.89
(H)	.045 ^b	.029 ^a	.046 ^b	.036 ^a	.036 ^a	.84	1.40 ^b	1.14	8.72 ^a	7.14	8.77 ^a	8.21 ^a	8.83
(CX)	.036 ^a	.023 ^b	.036 ^a	.029 ^b	.029 ^b	.81	1.34 ^a	1.10	8.28 ^b	7.24	8.21 ^b	8.40 ^a	8.71
R ²	.77	.56	.79	.68	.69	.63	.67	.69	.47	.62	.93	.71	.91

a, b, c, Least-squares means with different letters signify a significant difference at $P < .10$.

d A = Angus; H = Hereford; CX = Charolais and Charolais cross.

[†] $P < .10$; * $P < .05$; ** $P < .01$; *** $P < .001$.

the gain. Breed differences for both models showed that Charolais-cross steers accumulated less fat in their gain (.029 mm/kg gain) than did Hereford and Angus steers (.036 mm/kg gain and .037 mm/kg gain), respectively. Weight^{.75} ($P < .10$), fat ($P < .05$), year ($P < .001$) and breed ($P < .01$) explained 67% of the variation in daily gain with weight^{.75} being positively related and fat negatively related to gain. Difference among years showed that cattle in 1977 gained the least (.90 kg/day) compared to cattle in 1978 and 1979 (1.11 kg/day and 1.04 kg/day, respectively). Also, Angus steers gained less (.95 kg/day) compared to Hereford (1.07 kg/day) and Charolais-cross steers (1.02 kg/day). Daily gain on the silage diet was described using fat ($P < .01$) which was negatively related and year ($P < .001$) with .63 of the variation being accounted for. Year variation was the result of the cattle in 1978 gaining more (.91 kg/day) than cattle in 1977 (.77 kg/day) and 1979 (.80 kg/day). Relative daily gain for cattle on both diets was negatively related to fat ($P < .10$ for the grain diet and $P < .01$ for the silage diet), year ($P < .001$) for both diets and breed ($P < .01$) for the grain diet only, with .67 and .69 of the variation being accounted for on the grain and silage diets, respectively. Weight^{.75} ($P < .001$), fat ($P < .10$) and breed ($P < .05$) were used to explain .47 of the variation in consumption of the grain diet with weight^{.75} being positively related and fat being negatively related. Breed variation was caused by the Charolais-cross steers consuming less feed (8.26 kg/day). Variation of consumption on the silage diet was also explained by weight^{.75} ($P < .001$) and fat ($P < .05$) with both variables being positively related to consumption and explaining .62

of the variation within consumption of silage. Two models were used to explain variation in feed efficiency on the grain diet. The first model used explained .95 of the variation with relative daily gain ($P < .001$), relative gain-squared ($P < .001$), fat ($P < .05$), fat-squared ($P < .10$), year ($P < .05$) and breed ($P < .01$) being significant variables in the model. Relative daily gain and relative daily gain-squared were the most powerful predictors of feed efficiency on the grain diet with partial b's = $-.21.15$ and 5.81 , respectively. Fat was also negatively related to feed efficiency while fat-squared was positively related. Variation among years showed that cattle in 1978 were more efficient (8.55 kg feed/kg gain) than were cattle in 1977 (8.94 kg feed/kg gain) and 1979 (8.74 kg feed/kg gain). Charolais-cross steers caused variation among breeds being more efficient (8.21 kg feed/kg gain) than Hereford or Angus steers (8.77 kg feed/kg gain and 9.05 kg feed/kg gain, respectively). The second model replaced relative gain and relative gain-squared with consumption. This model explained .71 of the variation with consumption ($P < .10$), year ($P < .001$) and breed ($P < .001$) being very significant. There were significant differences between all years of the study with cattle in 1978 being most efficient (7.77 kg feed/kg gain), respectively. Breed differences showed that Angus steers were less efficient (88.42 kg feed/kg gain) than Hereford (8.21 kg feed/kg gain) or Charolais-cross steers (7.40 kg feed/kg gain). Feed efficiency on the silage diet showed the same pattern as feed efficiency of cattle on the grain diet with relative gain ($P < .001$) being negatively related to feed efficiency and explaining .91 of the variation. A second model was shown that replaced relative gain with

consumption. This model explained 73% of the variation with fat ($P < .01$), consumption ($P < .001$) and year ($P < .001$) being a significant set of variables. Year variation was caused by cattle in 1978 being more efficient (8.07 kg feed/kg gain) compared to cattle in 1977 and 1978 (kg feed/kg gain and 9.06 kg feed/kg gain, respectively).

CHAPTER V

DISCUSSION

In reviewing the analyses, significant patterns become evident. When initial measurements were regressed on performance variables, initial fat, on the silage diet and initial height, on the grain diet, were significant in most of the models analyzed. Initial fat was negatively related to weight ($P < .001$), daily gain ($< .01$), relative daily gain ($P < .01$), consumption ($P < .05$) and positively related to fat ($P < .001$) and feed efficiency ($P < .05$); while initial height for cattle on the grain diet was negatively related to fat ($P < .05$), percent fat in the gain ($P < .01$) and positively related to daily gain ($P < .05$), relative daily gain ($P < .10$) and consumption ($P < .10$).

Throughout the various analyses used in this study, it became evident that initial height and initial fat were inversely related to one another. This inverse relationship was described in the residual correlation with the initial height being negatively correlated, $-.52$ and $-.59$, with initial fat on the silage and grain diets, respectively. This relationship was also described by factor and canonical correlation analyses with initial height and initial fat explaining variation in the first factors and first canonical variables. This highly negative relationship is a main descriptive term that described differences in feeder calves and accounted for variation in mature size and rate of maturing. Initial height described the mature size differences of feeder calves on the grain diet, while initial fat described differences in physiological maturity of cattle on the silage diet. Overall,

initial height related, within and across breed, to the taller, thinner, lighter muscled steers that gained more rapidly and consumed more feed/day. This conclusion was consistent for all variables tested except for consumption in which initial height was positively related ($P < .10$) but the generally taller Charolais-cross steers consumed less than the generally shorter British breeds. In general, taller framed cattle were thinner, lighter muscled and later maturing which inabled this type of steer to gain more rapidly, fatten slower and consume more feed in the feedlot. This assumption agrees with Klosterman et al. (1976b) in that selection for mature size would increase rate of gain but would not substantially improve feed efficiency.

Subcutaneous fat measurements, like initial fat, were also significant in most models used in the analyses. Fat was positively related to fat change ($P < .05$) amount of fat in gain ($P < .01$), feed efficiency for cattle on the silage diet ($P < .01$), and negatively related to consumption ($P < .10$), daily gain ($P < .05$ on the grain diet and $P < .01$ on the silage diet), relative daily gain ($P < .10$ on the grain diet and $P < .01$ on the silage diet) and feed efficiency for cattle on the grain diet ($P < .05$). These results seem to indicate that fatter cattle accumulate fat more rapidly, gain less weight and are less efficient if fed on a silage diet. While the negative relationship between fat and feed efficiency on the grain diet indicated that faster gaining cattle were also cattle that were depositing fat at a faster rate.

Relative gain and relative gain-squared were negatively related to feed efficiency ($P < .001$) while fat was also negatively related to

feed efficiency of a lower significance ($P < .05$). The relationship between relative gain and relative gain-squared agrees with work by Brundgardt (1971), Klosterman et al. (1976b), Lipsy et al. (1978) and Loveday et al. (1980) in which these researchers suggested that as rate of gain increases, feed efficiency increases. Smith (1979) determined a correlation of $-.94$ between efficiency and gain in an age- or weight-constant interval. This agrees with results of this study in which correlations of $-.82$, $-.78$, $-.87$ and $-.83$ were calculated for gain and relative gain with feed efficiency for the grain and silage diets, respectively.

Fitzhugh and Taylor (1971), Lipsey et al. (1978) and Long et al. (1978) related feed intake to efficiency of gain, mature size and rate of maturing. In this study, feed consumption was highly related to weight^{.75} ($P < .001$) and negatively related to fat ($P < .10$). Even though fat was negatively related to consumption, least-squares means indicated that earlier maturing cattle, as a group, consumed more feed/day. This result can be related to findings of Klosterman et al. (1976a) and Lipsey et al. (1978) in which earlier maturing breeds of cattle consumed more feed/weight^{.75} daily than late maturing breeds of cattle. Lipsey et al. (1978) also concluded that animals with higher consumption of feed/weight^{.75} were slower gaining and less efficient. This conclusion was also true in this study with Angus steers, in general, consuming more feed and being less efficient compared to Hereford and Charolais-cross steers. These results are in contrast to research reported by Bath et al. (1966), Garrett (1971) and Prior et al. (1977)

in which later maturing breeds of cattle consumed more feed/weight than did earlier maturing breeds.

Results from this study also seemed to indicate a breed type * nutrition interaction. Hereford steers fattened faster, had a higher degree of fat in their gain, gained more weight and were more efficient compared to Angus steers on the grain diet, while on the silage diet, there was no significant difference between the two breeds. This agrees with findings of Prior et al. (1977) and Smith (1979) and disagrees with results found by Guenther et al. (1965), Jesse et al. (1976), Ferrell et al. (1978) and Loveday et al. (1980).

Results from this study also question generalizations in the California Net Energy System (CNES). The CNES assumed that cattle of identical weight require the same amount of energy for fat and muscle production. From this study, it was concluded that later maturing cattle required less energy for growth than did earlier maturing cattle. Least-square means indicated that Charolais-cross steers, on the grain diet, consumed less feed and gained more weight more efficiently than did Angus steers. This indicates that Charolais-cross steers were converting feed to muscle growth while Angus steers were converting feed to mostly subcutaneous fat. This conclusion agrees with those of Blaxter (1962) and Jesse et al. (1976b) in which protein deposition was more efficient than fat accumulation.

CHAPTER VI

CONCLUSIONS

Results of the study led to the following conclusions:

1. The use of initial objective measurements of feeder calves is a more accurate method of predicting future performance as compared to initial subjective measurements.
2. Although actual animal measurements explained more variation in feedlot performance, objective initial measurements of feeder calves is a useful and accurate method of predicting performance in the feedlot.
3. Initial height and initial fat were predictors of mature size and rate of maturing for cattle on the grain and silage diets, respectively.
4. Average daily gain and relative average daily gain were highly related to feed efficiency with faster gaining cattle being more efficient.
5. Later maturing, growthier cattle were more efficient in producing lean growth when fed a high-energy diet.
6. Generalizations in the California Net Energy System should be examined and adjustments should be made for differences in rates of maturing and mature size which are inherent differences found in feedlot cattle.

CHAPTER VII

SUMMARY

Data from 630 Angus, Hereford and Charolais-cross feeder calves were utilized to study the relationship between initial calf measurements, selected performance variables and feedlot performance.

Calves were fed either a silage plus limited concentrate diet (medium-energy) or a growing-finishing grain diet (high-energy) and were serially slaughtered at a predetermined date to give a range in carcass quality from standard to high choice.

The steers were photographed, weighed and sonorayed for subcutaneous fat thickness upon arrival at the farm. This, along with weight of the calves at time of purchase, made up the objective initial measurements. Initial subjective scores were obtained from the evaluation of the animals by a single grader before the initiation of the trial. During the trial, animals were weighed and sonorayed for subcutaneous fat at biweekly intervals. These measurements and variables calculated from them along with average daily feed consumption records were used for performance variables in the analyses.

Means for each diet indicated that cattle on the grain diet were heavier, fatter cattle that gained weight more rapidly and consumed more feed.

Residual correlation within year and within year-breed groups were used to determine simple relationships that existed among the variables used in this study. Initial weight was related to initial depth, weight, weight^{.75} ($P < .001$) and fat ($P < .01$) for cattle on the

grain diet while on the silage diet, initial weight was related to these variables along with DE efficiency and feed efficiency ($P < .01$). Initial height was highly correlated with initial depth, frame, subjective and objective carcass weight and days on feed ($P < .001$) for both diets, and negatively related to initial fat, subjective fat and fat measured at biweekly weigh dates for both diets ($P < .001$). Initial fat was negatively related to frame, initial height, objective and subjective carcass weight and days on feed, gain, relative gain and consumption ($P < .001$) while being positively related to subjective fat and fat measured during the trial. Coefficients for frame were the same as for initial height. Subjective fat described the same relations as initial fat and objective and subjective carcass weight and days on feed followed the same patterns as initial height and frame. Correlation coefficients for gain and relative gain showed strong negative correlations with efficiency variables ($P < .001$).

Factor analyses were conducted within year-breed groups for both diets to test for redundancies among variables and to describe the sample of calves. Five factors were used to explain variation among calves with factor 1 being a shape or rate of maturing factor and explaining 49 and 43% of the correlation structure for the grain and silage diets, respectively. Factor 2 explained an additional 17 and 22% of the variation for cattle on the grain or silage diet, respectively and was considered a factor that explained differences in feed efficiency. Factor 3, 4 and 5, for cattle on grain diet, explained an additional 25% of the correlation structure with factor 3 explaining fat and fat change variation, factor 4 explaining differences

in consumption and factor 5 explaining variation caused by size differences. Factors 3,4 and 5, for cattle on the silage diet, explained an addition 22% of the variance with factor 3 being a consumption factor, factor 4 explaining shape variation and factor 5 explaining variation in weight.

Canonical correlation analyses, for cattle on each diet, were calculated correlating objective and subjective initial measurements with selected performance variables. Two major relationships were described using canonical correlations. First, initially taller, thinner or initially large framed, thinner cattle were related to heavier, thinner cattle that consumed more feed, gained more weight and converted feed to gain slightly more efficiently than the average. Secondly, initially heavier, deeper bodied feeder calves were heavier, fatter cattle that gained relatively little weight and converted feed to gain less efficiently than other types of cattle described.

Multiple regression analyses were utilized to develop prediction equations for selected performance variables for cattle on both diets. Prediction equations regressing initial measurements on performance traits were found to be an accurate method in predicting performance with R^2 values ranging from .43 for consumption on the grain diet to .73 for relative gain on the silage diet. Regressing selected performance variables on other variables of feedlot performance calculated R^2 values ranging from .47 for consumption of feed on the grain diet to .93 for feed efficiency on the grain diet. Initial height and initial fat were found to be initial measurements of mature size and rates of maturing with each being significant in most models used in predicting

performance of cattle on the grain and silage diets, respectively. Fat measured at biweekly intervals was also significant in every model used in the analyses. Fatter cattle deposited fat more rapidly, gained less weight, consumed less feed and were less efficient on the silage diet while being more efficient on the grain diet. Average daily gain and relative average daily gain were found to be highly related to feed efficiency ($P < .001$) with faster gaining cattle being more efficient. It was also concluded that later maturing, growthier cattle were more efficient in producing edible protein than were earlier maturing cattle when fed a high-energy diet.

Questions were also raised concerning the broad generalizations that the California Net Energy System (CNES) makes concerning energy requirements for feedlot cattle. Charolais-cross steers, which were considered the late-maturing group of steers gained more weight and consumed less feed being more efficient than earlier maturing Angus steers on the grain diet. These results indicate that protein deposition is more efficient than fat deposition and adjustments in the CNES should be made for the differences in rate of maturing and mature size.

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BIBLIOGRAPHY

BIBLIOGRAPHY

- Adams, N.J., W.N. Garrett and J.T. Eling. 1973. Performance and carcass characteristics of crosses from important breeds. *J. Animal Sci.* 37:623.
- Bath, D.L., M. Ronning, G.P. LofGreen and J.H. Meyer. 1966. Comparative utilization of energy by cattle for growth and lactation. *J. Anim. Sci.* 25:1138.
- Blaxter, K.L. 1962. *Energy Utilization in Fattening, Growth and Lactation; The Energy Metabolism of Ruminants.* Charles C. Thomas, Springfield.
- Brody, S. 1945. *Bioenergetics and Growth.* Reinhold Publ. Co., New York.
- Brown, J.E., C.J. Brown and W.T. Butts. 1972. A discussion of the genetic aspects of weight, mature weight and rate of maturing in Hereford and Angus cattle. *J. Anim. Sci.* 34:525.
- Brungardt, V.H. 1971. Efficiency and profit differences in Angus, Charolais and Hereford cattle varying in size and growth. Pub. of the Dept. of Meat and Anim. Sci., Univ. of Wisconsin.
- Butts, W.T., W.R. Backus, E.R. Lidvall, J.A. Corrick and R.F. Montgomery. 1980a. Relationships among definable characteristics of feeder calves subsequent performance and carcass traits. I. Objective measurements. *J. Anim. Sci.* 51:1297.
- Butts, W.T., E.R. Lidvall, W.R. Backus and J.A. Corrick. 1980b. Relationships among definable characteristics of feeder calves, subsequent performance and carcass traits. II. Subjective scores. *J. Anim. Sci.* 51:1306.
- Byer, F.M. and C.F. Parker. 1980. Choose nutritional level by cattle size. *Animal Nutrition and Health.* June/July (abstract).
- Crickenberger, R.G., D.G. Fox and W.T. Magee. 1976. Effect of cattle size, selection and crossbreeding on utilization of high corn silage or high grain rations. *Michigan Agr. Exp. Sta. Res. Rep.* 328.
- Danner, M.L., D.G. Fox and J.R. Black. 1980. Effect of feeding system on performance and carcass characteristics of yearling steers, steer calves and heifer calves. *J. Anim. Sci.* 50:394.
- Ferrell, C.L. and J.D. Crouse. 1978. Feed utilization by various types of steers. *J. Anim. Sci.* 47:1167.
- Ferrell, C.L., R.H. Kohlemeir, J.D. Crouse and H. Glimp. 1978. Influences of dietary energy, protein and biological type steer upon rate of gain and carcass characteristics. *J. Anim. Sci.* 46:255.

- Fitzhugh, H.A. and C.S. Taylor. 1971. Genetic analysis of degree of maturity. *J. Anim. Sci.* 33:717.
- Garrett, W.N., J.H. Meyer and G.P. Lofgreen. 1960. The comparative energy requirements of sheep and cattle for maintenance and gain. *J. Anim. Sci.* 18:528.
- Garrett, W.N., G.P. Lofgreen and J.H. Meyer. 1964. A net energy comparison of barley and milo for fattening cattle. *J. Anim. Sci.* 23:470.
- Garrett, W.N. 1965. Energetic efficiency of three breeds of cattle. *J. Anim. Sci.* 24:881.
- Garrett, W.N. 1971. Energy efficiency of beef and dairy steers. *J. Anim. Sci.* 32:451.
- Graham, N. McC., T.W. Searle and D.A. Griffiths. 1974. Basal metabolic rate in lambs and young sheep. *Aust. J. Agric. Res.* 25:957-71.
- Guenther, J.J., D.H. Bushman, L.S. Pope and R.D. Morrison. 1965. Growth and development of the major carcass tissues in beef calves from weaning to slaughter weight, with reference to the effect of plane of nutrition. *J. Anim. Sci.* 24:1184.
- Hogan, A.G., W.D. Salomon and H.D. Fox. 1922. The influence of the plane of nutrition on the maintenance requirement of cattle. *Missouri Agri. Exp. Sta., Res. Bull.*, 51.
- Jesse, George W., G.B. Thompson, J.L. Clarke, H.B. Hedrick and K.G. Weimer. 1976a. Effects of ration energy and slaughter weight on composition of empty body and carcass gain of beef cattle. *J. Anim. Sci.* 43:418.
- Jesse, George W., G.B. Thompson, J.L. Clark, K.G. Weiman and D.P. Hutcheson. 1976b. Effects of various ratios of corn and corn silage and slaughter weight on the performance of steers individually fed. *J. Anim. Sci.* 43:1049.
- Kleiber, M. 1947. Body size and metabolic rate. *Physiol. Rev.* 27:511.
- Kleiber, M. 1961. *The Fire of Life*. John Wiley and Sons, New York/London.
- Klosterman, Earle W. 1972. Beef cattle size for maximum efficiency. *J. Anim. Sci.* 34-875.
- Klosterman, Earle W., V.R. Cahill and C.R. Parker. 1976a. A comparison of the Hereford and Charolais breeds and their crosses under two systems of management. *Ohio Agr. Exp. Sta. Bul.* 1011.

- Klosterman, Earle W. and C.F. Parker. 1976b. Effect of size, breed and sex upon feed efficiency in beef cattle. Ohio Agr. Res. Dev. Cent. Bul. 1088.
- Lipse, Jerry R., M.E. Dikeman and R.R. Schalles. 1978. Carcass composition of different cattle types related to energy efficiency. J. Anim. Sci. 46:96.
- Lofgreen, G.P. and K.K. Otagaki. 1960. The net energy of blackstrap molasses for fattening steers as determined by a comparative slaughter technique. J. Anim. Sci. 19:392.
- Lofgreen, G.P., D.L. Bath and V.R. Young. 1962. Determination of the net energy of dried beet pulp using barley as a reference standard. J. Anim. Sci. 21:766.
- Lofgreen, G.P., D.L. Bath and H.T. Strong. 1963. Net energy of successive increments of feed above maintenance for beef cattle. J. Anim. Sci. 22:598.
- Lofgreen, G.P. 1964. A comparative slaughter technique for determining net energy values with beef cattle. Energy Metabolism. European Assn. Am. Prod. Pub. No. 11:309. Academic Press, London/New York.
- Lofgreen, G.P. and W.N. Garrett. 1968. Net energy for gain and maintenance with different maturing cattle. J. Anim. Sci. 27:793.
- Loveday, H.D. and M.E. Dikeman. 1980. Diet energy and steer type effects on composition and carcass composition. J. Anim. Sci. 51:78.
- Luitingh, H.C. 1961. The maintenance requirements of beef steers and the relationship of maintenance needs and total fattening requirements. J. Agric. Sci. 56:389.
- Marion, W.F., M.E. Dikeman and A.D. Dayton. 1980. Performance and composition of steers and heifers of two biological types related to net energy for production efficiency. J. Anim. Sci. 51:882.
- McCullough, M.E. 1973. Optimum Feeding of Dairy Animals. Univ. of Georgia Press, Athens.
- Moe, P.W., H.F. Tyrrell, W.P. Flatt. 1971. Energetics of body tissue mobilization. J. Dairy Sci. 54:4:548.
- Mulaik, S.A. 1972. The Foundations of Factor Analysis. McGraw-Hill, New York.

- NRC. 1976. Nutrient Requirements of Domestic Animals, No. 4. Nutrient Requirements of Beef Cattle. National Academy of Sciences, National Research Council, Washington, D.C.
- Prior, R.L., R.H. Kohlmeier, L.V. Cundiff, M.F. Dikeman and J.D. Crouse. 1977. Influence of dietary energy and protein on growth and carcass composition in different biological types of cattle. J. Anim. Sci. 45:132.
- Reid, J.T. and J. Robb. 1968. Relationship of body composition to energy intake and energetic efficiency. J. Dairy Sci. 54:4:453.
- Smith, Gerald M., D.B. Laster, L.V. Cundiff and E. Gregory. 1976. Characterization of biological types of cattle. II. Post-weaning growth and feed efficiency of steers. J. Anim. Sci. 34:37.
- Smith, Gerald, M. 1979. Size as a component of beef production efficiency: Feedlot production and integrated efficiency. J. Anim. Sci. 48:966.
- Song, Hoon and C.A. Dinkel. 1978. Mathematical models of postweaning growth, feed intake and carcass composition of beef cattle. II. Empirical predictive model of voluntary feed intake from weaning to slaughter. J. Anim. Sci. 47:56.
- Taylor, C.S. St. and G.B. Young. 1966. Variation in growth and efficiency in twin cattle with live weight and food intake controlled. J. Agri. Sci. 66:67.
- Trowbridge, P.F., C.R. Moulton and L.D. Haigh. 1915. The maintenance requirements of cattle. Missouri Agri. Exp. Sta., Res. Bul. 18.
- Tyrrell, H.E. and P.W. Moe. 1979. Energetics of growth in cattle. Proceedings 8th Symposium on Energy Metabolism, Cambridge.
- Webster, A.J.E., J.M. Brockway and J.W. Smith. 1974. Production of the energy requirements for growth in beef cattle. I. The irrelevance of fasting metabolism. Anim. Prod. 19:127.
- Young, L.D., L. Cundiff, J.D. Crouse, G.M. Smith and K.E. Gregory. 1978. Characteristics of biological types of cattle. VIII. Postweaning growth and carcass traits of three-way cross steers. J. Anim. Sci. 46:1178.

APPENDIX



Table A-1. Rotated Factor Pattern for Measurements Within Year Groups for Grain Diet

Variables	Factor loadings ^a				
	1	2	3	4	5
Initial weight	.40	-.13	-.07	.47	.32
Initial height	.83	.14	.15	.24	.03
Initial fat	-.78	.19	-.18	-.08	.18
Initial depth	.05	.23	-.19	.31	-.04
Frame	.94	.11	.19	-.11	.12
Pfat	-.91	-.01	-.23	.03	.12
Muscle	.10	-.17	.04	.19	.95
Obj. cwt. grain	.92	.12	.19	.20	-.01
Obj. cwt. silage	.91	.11	.20	.19	-.02
Obj. days on feed grain	.92	.14	.22	.15	-.05
Obj. days on feed silage	.85	.11	.23	.07	-.10
Sub. cwt. grain	.93	.07	.18	.14	.17
Sub. cwt. silage	.93	.07	.18	.14	.17
Sub. days on feed grain	.95	.09	.20	.08	.12
Sub. days on feed silage	.95	.07	.22	.06	.13
Weight	.18	.14	.02	.96	.10
Weight ^{.75}	.18	.15	.02	.96	.10
Fat	-.90	-.04	-.23	.11	-.04
Fat change	.60	.07	.27	.05	-.30
Gain	.39	.26	.86	.13	-.01
Rel. gain	.36	.24	.88	-.07	-.01
Consumption	.15	.96	-.08	.18	-.04
Rel. consumption	.11	.97	-.09	-.14	-.08
DE consumed	.14	.98	-.08	.17	-.05
DE consumed for gain	.15	.96	-.08	.12	-.04
DE for gain efficiency	-.23	.37	-.89	-.02	-.03
DE efficiency	-.23	.27	-.92	.01	-.01
Feed efficiency	-.25	.27	-.92	.01	-.01
Cumulative portion	.49	.68	.79	.88	.92

^aPrincipal axis method, varimax rotation.

Table A-2. Rotated Factor Pattern for Measurements Within Year Groups for Silage Diet

Variables	Factor loadings ^a				
	1	2	3	4	5
Initial weight	.32	.01	.13	.46	.54
Initial height	.85	.12	-.08	.09	-.01
Initial fat	-.79	-.16	.22	-.11	.26
Initial depth	.24	.15	.14	.28	-.12
Frame	.92	.15	-.10	.09	.16
Pfat	-.91	-.12	.21	.02	-.02
Muscle	.13	-.03	-.04	.18	.92
Obj. cwt. grain	.93	.13	-.16	.15	-.03
Obj. cwt. silage	.91	.13	-.18	.16	-.04
Obj. days on feed grain	.94	.13	-.19	.10	-.09
Obj. days on feed silage	.81	.11	-.24	.09	-.13
Sub. cwt. grain	.91	.14	-.10	.12	.24
Sub. cwt. silage	.91	.14	-.10	.12	.24
Sub. days on feed grain	.94	.15	-.13	.06	.18
Sub. days on feed silage	.94	.14	-.15	.04	.18
Weight	.12	.21	.03	.95	.12
Weight ^{.75}	.12	.22	.04	.95	.12
Fat	-.86	-.14	.24	.16	-.05
Fat change	-.55	-.06	-.03	.12	-.10
Gain	.36	.28	-.88	.10	.04
Rel. gain	.32	.22	-.90	-.14	.02
Consumption	.23	.94	.09	.23	.01
Rel. consumption	.23	.96	.08	-.10	-.05
DE consumed	.22	.95	.09	.18	.01
DE consumed for gain	.22	.93	.09	.25	.02
DE for gain efficiency	-.14	.54	.82	.01	.01
DE efficiency	-.19	.43	.88	.04	.01
Feed efficiency	-.18	.41	.89	.04	.02
Cumulative portion	.48	.69	.78	.85	.90

^aPrincipal axis method, varimax rotation.

Table A-3. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variables of Group 1 and Group 2 for Objective Measurements for Grain Diet

	Canonical variables ^{a,b}			
	1	2	3	4
Group 1				
Initial weight	.3200	.8771	-.2617	.2444
Initial height	.8513	.2650	.0628	.4484
Initial fat	-.9154	.0901	-.2907	.2636
Initial depth	.0950	.6207	.7231	.2879
Group 2				
Weight	.3749	.7299	.1384	.1194
Fat	-.9235	.1274	.1354	-.0817
Fat change	-.4483	-.3022	.1356	-.4999
Rel. gain	.6060	-.4078	-.2317	.1332
Consumption	.3756	.0592	.8312	.2431
Feed efficiency	-.4910	.2212	.5200	.0887
Canonical correlations	.9425	.7709	.5874	.4759
Chi-square				
Degrees of freedom	24	15	8	3
Probability chi-square	.0001	.0001	.0010	.0195

^aCanonical variables are the sums of the products of the criterion variables and its normalized characteristic vector.

^bCanonical variables are on a within year basis.

Table A-4. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variables of Group 1 and Group 2 for Objective Measurements for Silage Diet

	Canonical variables ^{a,b}			
	1	2	3	4
Group 1				
Initial weight	.5556	-.0868	-.1956	-.0459
Initial height	.8408	.0271	-.1887	.5067
Initial fat	-.8669	-.4190	-.2227	.1524
Initial depth	.3504	-.4160	.5152	.6624
Group 2				
Weight	.4243	-.6340	.5463	.1249
Fat	-.8850	-.3748	.2591	.0019
Fat change	-.5630	.0778	.7701	.2573
Rel. gain	.3852	.6048	-.0699	-.2023
Consumption	.5450	-.0680	.4184	.7057
Feed efficiency	-.1798	-.5175	.1649	.5741
Canonical correlations	.9317	.6980	.3865	.1717
Chi-square				
Degrees of freedom	24	15	8	3
Probability chi-square	.0001	.0046	.4963	.7647

^aCanonical variables are the sums of the products of the criterion variables and its normalized characteristic vector.

^bCanonical variables are on a within year basis.

Table A-5. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variables of Group 1 and Group 2 for Subjective Measurements for Grain Diet

	Canonical variables ^{a,b}			
	1	2	3	4
Group 1				
Initial weight	.1955	.9041	-.3691	-.0899
Frame	.9147	-.3102	-.1976	.1673
Pfat	-.9639	-.0568	-.0685	.2508
Muscle	.0337	.7621	.5359	.3618
Group 2				
Weight	.1452	.6609	-.5491	.0159
Fat	-.9820	-.0722	-.0786	.0261
Fat change	-.5323	-.5102	-.2313	-.2440
Rel.gain	.6257	-.1612	.2118	.1806
Consumption	.2679	-.1424	-.7004	.5522
Feed efficiency	-.5039	-.0379	-.3178	.0839
Canonical correlations	.9564	.7963	.4772	.3446
Chi-square				
Degrees of freedom	24	15	8	3
Probability chi-square	.0001	.0001	.0628	.1817

^aCanonical variables are the sums of the products of the criterion variables and its normalized characteristic vector.

^bCanonical variables are on a within year basis.

Table A-6. Correlation Coefficients Between Each Canonical Variable of Group 1 and Group 2 and the Individual Criterion Variables of Group 1 and Group 2 for Subjective Measurements for Silage Diet

	Caonical variables ^{a,b}			
	1	2	3	4
Group 1				
Initial weight	.4772	.8532	-.1513	-.1464
Frame	.9872	.0491	.1276	.0820
Pfat	-.9070	.2398	.3451	.0272
Muscle	.2177	.5560	-.2250	.7700
Group 2				
Weight	.2249	.6669	-.1937	-.2424
Fat	-.9565	.2519	.0554	-.0487
Fat change	-.7118	-.1838	-.5041	-.3694
Rel. gain	.4324	-.5229	-.3386	.5555
Consumption	.5024	.0984	.2337	-.4124
Feed efficiency	-.2031	.4380	.4430	-.7065
Cononical correlations	.9262	.7336	.3573	.2027
Chi-square				
Degrees of freedom	24	15	8	3
Probability chi-square	.0001	.0014	.5501	.6561

^aCanonical variables are the sums of the products of the criterion variables and its normalized characteristic vector.

^bCanonical variables are on a within year basis.

Table A-7. Coefficients of Partial Regression and Least-Squares Means (Weight)

	Weight (kg)		Fat (mm)		Fat change (mm/day)		Percent fat in gain (fat change/gain)		Gain (kg/day)		Rel. gain (kg/day/wt. ^{.75})		Consumption (kg/day)		Feed efficiency (consumption/gain)	
	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage
Intercept	109.47	216.37	18.50	17.55	.21	.17	.23	.23	-.92	1.09	-.57	1.81	5.11	2.63	12.03	2.96
Initial weight (kg)	.87*	.62*	.007	-.017	-.0003	-.0002 [†]	-.00007	-.0002	-.004	-.0008	-.007	-.002	-.02	.008	-.01	.02
Initial height (cm)	.43	-.29	-.16	-.11 [†]	-.001	-.0008*	-.002***	-.001**	.03*	.0007	.03 [†]	.0004	.07	.03		
Initial fat (mm)	-7.59**	-8.02**	1.25	1.06 [†]	.013				.14	-.15**	.22	-.19*	-.13	-.15*	-.53	1.18*
(Initial fat/2 (mm) ²)			-.15	-.11	.003 [†]				-.03 [†]	.02*	-.04 [†]	.03*			.16	-.22 [†]
Year																
1977	327 ^a	321 ^b	5.12 ^a	4.47 ^a	.039	.028	.044 ^a	.037 ^a	.89 ^b	.77 ^a	1.16 ^a	1.01 ^a	8.67	7.34 ^a	9.77 ^a	9.61
1978	319 ^b	301 ^a	4.85 ^b	3.99 ^b	.040	.028	.037 ^b	.031 ^b	1.10 ^a	.91 ^b	1.47 ^b	1.27 ^b	8.38 ^a	6.98 ^b	7.61 ^b	7.73
1979	331 ^a	308 ^a	5.56 ^a	4.52 ^a	.042	.026	.041 ^{a,b}	.032 ^b	1.05 ^a	.80 ^a	1.36 ^c	1.08 ^c	8.82 ^b	7.34 ^a	8.64 ^c	9.23
R ²	.56	.54	.64	.69	.38	.28	.49	.36	.59	.66	.53	.65	.30	.41	.47	.60

a, b, c Least-squares means with different letters identify significant differences at P < .10.

[†] P < .10.

* P < .05.

** P < .01.

*** P < .001.

Table A-8. Coefficients of Partial Regression and Least-Squares Means (Fat Change)

	Fat change (mm/day)		Percent fat in gain (fat change/gain)		Gain (g/day)		Rel. gain (kg/day/wt. ⁷⁵)		Consumption (kg/day)		Feed efficiency (consumption/gain)	
	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage	Grain	Silage
Intercept	-.16	-.03	.007	.035	.95	.61	2.55	1.94	-.28	-2.44	-40.42	16.29
Weight ⁷⁵ (kg)	.0003	.0005	-.0002	.0004	.0001	.005	-.01	-.009 [†]	.12***	.11***	.02	.02
Rel. gain (ADG/wt. ⁷⁵)	.15*		.005	-.094					3.37	-23.15***	-7.29***	
Rel. gain ² (ADG/wt. ⁷⁵) ²	-.04 [†]			.037					-1.49	6.38***		
Fat (mm)	.02**		.007***	.006***	.006***	-.05***	-.04***	-.06***	.003	-.09 [†]	.44***	-.09
Fat ² (mm) ²	-.0007								.02			.37***
Consumption (kg)				.10						10.78		1.31***
(Consumption) ² (kg) ²				-.007						-.57		
Year												
1977	.045 ^b	.027 ^a	.045 ^b	.035	.036 ^a	.89 ^b	.77 ^a	1.17 ^b	1.04 ^a	8.74	8.86	9.81 ^b
1978	.038 ^a	.030 ^b	.038 ^a	.035	.034 ^a	1.10 ^a	.91 ^b	1.45 ^a	1.23 ^b	8.54	8.52	7.86 ^a
1979	.038 ^a	.025 ^a	.038 ^a	.032	.032 ^b	1.05 ^a	.80 ^a	1.38 ^a	1.09 ^a	8.59	8.65	8.36 ^a
R ²	.70	.45	.72	.61	.62	.58	.63	.58	.68	.37	.91	.63
											.90	.72

a, b Least-squares means with different letters signify a significant difference at P<.10.

†P<.10.

*P<.05.

**P<.01.

***P<.001.

VITA

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