To the Graduate Council:

I am submitting herewith a thesis written by Terry L. Worley entitled "Patterns of Forage and Milk Intake by Angus Calves Grazing High or Low Quality Pastures." 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.

J. W. Holloway, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

PATTERNS OF FORAGE AND MILK INTAKE BY ANGUS CALVES GRAZING HIGH OR LOW QUALITY PASTURES

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ABSTRACT

Milk and forage intake was measured on 158 Angus calves during a five year study beginning 1977. These calves were born in January through March, weaned in October, and grazed pastures of either high quality forage (red and white clover, Korean and Kobe lespedeza and tall fescue) or low quality forage (100% tall fescue). Milk intake estimates were performed monthly from April through October by the calf suckle technique. On June 26, July 31 and September 15 of each year, forage intake and digestibility trials were performed using the ADL (internal)/chromic oxide (external) indicator technique with trials containing a 5-day preliminary and 5-day collection period. Milk DE was estimated by total milk-out procedures during the 4th, 5th and 6th months of lactation. Forage DE and (milk DE) intakes for the June, July and September trials were 9.8 (4.5), 15.8 (4.0) and 19.8 (3.3) Mcal DE/day for calves grazing high quality pastures and 6.7 (3.9), 9.6 (3.4) and 14.8 (2.8) Mcal DE/day for calves on low quality pastures, respectively. An increase in milk DE intake was associated with a larger increase in weight gain for calves grazing low quality pastures than for calves grazing high quality pastures. Regarding calves on high quality pastures, as age increased, forage DE intake was associated with smaller increases in weight. All calves grazing low quality pastures were more dependent upon milk rather than forage for growth and performance.

In addition, the relationship of lactation curve shape to the pre-weaning performance of these same Angus calves was studied using the estimates of milk intake taken at various times during lactation. At

weaning, calves were measured for height at withers, ultrasonic fatness at the 12th rib and weight. Milk intake for each calf was described by the function milk production = $Ae^{-ct}t^{b}$ where A, b and c are constants estimated by evaluating these functions, t is a time value and e is the logarithmic function. Peak lactation occurred at 80 and 68 days for the calves on high and low quality pasture, respectively. Average milk intake explained 53% of the variation in weaning weight for calves on low quality pastures whereas, for calves on high quality pastures, it explained only 33% of the variation in weaning weight. When milk intakes at birth, peak lactation and weaning were adjusted for average milk intake, they explained 15 to 40% of the variation in weaning weight that was not explained by average milk intake. Generally, shape of the lactation curve was more important for the growth of the calves on low quality pastures than for calves on high quality pastures. Desirable curves in this study were determined to be associated with high peaks and low persistence.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	LITERATURE REVIEW	3
	Lactation Characteristics of Cow	4
	Milk and Forage Utilization for Calf Growth	9
	Effect of Creep Feed Intake on the Utilization of Milk and Forage	18
	Patterns of Milk Composition in Relation to Calf Growth Characteristics	21
III.	UTILIZATION OF FORAGE AND MILK BY ANGUS CALVES GRAZING HIGH OR LOW QUALITY PASTURE	23
	Summary	23
	Introduction	24
	Materials and Methods	25
	Statistical Analysis	29
	Results and Discussion	32
IV.	RELATIONSHIP OF LACTATION CURVE TO PREWEANING PERFORMANCE OF ANGUS CALVES GRAZING HIGH OR LOW QUALITY PASTURES	59
	Summary	59
	Introduction	60
	Materials and Methods	61
	Statistical Analysis	64
	Results and Discussion	80
LITERATURE CITED		89
VITA		94

CRANESE CREST

LIST OF TABLES

TABLE		PAGE
1.	Least-squares means of forage and milk variables.	34
2.	Partial b values associated with the conversion of forage DE and milk DE to weight and change in weight	43
3.	Correlation coefficients of calf growth and performance during lactation.	46
4.	Standard partial B values for the determination of pathway coefficients.	51
5.	Least-squares means in the proportion for utilization of forage and milk DE intake to weight and change in weight. . .	54
6.	Correlation coefficients associated with pathway coefficients .	56
7.	Least-squares means of variables associated with milk intake, weaning measurements and growth variables	65
8.	Partial b values utilized to determine the effect of average milk intake on shape of curve	73
9.	Coefficients of simple correlation among weaning traits and milk intakes estimated at various times (average milk intake included	75
10.	Coefficients of simple correlation among weaning traits and milk intakes estimated at various times (corrected for average milk intake)	78
11.	Regression equations showing relationship of weaning traits, average milk intake and milk intakes estimated at various times	79

LIST OF FIGURES

FIGURE		PAGE
1.	Pathway coefficients for intake variables (diagram)	31
2.	Utilization of milk DE and forage DE for change in weight (high quality pasture, Trial 1)	37
3.	Utilization of milk DE and forage DE for change in weight (low quality pasture, Trial 1)	38
4.	Utilization of milk DE and forage DE for change in weight (high quality pasture, Trial 2)	39
5.	Utilization of milk DE and forage DE for change in weight (low quality pasture, Trial 2)	40
6.	Utilization of milk DE and forage DE for change in weight (high quality pasture, Trial 3)	41
7.	Utilization of milk DE and forage DE for change in weight (low quality pasture, Trial 3)	42
8.	Pathway coefficients for the utilization and milk DE intake for weight and change in weight	52
9.	Utilization of forage DE, milk DE intake and forage DE intake by calves grazing high and low quality pasture . . .	57
10.	Effect of pasture quality on lactation curve shape and preweaning growth (1976)	66
11.	Effect of pasture quality on lactation curve shape and preweaning growth (1977)	67
12.	Effect of pasture quality on lactation curve shape and preweaning growth (1978)	68
13.	Effect of pasture quality on lactation curve shape and preweaning growth (1979)	69
14.	Effect of pasture quality on lactation curve shape and preweaning growth (1980)	70
15.	Comparison of lactation curves as affected by pasture quality differences between 1976-1979 and 1980	72
16.	Effect of average milk intake on shape of lactation curve .	74
17.	Milk intake above average milk intake associated with maximum weaning weight	76

CHAPTER I

INTRODUCTION

Many factors influence the growth rate and performance of beef calves during the preweaning period. Two of these factors, milk and forage intake, and how they relate to one another are usually not considered by the average beef producer in the Southeast.

Forage intake can be affected by factors such as age of calf, seasonality, quantity and quality of forage present, milk intake, creep feed intake and other environmental and genetic interactions. Age of calf is a contributing factor since it can determine the ability or capacity of the calf to consume forage. Further, seasonality affects whether the amount of quality of forage will be present in sufficient amounts for an adequate source of nourishment.

Much research has been published on the factors associated with the determination of milk production and its relation to calf growth. In general, the factors affecting forage intake also affect milk intake: age of calf, season of birth, forage intake and milking ability of the dam. Although milk producing ability by the dam should be considered as the most important factor affecting early calf growth, it can be governed by capacity of the calf's stomach, composition of the milk, quality and amount of forage available. As before, age and season of birth will play an important role in establishing the interaction of forage intake with milk intake by determining to what extent the calf utilizes both feed stuffs for maintenance and growth.

Milk yield, measured by various techniques, is often associated with calf performance and the level of production is affected by many factors. Age of cow, persistency of production, peak lactation, forage consumption, season of year and other environmental influences play a large role in total milk production performance. Persistency, generally associated with cow age, can be utilized in measuring calf milk intake, peak production relative to calf age and average milk intake. Forage intake of the cow also affects milk production by its association with grazing intensity, forage quality in relation to intake, digestible energy of the forage and milk or composition of the milk itself.

The lactation curves of beef cattle have been reported in little research, with little work being conducted regarding the factors that affect the shape of the lactation curve in its relation to calf performance. Are heavier producing cows with less persistency producing a heavier calf at weaning or are the cows which are more persistent in milk production throughout lactation producing heavier weaning calves?

The purposes of this study were: (1) to determine intake of both forage and milk, (2) to measure the utilization of forage and milk for maintenance and growth, and (3) to determine the relationship between shape of lactation curve and weaning traits of calves grazing high or low quality pastures.

CHAPTER II

LITERATURE REVIEW

Much research has been conducted in the area of milk production in beef cattle and its relationship with various growth characteristics as exhibited by the calf. Since both genetics and environment play a role in calf growth, many researchers have reported varying results in the study of beef cow lactation performance, forage consumption by the cow-calf pair, calf milk consumption and its influence on forage and creep feed intake by the calf.

Little research has been reported on the relationship of milk intake and forage intake on calf growth. In addition, little has been reported on how the beef calf utilizes its dam's milk as a supplement to forage consumption during latter stages of lactation. Also, if allowed to supplement milk and forage consumption with a particular creep feed, to what extent does the calf utilize each of these nutritional constituents?

There have been various results reported pertaining to the descriptive methods of lactation curves and their importance in determining both persistency of milk production and correlations of milk production with various calf growth characteristics. In the determination of milk production, much conflict is reported in the area of sampling interval within a lactation, accurate estimations of milk yield, physiological versus induced milk letdown, etc.

This literature review will be concerned with the review of: (1) the construction of lactation curves, (2) how lactation curve shape

is related to calf performance, (3) milk, forage and creep feed utilization by the calf, and (4) correlations of these variables during the course of lactation.

I. LACTATION CHARACTERISTICS OF COW

A. Development and Construction of Lactation Curves

Many methods have been developed for the purpose of constructing lactation curves (Wood, 1969; Kellogg et al., 1977; Wood, 197u; Schaeffer et al., 1977). These methods are sometimes conflicting in terms of variables utilized in specific formulas. Wood (1976) utilized the records of 859 Holsteins to develop the formula:

$Y_t = Ae^{-ct}t^b$ where,

Y_t = milk yield at a particular time, t

t = time (a specific interval)

A = initial rise in lactation

b = associated with pre-peak curvature

c = decay rate or decline in lactation following peak production

e = logarithmic function

Particular attention was made in regard to seasonality, parity and month of calving. The researcher reported a significant ($P < .001$) variation between months with lactation yields averaging 4.0 kg/day at peak lactation. Variation with parity was highly significant ($P < .001$) with the third parity having the highest peak lactation in terms of kg/day. It was also reported that seasonality, associated with the "spring hump," should be considered a bias in the development of lactation curves and that the previously mentioned formula should be rewritten:

$Y_{nk} = A\ n^{b}e^{-cn}f_{n+k}$ where,

f_{n+k} = adjustment factor for a particular calving month

Wood (1974) also reported further variations in lacatation curves which were due to significant ($P < .01$) variations in lactation yield estimated prior to peak lactation at about three months postpartum. Schaeffer and Burnside (1976) also reported a variation ($P < .05$) with season, especially as parity increased, to about seven years of age. The researchers suggested that the shape of the lactation curve might vary from one geogrphic region to the next and can possibly be considered a bias when shape determinations are made. Kellogg et al. (1977) used the model:

$Y_i = \beta_1 t_i^{\beta_2} e^{-\beta_3 t_i} + e$ where,

β_1 = associated with peak lactation

β_2 = associated with the rising portion of initial lactation

β_3 = decline or decay rate succeeding peak lactation

This model is in contrast with the model utilized by Wood (1964) in that the researchers suggest more variation is accounted for regarding individuality of lactation curves prior to peak lactation. They reported significant ($P < .005$) variation among cows in a comparison of first lactation versus second, third and fourth lactations. Regarding persistency, the researchers reported that lactation curves representing the first parity were flatter and more persistent while later lacatations were associated with lactation curves achieving higher peak heights and more rapid decay rates. Wood (1977), using the previously developed model, reported a 40% variation ($P < .05$) in lactation curve shape due to actual stage of lactation in relation to milk yield.

Shaeffer et al. (1977) utilized three dissimilar methods for lactation curve description: (1) non-linear model:

$$Y_{ij} = A \exp(-\beta(i-t_0))\,[1-\exp(-B(i-t_0))]/B \exp(E_{ij}) \text{ where,}$$

Y_{ij} = lactation yield on the i^{th} day of the j^{th} cow

t_0 = "lag time," or prepartum lactation

B = rise in lactation

A = peak production

β = decay rate or decline after peak lactation

(2) multiplicative factor method commonly used with cumulative yield records, and (3) linear regression method utilizing total lactation records. These models were compared for three time periods:

(1) increase in production, postpartum

(2) peak production

(3) decline in production following peak lactation

The researchers reported that the multiplicative and linear regression procedures tends to overestimate 305-day lactation yield while the non-linear model tends to underestimate it. But, the non-linear model was more accurate ($P < .01$) in predicting lactation yield after 60 days postpartum.

Although the formulations above are similar in regard to measurable points on the lactation curve (initial rise, peak height and decline following peak of lactation), there are other factors than parity, seasonality, stage of lactation and persistency which determine how the shape of the lactation curve is expressed. It must be noted here that both age of dam and variation of lactation prior to peak height are important sources of variation in regard to their influence on shape of

the lactation curve. Further, little research has been reported pertaining to how the shape of the lactation curve determines preweaning performance traits and growth patterns in accordance with the association of particular points on the lactation curve with gain.

B. Factors Relating Lactation Characteristics of Beef Cattle

1. Total lactation. Utilizing 15 cows each of Angus, Charolais and Hereford breeding, Melton et al. (1966) studied milk production in its relation to calf gain. Total lactation yields for the three breeds were: 664 kg (Angus), 684 kg (Charolais) and 581 kg (Hereford). The researchers also reported that 5.2 kgs of milk were required for each additional kg of additional gain by the calf. Dawson et al. (1960) reported a range of total lactation from Shorthorn beef cows of 1143.0 to 2813.0 kg which is in direct contrast to that reported by Melton et al. (1966), possibly due to breed differences and statistical significance in reference to Dawson et al. (1960).

2. Mean lactation yield. Dickey et al. (1970) compared mean lactation records of 119 Angus and 105 Hereford cows and reported values of 2.58 $\pm$ 0.11 and 2.54 $\pm$ 0.11 kg/day, respectively, with mean yield significantly ($P < .01$) affected by lactation day and weigh date at final collection. In similar studies, Jeffrey et al. (1971) reported values measured through the injection of oxytocin to be 6.11 $\pm$ 1.75 and 5.12 $\pm$ 1.86 kg/day, respectively. These values are appreciably higher when compared to values reported by Dickey et al. (1970), possibly due to a difference in estimation method (calf suckle versus oxytocin injection). Kress and Anderson (1974) utilized the calf suckle technique and reported

a mean milk yield value of 7.3 kg/day which decreased to about 1 kg/day at 195 days of lactation. The variation in mean milk productions reported are possibly due to milk production estimation technique, sampling interval during a single lactation, breed and other factors.

3. Peak lactation. Melton et al. (1966) reported a value of 77 days postpartum to peak lactation with cows five years of age and older having lactation curves with higher peak values when compared to younger cows. This is in agreement with studies performed by Spike and Freeman (1967) in which peak lactation occurred at about two months postpartum. Also, Totusek et al. (1973) reported similar results of 7 weeks to a peak lactation of about 6.6 kg/day. In contrast, Kress and Anderson (1974) utilized 89 Hereford cow-calf pairs to establish a peak lactation at about 20 days postpartum. The researchers indicated that this value did occur on the first milk production estimate recorded for that particular year.

4. Persistency of lactation. Rollins and Guilbert (1954) studied the growth of Hereford calves from birth to 240 days in a seven-year study and reported that a greater persistency in lactation is associated with younger first or second calf females which results in greater calf gains from four to eight months of age. Also, the researchers indicated that the more persistent curves tend to have lower average milk productions. In similar studies, Christian et al. (1965) reported values indicating that two year old dams were more persistent in their milk production when compared with cows four years and older in age with the younger cows giving 4.7% more of their total milk from 60 to 240 days postpartum.

Spike and Freeman (1967) indicated that the lowest total milk production resulted from the youngest cows, but they were more persistent throughout the lactation period. Boggs et al. (1980) concluded that calves consumed more milk ($P < .05$) during peak lactation and that milk decreased as stage of lactation increased ($P < .05$) after peak lactation. A general trend for lactation characteristics was reported by Lamond et al. (1969) in which the lactation curves of 62 cows were compared in regard to lactation performance. The researchers reported that 46 cows had a significant linear decline in milk production as lactation progressed while 14 of these cows had both linear and curvilinear portions associated with their lactation curves. The cows which had linear components in their respective curves were generally associated with being higher in milk production or total yield.

Although the variables mentioned coincide with many variables associated with calf gain and performance, the elements of mean milk production, total lactation, peak lactation and persistency, along with their corresponding values, are measures of lactation yield that effect how the shape of the lactation curve is determined.

II. MILK AND FORAGE UTILIZATION FOR CALF GROWTH

A. Milk Intake and Its Effect on Preweaning Performance

1. Rate of gain at various times. Many researchers have reported similar results in regard to the amount of milk required for its conversion to weight gain (Drewery et al., 1959; Dawson et al., 1960; Neville, 1962; Christian et al., 1965; Melton et al., 1966; Hohenboken et al., 1973; Reynolds et al., 1978). Values have also been reported regarding

the correlation of lactation or milk intake to rate of gain with values ranging from .30 to .90, depending on the stage of lactation.

Drewery et al. (1959) studied the lactation records of 48 Angus cow-calf pairs and reported average lactation estimates associated with milk/kg addition gain during the first, third and sixth month of lactation. Average milk production (milk/gain) figures were 6.4 (5.67), 7.26 (4.90) and 4.08 kg/day (2.86 kg milk/kg gain) for the three respective time periods. These figures might possibly contain a bias since the researchers indicated that non-milk inputs were not considered in this study. Utilizing lactation records of 30 Shorthorn cows over a six-year period, Dawson et al. (1960), reported positive correlation coefficients ranging from .40 to .50 for the association of rate of gain with average milk intake. These values will tend to vary with the stage of lactation. Neville (1962) utilized three different nutritional levels fed to 135 Hereford cows to determine how nutritional level affected lactation and calf gain. The three levels considered are:

Level 1: grass silage + cottonseed meal

Level 2: corn silage + cottonseed meal

Level 3: corn silage + cottonseed meal + limited pasture

Kilograms of milk/kg addition gain values ranged from 5.67 for Levels 1 and 2 to 10.66 for Level 3, tending to indicate that, as nutritional level of the cow increased, a larger quatity of milk was required for additional gain by the calf. Milk was also reported to be less associated with gain as lactation proceeds. Christian et al. (1965) utilized the eight independent variables of birth weight, milk 0 - 60 days, milk from 60 - 240 days, butterfat 0 - 60 days, butterfat 60 - 120 days, creep TDN,

calf sex and weaning weight of the dam to account for 74% ($P < .01$) if the variation in weaning weight with milk production and sex of calf being most important. Melton et al. (1966) reported figures similar to Drewery et al. (1959) and Neville (1962) in regard to kg milk/kg added gain (5.2). Hohenboken et al. (1973) reported a positive correlation between size at weaning and gain during lactation, but a significantly higher correlation ($P < .01$) between size at birth and gain during lactation, possibly due to a part/whole relationship between the two variables in question. Reynolds et al. (1978) utilized British, Zebu and Zebu cross-breeds of dam to study the relationships of milk yield to early calf growth. The researchers reported correlation coefficients associated with gain and total milk yield ranging from .74 to .99, and that early milk yields were more highly correlated with average daily gain throughout lactation.

2. Weaning weight. Drewery and co-workers (1959) utilized bi-monthly intervals to determine if and when the variables calf age, birth weight and total milk production were important. At one month of lactation, age was a significant source of variation in determining weaning weight, but at three months of lactation, all three variables explained 77% ($P < .05$) of the variation in weaning weight. At six months of lactation, 66% of the variation ($P < .05$) was explained by calf age and total milk production to that period of time. Neville (1962) reported correlation coefficients between weaning weight and average daily milk production for 60, 120, 180 and 240 days of age of .74, 163, 159 and .66, respectively. Christian et al. (1965) determined that 78% ($P < .01$) of the variation in weaning weight was due to birth

weight, sex of calf and total milk production. This value is slightly higher than those reported by Rutledge et al. (1971) whereby a within herd, year and sex comparison revealed that total milk production was the most important determining factor of weaning weight with 60% of the variation ($P < .01$) being accounted for.

The presented studies revealed that lactation makes up the greatest variation in weaning weight, but little is reported as to what variables are responsible for the addition 20 to 40% variation of weaning weight. Correlation coefficients relate milk production as being highly associated with gain, but decreasing association generally occurs as lactation proceeds. This could possibly be due to non-milk inputs, milk inputs not generally associated wtih average lactation and non-controllable environmental influences.

3. Various correlations associated with milk production. Drewery et al. (1959) reported correlation coefficients between birth weight and average daily milk productions to be .43, .29 and .12 for the first, third and sixth month of lactation, respectively. Dickey et al. (1970) reported similar findings with correlations of average milk yield with calf birth weight and calf weight to be .35 and .52, respectively.

Kress and Anderson (1974) calculated correlation coefficients between average milk production and various traits associated with calf growth. These associations were:

1. Average milk production - milk production at various times .32
2. Average milk production - calf weight .49
3. Average milk production - future calf weight (to weaning) .59
4. Average milk production - calf condition score .33

Reynolds et al. (1978) reported correlation values relating total milk yield to May and June milk production estimates for winter calving cows to be .83 and .94 ($P < .01$), respectively, but correlations of calf age with milk yield were non-significant. These values would appear to be high since winter calving cows should be past their peak lactation and the association with total milk yield should be decreasing. In general, as lactation progresses the associations of lactation yields with various calf growth variables tend to decrease in both value and significance. It is logical to assume that all calf traits early in lactation should be highly correlated with average lactation, total lactation yield and lactation to peak height.

B. Forage Utilization for Weight Gain

Much variation has been reported in relation to the utilization and quality of different forage species. Variation is reported not only in terms of calf weight gain, but in chemical composition as it relates to consumption by the calf (Harrison et al., 1953; Van Soest, 1964; Burns et al., 1973; Thompson et al., 1973; Smith et al., 1976; Horn et al., 1979; Holloway et al., 1979).

Regarding chemical composition and selectivity, Harrison et al. (1953) utilized pastures containing dissimilar forage species:

(1) bluegrass, timothy and meadow fescue

(2) quackgrass, timothy, alfalfa and red clover

(3) quackgrass, timothy, alfalfa and red clover (less legume than in 2)

These pastures were grazed by 66 growing steers with the legume pastures being significantly higher ($P < .05$) in crude protein, ether extract,

minerals and crude fiber. Also, the researchers determined that the degree of selection was not related ($P > .05$) to forage dry matter. In similar studies utilizing bermudagrass fertilized at three nitrogen levels (67, 202 and 326 kg N/hectaire), Horn et al. (1979) determined the effect of forage quality, as determined by nitrogen level, on cow and calf performance and reported that the calves tended to select less digestible forages as nitrogen level increased while cows selected forage of similar quality, regardless of nitrogen level. Forage digestion trials were conducted in May and July of each year using chromic oxide as an indicator of intake. In May, forage chosen by the calves was highest ($P < .05$) in gross energy for the highest two nitrogen levels; whereas, in the July trial, the gross energy of the forages chosen by the calves tended to decrease with increased nitrogen levels. Thus, selectivity in the two reported studies was related directly to forage maturity and quality. Van Soest (1964) studied the effects of 11 forage species in relation to intake and quality. He reported a significantly high association ($P < .05$) between voluntary intake and either digestibility or chemical composition of the forage. Also, results indicated a significant correlation ($P < .05$) between lignin and voluntary intake of tall fescue. It was concluded that the voluntary intake in grasses is lower than that of legumes because of the amount of fibrous mass ingested and the maturing of the grasses in relation to an increased lignification of the cell-wall constituents.

Pertaining to gain on forage, Burns et al. (1973) evaluated four different pastures treatments in relation to calf performance. For the two time periods (Period 1: April 1 to May 31 and Period 2: May 31 to

September 30), calves grazing ladino clover-fescue pasture had significantly ($P < .05$) higher gains than those calves on either fescue or fescue-bermudagrass (6 kg/head more). In studies conducted by Thompson et al. (1973), three pastures comprised of (1) alfalfa-orchardgrass, (2) ladino clover-orchardgrass, and (3) ladino clover-Kentucky 31 tall fescue, were evaluated in terms of calf weight gain. During the three-year study, calf weight gains were significantly higher ($P < .05$) for calves grazing ladino clover-orchardgrass (12.2 kg/head more) when compared to gains on ladino clover-Kentucky-31 tall fescue with gains on alfalfa-orchardgrass being intermediate. Comparable average daily gains and weaning weights were reported by Smith and co-workers (1976) in research conducted using orchardgrass, fescue or fescue-legume pasture compositions. Values for average daily gain (weaning weight) were: orchardgrass, .81 (195); fescue, .58 (160); fescue-legume, .83 kg/day (194 kg.). The researchers concluded that overseeding fescue pastures with some form of legume would diminish a significant depression in performance with calves grazing straight fescue pastures. Holloway et al. (1979) utilized pastures comprised of either fescue-legume or straight fescue and reported increased gains of 18 kg/head for calves grazing fescue-legume when compared to calves grazing straight fescue (independent of milk intake). Average daily gains for the fescue-legume and straight fescue pastures were .84 and .76 kg/day, respectively. As a result, studies indicated that forage quality should be considered the most important factor in its relation to calf weight gain, especially during latter stages of lactation.

C. Milk and Forage Intake for Calf Growth and Performance

Little research has been performed on the interrelationship between milk and forage intake in regard to their utilization for calf growth (Burns et al., 1973; Garrigus et al., 1975; Wyatt et al., 1977; Boggs et al., 1980).

Earlier studies conducted by Burns et al. (1973) indicated that a "buffering" effect occurs by the cows in relation to allowance of the calf to make suitable gains through lactation when poor quality forage is present, thus making the calf more dependent upon the cow during critical or stressful months of forage production.

Garrigus et al. (1975) conducted studies with 40 two-year-old Polled Hereford cow-calf pairs which grazed either orchardgrass or Kentucky-31 tall fescue to determine the effect of forage quality on calf performance. Average milk production was significantly ($P < .01$) affected by treatment (6.85 kg for orchardgrass versus 4.10 kg for tall fescue) with milk production differences, measured by the calf suckle technique, being significantly greater ($P < .01$) in early lactation with cows grazing orchardgrass. Calves grazing orchardgrass consumed more ($P < .05$) digestible dry matter during the spring than did the calves grazing tall fescue throughout the remainder of lactation.

Wyatt et al. (1977) conducted trials involving cross-fostered calves which nursed either low (Hereford) or high (Holstein) milk producing dams. The cow-calf pairs grazed either tall grass range pasture or were confined to drylot with calves receiving supplemental feed. The cross-fostered Angus x Hereford calves on high milk producing dams consumed more milk ($P < .05$), weaned heavier ($P < .05$) and had higher gains

($P < .05$) than did calves nursing low milk producing dams, resulting in a 20% increase in weaning weight. Drylot calves (Angus x Hereford) on high producing dams had a 19% increase in weaning weight when compared with drylot calves on low producing dams. Charlois x Holstein range and drylot calves on high milk producing dams had a 23% and 22% increase in weaning weight over their low milk counterparts in each treatment, respectively.

In similar studies, Boggs et al. (1980) utilized 51 Polled Hereford cow-calf pairs to evaluate milk and forage utilization. Using chromic oxide as an external/ADL internal marker, they reported that calves at two months of age consumed .03 kg/day less grass for energy kilogram increase in milk. As lactation progressed, the replacement of milk with forage increases, resulting from a decrease in lactation and an increase in the utilization of forage. Also, milk production and past producing ability of the dam had the greatest effect on calf performance ($P < .001$). In the first two months of lactation, forage intake was negatively correlated with average daily gain (-.19), but at 60 to 150 days, additional forage tended to improve gain ($P < .10$) with each additional kilogram of forage making possible a .02 kg/day increase in gain.

The relationship of milk and forage intake in regard to patterns of use during lactation varies in many cases. The question arises in reference to how efficient calves are in the conversion of milk and forage to weight, especially when forages of different qualities are considered.

III. EFFECT OF CREEP FEED INTAKE ON THE UTILIZATION OF MILK AND FORAGE

A. General Associations of Creep Intake with Calf Performance

Early research dealing with creep feed intake reported values concerned with the relationship of creep feed intake to rate of gain (Marlowe and Gaines, 1958; Brown, 1960; Christian et al., 1965; Totusek, 1968).

Marlowe and Gaines (1958) studied the records of 4,166 non-creep fed calves with 2,007 creep fed calves and reported that season of birth was directly affected by feeding treatment. Non-creep fed calves born June to December grew about .05 kg/day slower ($P < .05$) than did the calves born February through March. The researchers reported that seasonality was the most highly significant variable ($P < .05$) due to creep feeding. Purebred Hereford and Angus cows bred throughout the year were utilized by Brown (1960) to study the effects of creep feed on calf growth rates. He reported a decrease in the advantage of season of birth with fall calves being lighter ($P < .05$) at each weigh period except at 240 days of age. Therefore, the effect of seasonality is generally corrected for with the supplementation of creep feed administered to fall calves.

Christian et al. (1965) reported correlations between creep feed intake and birth weight or rate of gain to be .38 and .27, respectively, for the time period from birth to 60 days of age. In general, creep feed intake should tend to increase with calves that were heavier at birth and exhibit a superior rate of gain.

Totusek (1968) studied the effect of creep feed intake on weaning weight by subjecting heifer calves to three dissimilar nutriton levels:

(1) weaning at 140 days, (2) weaning at 240 days, and (3) creep feeding and weaning at 240 days of age. At 240 days, the normal and creed fed heifers weighed 23.1 and 53.1 kg more ($P < .05$) than the early weaned heifers. But, the creep fed heifers did not maintain their advantage in weight over the normally weaned heifers at four years, a direct result of deposition of fat rather than muscle or a case of compensatory growth in the normally weaned heifers.

B. Relationship of Creep Feed Intake to Milk Utilization

Drewery et al. (1959) suggested that calves tend to compensate for low lactation yields in later stages of production by consuming more creep in the form of forage consumption. Holloway et al. (1975) indicated, that Holstein calves consumed less creep feed than Hereford calves due to an adequate supply of milk from their straightbred dams. In similar studies, Lusby et al. (1976) concluded that Holstein calves consumed less creep ($P < .05$) than Hereford x Holstein or Hereford calves with higher increases in milk and creep ($P < .05$) due to larger calf size. The Hereford calves consumed the least amount of milk ($P < .05$), but the highest amount of creep feed ($P < .05$). Also, on range studies, the Holstein calves consumed less forage than the Herefords ($P < .05$), due possibly to lactation yields or calf age. The low non-milk intakes by the grazing calves tended to decrease overall efficiencies, results indicating that the Hereford progeny were more efficient in the conversion of milk and non-milk inputs to weaning weight or average daily gain. Similarly, Marshall et al. (1976) reported that milk production accounted for 69% ($P < .05$) of the variation in creep feed intake with calves consuming more milk tending to consume less creep TDN.

C. Creep Feed Intake in Relation to Forage Intake

Crosthwait and co-workers (1978) reported that creep feed calves were heavier at weaning ($P < .02$), longer ($P < .10$) and taller ($P < .02$) than non-creep fed calves. Also, creep fed calves consumed less forage ($P < .10$) resulting in a 11.7% reduction in forage intake when compared to non-creep fed calves while both treatments had similar average daily gains ($P > .17$).

Hill et al. (1979) measured cow-calf performance on tall fescue or bluegrass-ladino clover pastures (with or without creep feed) and reported a conversion factor of 10 kg creep feed/kg added gain for all calves. Weaning weights of blue-grass-non-creep calves were 22.1 kg ($P < .05$) heavier than fescue-non-creep and only 10.6 kg lighter than calves on fescue-creep feed. Bluegrass-creep calves had weaning weights 17.9 kg heavier ($P < .10$) than bluegrass-non-creep fed progeny with bluegrass calves having higher average daily gains when compared to fescue fed calves. An indication that forage quality has a direct effect on the amount and utilization of creep feed for calf growth.

Stricker et al. (1979), studying the effect of creep feeding on fescue-legume pasture, reported that creep fed calves were 31.0 kg heavier ($P < .05$) for adjusted 205-day weaning weight than the non-creep fed calves, but the creep fed calves required 9.78 kg of additional creep feed for every kilogram of additional weight gain.

These results reveal that calves are replacing milk and forage in their diet with creep feed and that creep fed calves grazing pasture with abundant legumes do not utilize creep feed as efficiently as calves grasing a pasture of poorer quality.

IV. PATTERNS OF MILK COMPOSITION IN RELATION TO CALF GROWTH CHARACTERISTICS

Variation in the constituents of milk is widespread regarding the utilization of each component during the lactation period for calf growth and performance (Christian et al., 1965; Melton et al., 1966; Spike and Freeman, 1967; Rutledge et al., 1971; Hohenboken et al., 197; Totusek et al., 1973; Wood, 1976).

Christian et al. (1965) suggested that, due to a significant ($P < .05$) importance of butterfat production, a highly concentrated source of energy is required by the calf at an early stage due to the limited capacity of its stomach. The researchers also stated that butterfat and solids-non-fat production were more necessary to early calf growth than total milk production with butterfat percentages reported ranging from 3.5 to 4.5%.

Melton et al. (1966) utilized Angus, Charolais and Hereford cows and reported butterfat (total solids) values of 2.68 (11.31), 2.87 (11.73) and 2.82 (11.76) for the three breeds, respectively. The researchers indicated correlations between calf gain and yields of butterfat, solids-non-fat and total solids to be .31, .43 and .41, respectively, and that this was partially due to high correlations with lactation yield. In contrast, Rutledge et al. (1971) reported that correlations between milk constituents and weaning weight were small and non-significant.

In related studies, Totusek et al. (1973) determined that correlation coefficients of calf weight at 210 days with total fat and total solids were .77 and .80, respectively, and that variation within each component was highly significant ($P < .01$), but correlations of calf weight at 210 days with percent butterfat and percent solids were low

($P > .10$). Hohenboken et al. (1973) reported correlations of milk, total butterfat and percentage butterfat with gain to be -.35, -.39 and .19, respectively.

In studies involving specific milk constitutent patterns, Spike and Freeman (1967) reported a decrease in percent composition of milk butterfat and solids-non-fat with the progression of lactation and, as lactation proceeded, both decreased until a minimum value was reached at about the third month followed by an increase to the seventh and eighth months. In general, milk butterfat tends to appear as completely opposite to lactation with their respective curves being mirror images of one another.

Wood (1976) sutdied the variation of milk constitutents during lactation and indicated that, as lactation proceeded, milk protein decreased and milk butterfat percentage increased with a fat/protein ratio at week one being 1:16 and at week forty-four being 1:37. Seasonality of production accounted for the most variation ($P < .05$) in milk fat and protein percentage associated with month of calving. Lowest percentage of both fat and protein occurred at week 8 and 11, respectively, with the rise in lactation resulting in a decrease in milk fat percentage.

Although the values and patterns of the various milk components are reasonably similar, the associations of these components with factors related to calf growth and performance are conflicting in terms of numerical value and significance. It can be assumed, though, that the association of lactation yield with the milk constituents is extremely high and this association varies as lactation progresses.

CHAPTER III

UTILIZATION OF FORAGE AND MILK BY ANGUS CALVES GRAZING HIGH OR LOW QUALITY PASTURE

I. SUMMARY

The estimation of milk and forage digestible energy intake was performed on a total of 158 Angus calves during a four year period beginning in 1977. The calves were born in January through March of each year with weaning occurring in mid-October at about 240 days of age.

The calves grazed pasture of either high quality, consisting of red clover, ladino-white clover, Korean and Kobe lespedeza, bluegrass and Kentucky-31 tall fescue, or low quality which consisted totally of Kentucky-31 tall fescue.

Milk productions were performed by the calf suckle technique on a monthly basis from April through October each year. Milk intakes were estimated by evaluating functions fitted through points obtained by this technique. Forage intake and digestibility was estimated by the ADL (internal)/chromic oxide (external) indicator technique using 5-day preliminary and 5-day collection periods with forage DE being estimated from dry matter digestibility. These trials were conducted beginning about June 26, July 31 and September 15 each year (average calf age of 109, 142 and 192 days, respectively). Milk DE was estimated from milk butterfat and dry matter samples obtained by total milk-out procedures during the 4th, 5th and 6th months of lactation. Forage DE and (milk

DE) intakes for the June, July and September trials were 9.8 (4.5), 15.8 (4.0) and 19.8 (3.3) Mcal DE/day for calves on high quality pasture and 6.7 (3.9), 9.6 (3.4) and 14.8 (2.8) Mcal DE/day for calves on low quality pasture, respectively. Values for weight and gain during the same three time periods were 141 (.77), 167 (.78) and 204 kg (.79 kg/day) for calves on high quality pasture and 132 (.70), 156 (.70) and 189 kg (.70 kg/day) for calves on low quality pasture.

Increases in milk DE intake were associated with larger increases in weight and average daily gain for the calves grazing low quality pastures than for calves on high quality pastures. In respect to calves on high quality pastures, as lactation proceeded, increases in forage DE intake were associated with larger increases in weight and increases in milk DE intake were associated with smaller increases in weight. Canonical correlations with calves on high quality pastures indicated that, the older calves depended more upon forage for growth while the young calves were more dependent upon milk. For calves grazing low quality pasture, all calves were more dependent upon milk rather than forage for growth and performance.

II. INTRODUCTION

Few researchers have reported findings on the effects of levels of milk production and forage consumption on the growth rate and performance of beef calves. Milk production can generally be affected by age of cow, seasonality and forage while calf performance is attributable to age of calf, daily milk production, capacity of the stomach relevant to age and composition of the milk itself (Rollins and Guilbert, 1954; Drewery et al., 1959; Christian et al., 1965).

Many researchers have reported findings in regard to what effect forage quality has upon calf gains with many researchers reporting significant effects of increasing gains with increasing pasture quality (Wyatt et al., 1977; Holloway et al., 1979; Hill et al., 1979). The purpose of this study was to determine to what degree beef calves utilize milk and forage for growth when grazing either tall fescue (low quality) or tall fescue-legume (high quality) pastures.

III. MATERIALS AND METHODS

A. Pasture Management

A four year project was conducted to study forage and milk intake and their utilization by calves allotted to two levels of forage quality.

The study involved the use of four pastures of about 8.0 ha each. During the initiation of the study in 1977, two pastures were comprised of high quality forage, and two pastures were comprised of low quality forage with the same management system used until the conclusion of the trial in 1980.

High quality forage pastures (Treatment 1) consisted primarily of red clover (Trifolium pratense L.), ladino white clover (Trifolium repens L.), Korean and Kobe Lespedeza (Lespedeza stipulacea Maxim), Kentucky-31 tall fescue (Festuca arundinacea Schreb.) and bluegrass (Poa pratensis L.). From year to year average composition percentages in the high quality pastures were 60-70% tall fescue and 30-40% legume. The two low quality forage pastures (Treatment 2) consisted of Kentucky-31 tall fescue (Festuca arundinacea Schreb.) with a small contamination of Dallis grass (Paspalum dilatatum Poir.) occurring in 1980. General renovation of the pastures occurred each spring at which time the high

quality pastures were reseeded with red and ladino white clover.

Cattle were grazed on their respective pastures year-round and were fed hay, ad libitum, which was harvested from the respective pastures in June of each year. High quality pastures were kept in a vegetative state each year by clipping at various times while the low quality pastures were allowed to grow, after harvesting the hay, and remained at a more mature vegetative state. Stocking rate was maintained at about .8 ha/cow-calf pair.

B. Animal Management

Twenty mature Angus cows, bred to calve in January, February and March of each year, were allotted to one of the two pasture treatments with a total of 40 Angus cow-calf pairs grazing the four pastures involved. Two calves expired during the span of the study which adjusted the total number of calves to 158 over the four year study. Cows were five to ten years of age with as many cows as possible being replaced each year. But, cows that remained on the study more than one year remained on the pasture of original allotment. Bulls were placed in the pastures on April 15 each year and removed on June 15 to facilitate a 3-month winter calving season with cow size being confounded with pasture to facilitate the mating of large cows to large bulls. Animals were rotated in their respective quality pastures to expose them to all species in the pasture treatment. Bull calves were castrated in April of each year, and all calves were weaned in mid-October at an average age of 240 days after which calves were taken to another location for postweaning and back-grounding studies.

C. Forage Digestibility Trials

During the months of June, July and September of each year (one trial/month), forage digestibility and intake trials were conducted using an ADL (internal)/chromic oxide (external) marker which was administered in gelatin boluses. During each trial a 5-day preliminary period preceded the 5-day collection period whereby calves were bolused twice daily at 0700 and 1600 hours. The amount of chromic oxide administered/bolus in 1977, 1978, 1979 and 1980 was 10.0, 8.8, 4.0 and 4.0 grams, respectively. During the 5-day collection period, fecal samples were retrieved either in the pasture or rectally at the time the animals were bolused. Fecal samples were frozen until analysis could be performed at which time the samples were thawed, dired in a 60°C oven for 7-10 days and then ground in a Wiley Mill using a 40-mesh screen to facilitate analysis. Acid detergent fiber and acid detergent lignin analyses were performed by methods described by Van Soest (1963). Dry matter and ash analyses were determined through procedures described in AOAC (1970), while Cr_2O_3 analysis was performed using an atomic absorption-emission spectrophotometer. In addition, forage samples were taken bi-weekly from pastures from April to October of each year with samples dried in a 60°C oven, ground in a Wiley Mill (40-mesh screen) and analyzed for dry matter (AOAC, 1970), acid detergent fiber and acid detergent lignin (Van Soest, 1963). Dry matter indigestibility was calculated by the following procedure:

$$\frac{\%\ \text{ADL (pasture)}}{\%\ \text{ADL (feces)}} \times 100$$

Dry matter digestibility was calculated as dry matter indigestibility subtracted from 100. The following is a composite of all calculations required to obtain data compared by least-squares means:

1. Dry matter intake (kg/day) = $\frac{\text{chromium fed}}{\text{chromium feces}} \div$ dry matter digestibility

   where, chromium (feces) = (Cr/68.42)/100

2. Digestible dry matter intake (kg/day) = dry matter intake x dry matter digestibility.

3. Forage DE (Mcal/kg DE) = -.168 + (.047 x DMD x 100) (Heany and Pigden, 1963).

4. Forage DE intake (Mcal/day) = dry matter intake x forage DE (Crampton and Harris, 1961).

5. Calf weight (kg) = B_0 calf + (B_1 calf x age) + (B_2 calf x age x age).

6. Change in weight (kg/day) = $\frac{\text{previous weight - present weight (for a particular day)}}{\text{number of days between weighings}}$

7. Milk dry matter intake (Mcal/day) = milk production x (total solids) x % DM.

8. Milk DE (Mcal/kg DE) = (41.84) x (milk fat x 100) + (22.9) x (SNF x 100) - (25.58) x (.9, digestibility of milk)$_2$ x 1/453.6 (Tyrrell and Reid, 1965; NRC, 1976).

9. Milk DE intake (Mcal/day) = (milk production x milk DE).

10. Milk production = $Ae^{-ct_b t}$ (Wood, 1976)

    where, A = associated with initial rise in lactation curve
    b = associated with pre-peak curvature
    c = associated with post-peak curvature
    e = natural logarithmic function
    t = time (30-day intervals)

D. Milk Production

Lactation yields were taken monthly by the calf suckle technique starting in April and proceeding through October with six estimates taken in 1978 and 1979 and seven estimates measured in 1977 and 1980. Calves were separated from their dams at 1800 hr preceeding the day of estimation with cows being placed in their respective pastures and calves held in a central holding area. At about 0600 hr the following day, calves were

weighed and then paired with their dams upon which they were allowed to nurse. After nursing was completed, calves were again separated from their dams and reweighed from the difference in weight assumed to be the 12-hour milk production. This procedure was repeated at about 1800 hr of the same day and the two 12-hour estimates totaled to achieve a 24-hour milk production measurement. Milk intake and forage trials were performed at different times during the months of June, July and September to allow for minimum stress and to allow for normal grazing during the forage intake and digestion trials.

Milk samples were taken in the months of June, July and August each year by machine milk-out procedure. Ten cows from each pasture treatment were milked on the first day of the two-day procedures followed by the remaining 10 cows of each pasture type on the succeeding day. Cows were given about 20 I.U. of oxytocin (Pitocin) intramuscularly and were then confined to a squeeze chute where their udders were evacuated with a milking machine. Cows were separated from their calves for about three hours prior to milking. Milk samples were preserved with and analyzed for butterfat (Mark III Milk-O-Tester) and dry matter (AOAC, 1970).

IV. STATISTICAL ANALYSIS

Analysis of variance procedures were performed on the variables forage dry matter digestibility (DMD), forage DE (FDE), forage dry matter intake (DMI), digestible dry matter intake (DDMI), forage digestible energy intake (FDEI), milk production (MP), calf weight, change in calf weight, milk dry matter intake (MDMI), milk solids-non-fat (SNF), milk fat (BF), milk digestible energy (MDE) and milk digestible

energy intake (MDEI). Utilizing the model Y = year, treatment (pasture quality), sex, calf birth date (Julian day), trial, least square means and residual standard deviations were calculated for each variable.

Relationship of growth, milk and forage intake was studied through regression procedures using the model Y (changes in weight = b_0 (year, sex, calf birth date (Julian day) + b_1 (milk DE intake) + b_2 (forage DE intake) to construct three-dimensional graphs depicting milk and forage intake across treatment (pasture quality) and trial and their effect upon change in weight.

Correlation coefficients were calculated for all characteristics of milk production, lactation curve and weaning data. Milk intake measurements to be utilized for correlation comparisons were calculated at 30-day intervals from milk intake at day 0 to day 210. Lactation curve characteristics were determined by milk production data with the equation: $MP = Ae^{-ct}t^{b}$ (Wood, 1976). All correlations were considered significant if $P < .05$ or less. All variables were corrected for year, sex and calf birth date to accomodate equal comparisons.

Pathway coefficients (Steel and Torrie, 1960) were calculated (Figure 1) using previous calculated partial b values to aid in determining what proportions of milk DE intake and forage DE intake were utilized for weight and change in weight or average daily gain. In addition, correlation coefficients were calculated for the following variables (Figure 1):

(1) DMD (forage) - milk DE intake

(2) DMD (forage) - forage DE intake

(3) Milk DE intake - forage DE intake

(4) Weight - change in weight

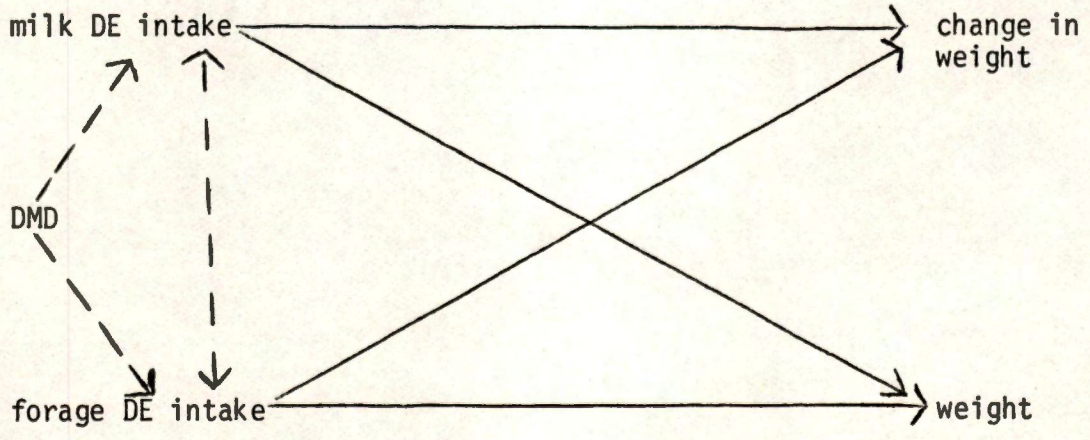


Figure 1. Pathway coefficients for intake variables (diagram).

Least-squares means were determined through analysis of variance using the model $Y = b_0$ (year, sex, calf birth date (Julian day) + b_1 (milk DE intake) + b_2 (forage DE intake). The least-squares values were then determined to distinguish the proportions of milk DE and forage DE intake being utilized for weight and change in weight with comparisons made across pasture quality and trial.

A composite of overall comparison was performed through the use of proxy variables to determine how forage DE intake is affected by milk DE energy intake and forage DE concentration. Digestible energy was utilized as a substitution for treatment and trial and weight became a proxy for trial for the purpose of combining the particular data across these associated variables for a composite comparison. Forage DE intake was utilized as the dependent variable with the model $Y = b_0$ (year, sex, calf birth date (Julian day), weight) + b_1 (milk DE intake) + b_2 (milk DE intake)^2 = b_3 (forage DE) + b_4 (milk DE intake * forage DE) + b_5 (milk DE intake)^2 * forage DE).

V. RESULTS AND DISCUSSION

A. General Characteristics

Weights of calves increased in a linear fashion, but as forage dry matter digestibility increased, the weight curves tended to become more curvilinear. A significant difference occurred between treatments ($P < .0001$), trials ($P < .0001$) and the treatment by trial interaction ($P < .0005$) for the prediction of forage dry matter digestibility. Values for DMD for the high and (low quality) treatments with each trial (1, 2 and 3) were .67 (.62), .71 (.62) and .66 (.60), respectively.

Forage dry matter intake (kg/day) and digestible dry matter intake (kg/day) followed the same pattern occurring with all forage associated variables with values increasing in relation to time. Calves grazing high quality pastures consumed about 1.1 kg/day more ($P < .0001$) forage DM than calves grazing low quality pastures (Table 1). Also, calves grazing high quality pastures consumed about .9 kg/day more ($P < .0001$) forage digestible dry matter when compared to calves grazing low quality pastures. Thompson and Holdaway (1954) reported an increase in performance with calves grazing a legume-fescue pasture over calves grazing only tall fescue.

Forage DE (Table 1) had significant differences in treatment, trial and treament by trial with the addition of year explaining 68% of the variation in forage DE. Slightly more variation was apparent within the high quality treatment for forage DE, possibly due to a variation in presence of legume from year to year. Forage DE intake was significantly higher ($P < .0001$) for calves on high quality pastures with an additional variation ($P < .0001$) occurring across trial. Values for the high and (low quality) pastures across trial were 9.8 (6.7), 15.8 (9.6) and 19.8 (14.8) Mcal/day, respectively. An increase from Trial 1 to Trial 3 is presumed to be associated with the calf's ability to consume additional forage as time progresses. Also, as lactation decreases, the calf has to consume additional non-milk nutrients to provide for maintenance and growth. Boggs *et al.* (1980) reported a slight negative correlation (-.10) between forage intake and average daily gain during the first 2 months of lactation, but as lactation progressed, the association between the two variables became more positively correlated.

Table 1. Least-squares means of forage and milk variables

	Treatment 1			Treatment 2			Residual standard deviation (each model)	Level of Significance		
	Calf trial			Calf trial					Calf	
	1	2	3	1	2	3		Treatment	trial	T * C
Dry matter digestibility (x 100, %)	.67257921	.70876194	.66066337	.61823355	.61822408	.60076082	.04287720	.0001	.0001	.0005
Forage digestible energy (Mcal/kg DM)	2.99312231	3.16318110	2.93711785	2.73769769	2.73765319	2.65557586	.20152282	.0001	.0001	.0005
Dry matter intake (kg/day)	3.13720222	4.91395221	6.65100245	2.38675774	3.46417394	5.52034460	1.27728651	.0001	.0001	.0593
Digestible dry matter (kg/day)	2.18786468	3.53363485	4.45324344	1.50976914	2.17380778	3.33875326	.92833696	.0001	.0001	.0057
Forage digestible energy intake (Mcal/day)	9.7559140	15.7825398	19.8128757	6.6949396	9.6349153	14.7647224	4.15196469	.0001	.0001	.0050
Milk production (kg/day)	7.11898257	6.30020675	5.20092487	5.22689700	5.42541340	4.39897481	1.69062718	.0001	.0001	.9704
Calf weight (kg)	140.862053	167.248922	203.989276	132.204402	155.543673	188.347881	20.51367185	.0001	.0001	.3358
Change in calf weight (kg/day)	.77183189	.78255379	.78745647	.6978817	.69782156	.69405353	.10331510	.0001	.8625	.7163
Milk dry matter intake (kg/day)	.84924162	.75422471	.62797851	.73474941	.64109201	.52282433	.22504013	.0001	.0001	.9819
Milk solids not fat (x 100, %)	.07939838	.07939838	.07938282	.07983309	.07983309	.07989784	.01168556	.6843	.9998	.9994
Milk fat (x 100, %)	.04127630	.04127630	.04117585	.03984109	.03984109	.03985072	.00722641	.0937	.9981	.9971
Milk digestible energy (Mcal/kg DM)	.64113530	.64113530	.64023487	.63099430	.63099430	.63136561	.07520824	.1776	.9994	.9964
Milk digestible energy intake (Mcal/day)	4.52461063	4.02135415	3.34620729	3.85789394	3.36501958	2.74041131	1.16454144	.0001	.0001	.9713

[a]Model $\hat{Y}$ = (year, sex, birth date (Julian date), trial) + all two- and three-way interactions.

Calf weight (kg) increased in a linear fashion with significant ($P < .001$) differences occurring with treatment and trial. Treatment differences can readily be explained by differences in forage intake and quality and a higher ($P < .0001$) milk intake. Trial differences occur because the calves are gaining as lactation progresses with the model accounting for 71% of the variation in weight. Change in weight or average daily gain varied significantly only across pasture quality with little variation occurring with trial or treatment by trial. Although calf size tended to vary within pasture quality, the calves were still able to make similar gains on the same type forage. Treatment differences were due largely to differences in forage quality and milk and forage intake. Milk intake (production, Table 1) and milk dry matter intake varied significantly ($P < .0001$) with pasture quality and trial with the addition of year in each model accounting for 72 and 76% of the variation in the two variables, respectively. Milk dry matter intake decreased more from Trial 2 to Trial 3 than from Trial 1 to Trial 2, possibly due to the increase in forage DE intake as related to the calf's ability to consume and digest additional forage as time progressed. Wyatt et al. (1977) reported that an increase in milk production resulted in a decrease in forage intake; thus, as lactation progressed, an increase in forage intake should occur relevant to decreased lactation yields.

Milk DE varied little with treatment or trial, due largely to the similar non-significance found in the variation of milk butterfat and solids-non-fat. Treatment and trial differences did occur for milk DE intake while milk DE intake decreased as lactation progressed. Wyatt

et al. (1977) and Boggs et al. (1980) reported a decrease in milk intake as lactation progressed, a relationship that was associated with an increase in forage dry matter and DE intake.

B. Comparison of Forage DE Intake and Milk DE Intake as Sources for Growth

The influence of forage and milk DE intake on rate of gain is shown in Figures 2-7. These graphs, constructed utilizing partial b values (Table 2), represent each trial within a treatment. Direct comparisons among the figures cannot be made because the units of minimum and maximum values between figures differ. Therefore, the partial b values must be analyzed for the comparison of slopes of the lines as each variable affects change in weight. In Trial 1, the interaction of forage DE intake with treatment (Table 2) was significant ($P < .05$), but the milk DE intake by treatment interaction was non-significant ($P > .05$). For Trial 2, forage DE intake and milk DE intake interacting with treatment proved significant ($P < .05$) while neither were significant during Trial 3 ($P > .05$). Preliminary analysis of the model used in the prediction of change in weight indicated that, for Trial 1, milk DE intake was more important ($P < .001$) for change in weight than was forage DE intake ($P < .05$) for both treatments. Also, during Trial 2, both milk DE intake and forage DE intake were important ($P < .001$) for change in weight in both treatments. Trial 3 analysis revealed that for Treatment 1 (high quality pastures), forage DE intake was more important ($P < .05$) for change in weight than was milk DE intake, but milk DE intake was slightly more important than forage DE intake ($P < .06$) for change in weight in Treatment 2 (low quality pastures). By close inspection of both the partial b values (Table 2) and the three-dimensional figures across

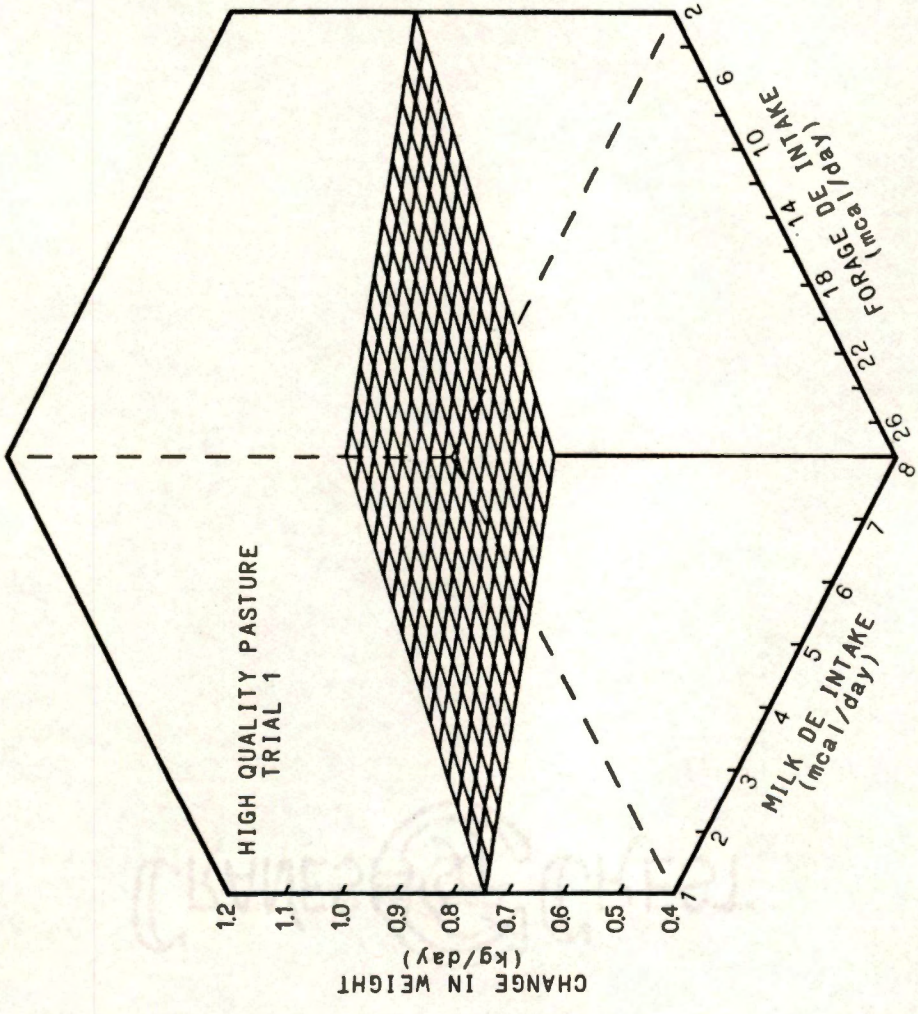


Figure 2. Utilization of milk DE and forage DE for change in weight (high quality pasture, Trial 1).

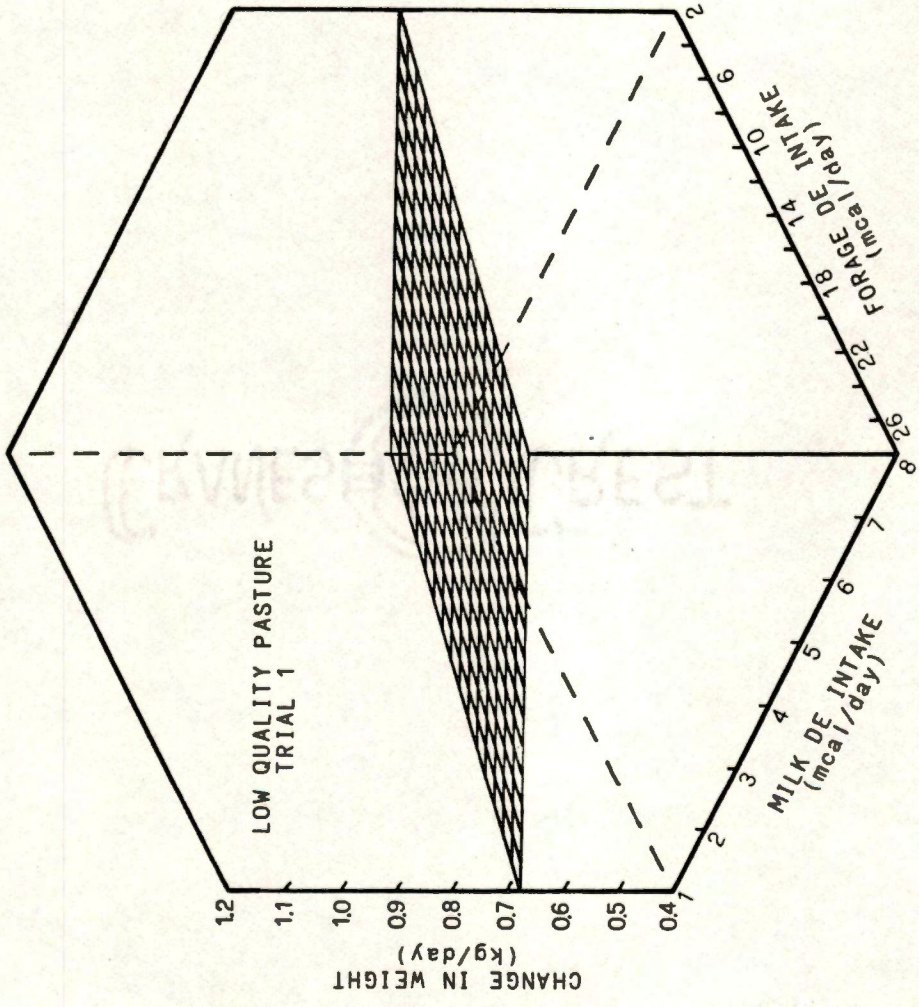


Figure 3. Utilization of milk DE and forage DE for change in weight (low quality pasture, Trial 1).

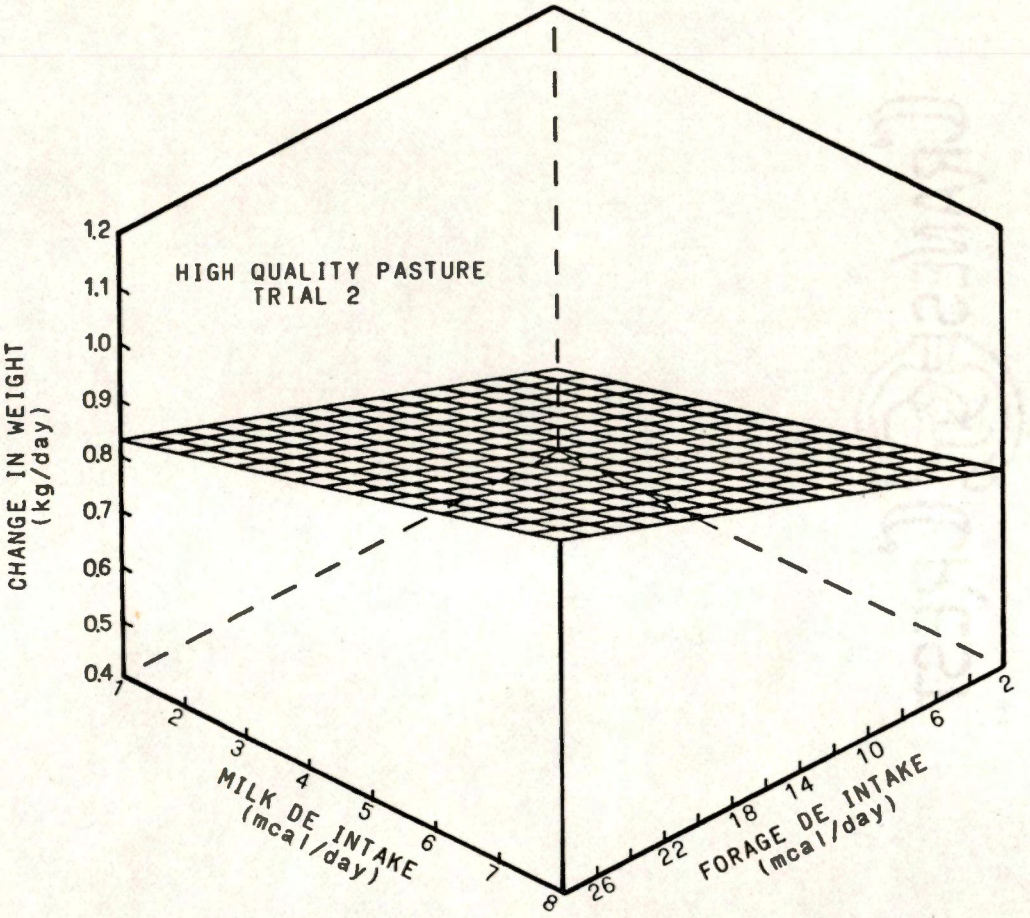


Figure 4. Utilization of milk DE and forage DE for change in weight (high quality pasture, Trial 2).

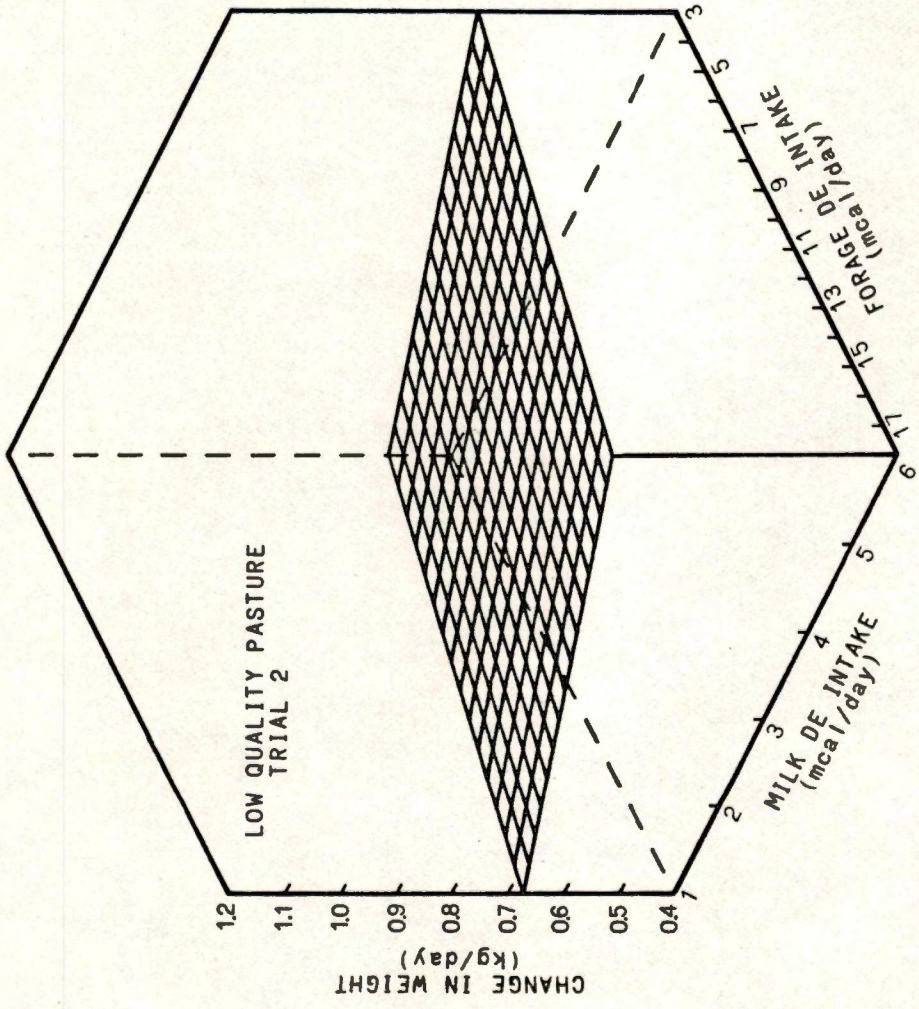


Figure 5. Utilization of milk DE and forage DE for change in weight (low quality pasture, Trial 2).

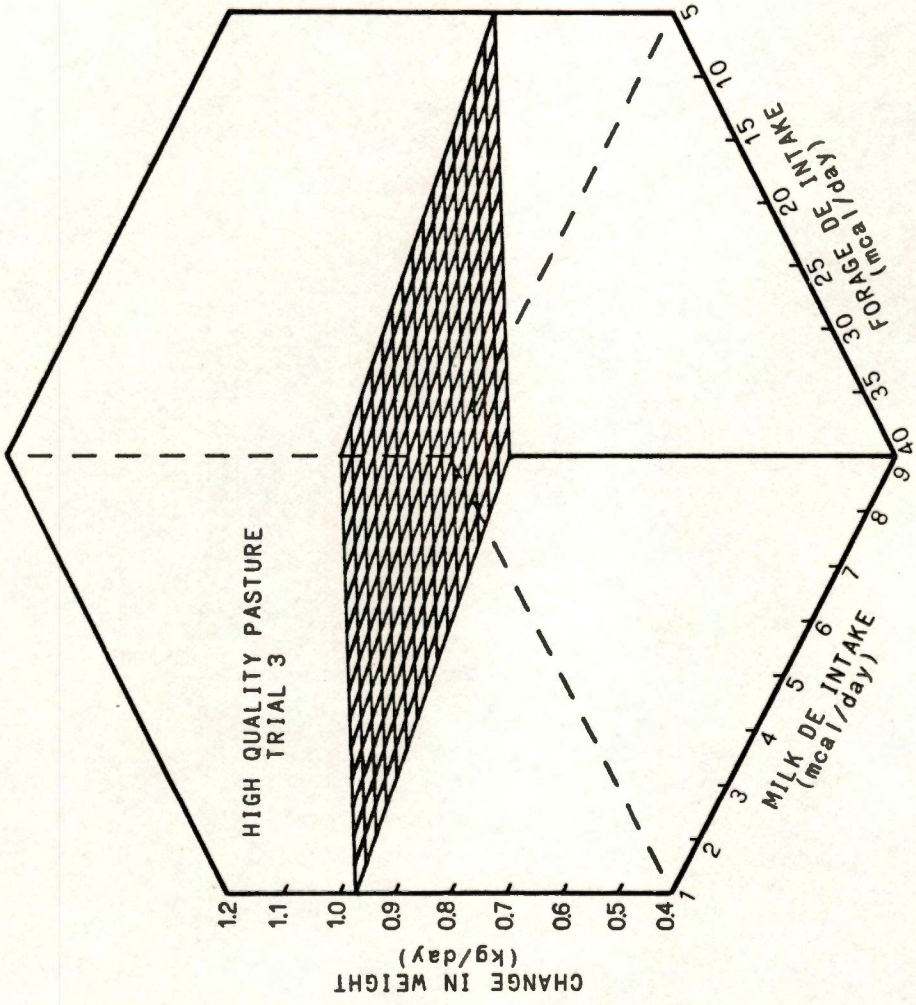


Figure 6. Utilization of milk DE and forage DE for change in weight (high quality pasture, Trial 3).

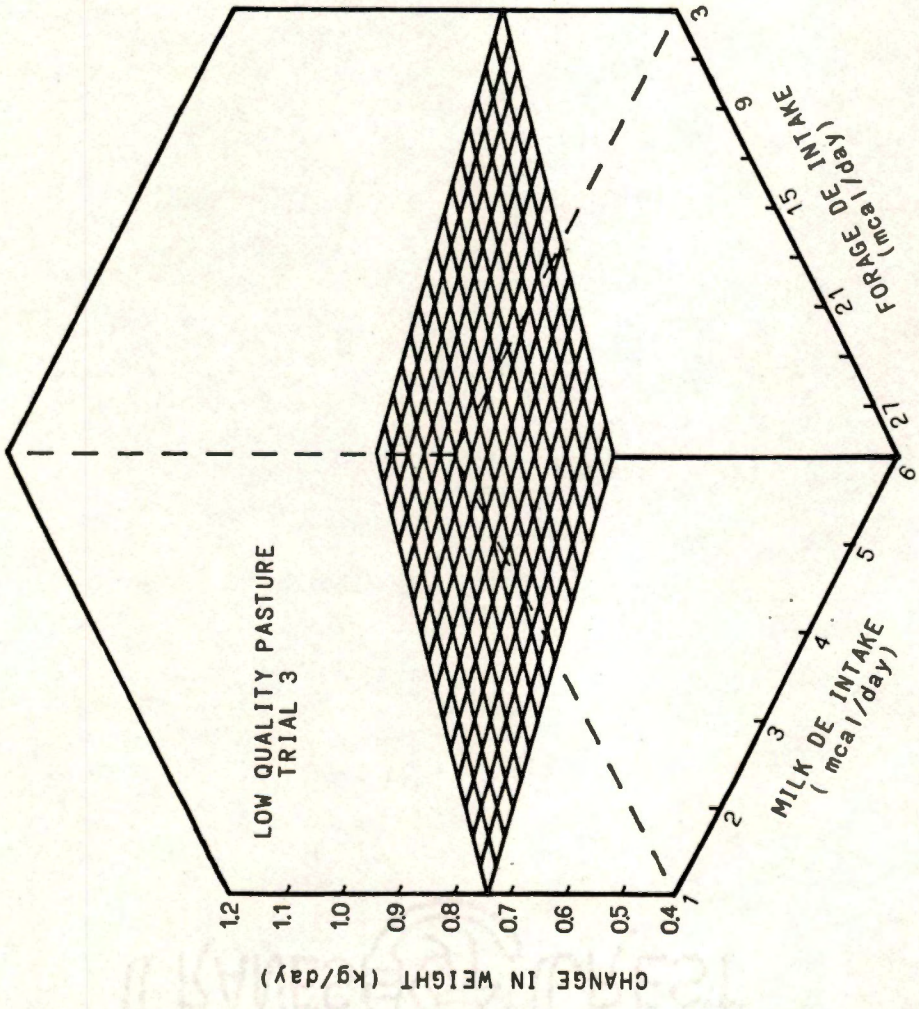


Figure 7. Utilization of milk DE and forage DE for change in weight (low quality pasture, Trial 3).

Table 2. Partial b values associated with the conversion of forage DE and milk DE to weight and change in weight

Model	Calf trial 1	Residual standard deviation	(R^2)	2	Residual standard deviation	(R^2)	3	Residual standard deviation	(R^2)
Treatment 1									
Weight = forage DE intake and milk DE intake									
Forage DE intake	.94288914*	14.09929804	(.67)	1.25137881**	16.48089642	(.66)	1.71621776***	20.10367431	(.61)
Milk DE intake	8.28755368****			7.86058766****			5.49276415***		
Change in weight = forage DE intake and milk DE intake									
Forage DE intake	.00575386*	.08307799	(.62)	.01077585****	.08957163	(.70)	.01065306***	.12582015	(.70
Milk DE intake	.03945212****			.03006783**			.01560579†		
Treatment 2									
Weight = forage DE intake and milk DE intake									
Forage DE intake	1.66949602**	11.95093331	(.75)	1.72133448**	13.58716654	(.5)	1.47352316**	18.03433465	(.62)
Milk DE intake	11.35892895***			13.01574776****			13.37249038****		
Change in weight = forage DE intake and milk DE intake									
Forage DE intake	.00638860†	.06351256	(.65)	.01055912****	.06259175	(.70)	.00792154**	.08518003	(.65)
Milk DE intake	.05517514****			.04808895****			.03541198****		

[a] $\hat{Y}$ (change in weight) = b_0 (year, sex, birth date (Julian day() + b_1 (milk DE intake) + b_2 (forage DE intake).

[b] $\hat{Y}$ (weight) = b_0 (year, sex, birth date (Julian day)) + b_1 (milk DE intake) + b_2 (forage DE intake).

†P<.10; *P<.05; **P<.01; ***P<.001; ****P<.0001.

treatment, comparisons as to the utilization of each variable can be defined more clearly. Since the units of minimum and maximum are identical for Figures 2 and 3 (pgs. 37 and 38), they can readily be appraised as milk DE intake being more important than forage DE intake for change in weight for both treatments. The slopes of the lines for milk DE intake are much steeper resulting in more importance placed on milk DE intake, although there is a difference among treatments for the actual gain with the high quality treatment calves having a slightly higher rate of gain. Comparison of b values (Table 2) by treatment in Trial 1 reveals a similar finding with b values from milk DE intake being much higher in numerical value when compared to forage DE intake values. Therefore, change in weight is more critically affected by a small change in milk DE intake. For Trial 2 (Figure 4 and 5), a wide difference in minimum and maximum values for milk DE intake and forage DE intake across treatments requires a closer comparison of partial b values and visual appraisal for the respective graphs. The partial b values reveal the similar advantage of milk DE intake utilization for change in weight when compared to values for forage DE intake for both treatments, but in reality, there is a steeper slope for the line pertaining to forage DE intake resulting in greater importance for calves grazing high quality pastures. Values for Treatment 2, Trial 2, are similar to values for Trial 1: larger partial b values for milk DE intake resulting in a steeper slope and more importance for milk DE intake relative to change in weight. Again, calves grazing high quality pasture (Treatment 1) had a significant increase in change in weight ($P < .0001$). A much higher importance for forage DE intake was seen for Trial 3 when compared to Trial 2 for calves grazing high quality pastures in relation to change in weight (Figure 6).

The actual b values for milk DE intake and forage DE intake are relatively similar, but when consideration of the minimum and maximum units for each variable is utilized, a clearly defined advantage is detected for forage DE intake over milk DE intake. For calves grazing low quality pasture during Trial 3 (Figure 7), a slight advantage is seen for forage DE intake relevant to change in weight, but the advantage of high quality pasture over low quality pasture, in terms of average daily gain, is still present.

Residual standard deviations with R^2 values for each model (partial b values) were calculated (Table 2) to evaluate conversion of forage and milk DE intake to daily gain. Analysis indicated that calves on low quality pasture had higher efficiencies for the conversion of milk DE intake to weight and daily gain. Forage DE intake to weight and daily gain efficiencies increased for calves on high quality pastures as lactation proceeded, while the conversion rate of milk DE intake to weight and daily gain increased as lactation progressed for calves grazing low quality pasture, similar to studies by Lusby et al. (1976) and Stricker et al. (1979).

C. Correlations of Variables Pertaining to Growth and Performance

Variables associated with the growth and performance of the calf during lactation were utilized for analysis by means of correlation coefficients (Table 3). The variables listed can be partitioned into three subdivisions of early, middle and late growth periods during lactation. Variables in the early growth period include milk intake at birth, B_0, weight at birth, change in weight at birth and milk intake at day 30. Those variables associated with the intermediate growth period are peak lactation (maximum level of milk production), persistency

Table 3. Correlation coefficients of calf growth and performance during lactation

	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	29	30	31	32
1. Weaning weight		.99	-.05	.56	.02	.17	.03	.02	-.01	.39	.69	-.26	.72	.54	-.10	.10	-.04	.55	.34	.39	.25	.69	.78	.41	.67	.55	.51	.49	.47	.43	.36	-.29
2. Weight at weaning†	.99		-.05	.55	.02	.16	.03	.02	-.01	.39	.69	-.26	.70	.57	-.10	.14	-.01	.53	.35	.39	.25	.69	.78	.42	.66	.54	.50	.48	.46	.42	.36	-.28
3. Peak height	-.06	-.07		-.05	.04	.33	.03	-.03	.23	-.11	-.13	.08	-.01	-.07	.05	-.09	-.05	.14	.15	-.11	.92	-.13	-.35	-.02	-.17	-.02	.08	.16	.23	.28	.32	.21
4. Peak height†	.25	.22	-.21		-.37	.23	-.37	.58	-.43	.18	.56	-.30	.34	.11	-.20	-.19	-.31	.90	-.03	.18	.24	.56	.60	.16	.86	.99	.97	.98	.80	.65	.47	-.77
5. Milk intake at birth	.17	.16	.37	-.45		.39	.99	-.86	.76	.26	.27	-.39	.07	.16	-.02	.18	.13	-.20	-.03	.26	.07	.27	.14	-.33	-.07	-.38	-.39	-.31	-.18	-.01	.17	.68
6. Milk intake at weaning	.31	.29	.18	.13	.22		.38	-.30	.67	.17	.18	-.10	.20	.06	-.09	-.06	-.12	.60	-.07	.17	.49	.18	.14	.03	.14	.23	.38	.54	.70	.84	.93	.40
7. A	.17	.16	.37	-.45	.99	.21		-.86	.75	.26	.27	-.39	.08	.16	-.02	.19	.13	-.20	-.02	.26	.06	.27	.14	-.32	-.07	-.38	-.39	-.31	-.18	-.01	.17	.68
8. B	-.18	-.19	-.17	.63	-.73	-.29	-.73		-.87	-.18	-.15	.26	-.08	-.26	-.05	-.25	-.25	.38	-.04	-.18	-.02	-.15	-.05	.27	.23	.59	.58	.48	.32	.13	-.07	-.81
9. C	.20	.21	.24	-.56	.61	.61	.61	-.89		.14	.05	-.14	.12	.18	.04	.14	.17	-.06	.12	.14	.25	.05	-.04	-.17	-.28	-.43	-.32	-.14	.07	.28	.49	.87
10. B_0	.44	.41	.05	.25	.28	.18	.28	-.24	.16		.15	.04	.37	.13	.09	-.05	.05	.21	-.03	1.00	.07	.15	.21	.24	.37	.21	.16	.15	.13	.17	.17	.01
11. B_1	.30	.28	-.02	.41	.31	-.01	.31	-.19	-.02	.17		-.82	.43	.50	-.31	.13	-.15	.50	.04	.14	.18	1.00	.21	.24	.80	.55	.45	.41	.37	.33	.28	-.29
12. B_2	.28	.29	.08	-.25	-.20	.13	-.20	.14	.05	.02	-.77		-.18	-.30	.33	-.13	.11	-.26	-.19	.03	-.12	-.82	-.56	.71	-.53	-.29	-.21	-.18	-.17	-.16	-.16	.09
13. Weaning height	.67	.66	.03	.21	.15	.31	.15	-.18	.17	.45	.25	.16		.43	.06	.02	.01	.39	.39	.37	.21	.43	.47	.23	.41	.33	.32	.34	.36	.37	.35	-.07
14. Weaning fat	.55	.59	-.06	-.16	.33	-.02	.33	-.37	.23	.27	.19	.12	.34		-.11	.37	.20	.12	.22	.13	.09	.50	.53	.12	.30	.10	.05	.06	.09	.11	.12	.04
15. Milk fat	-.00	-.02	.16	-.08	-.16	.16	-.16	.01	.11	.03	-.31	.30	.08	-.09		-.11	.42	-.19	.03	.09	-.05	-.31	.24	.17	-.22	-.20	-.19	-.17	-.16	-.14	-.11	.12
16 S.N.F.	.18	.24	.02	-.28	.26	.02	.26	-.27	.20	.06	.01	.06	.22	.45	-.20		.80	-.20	.19	-.05	-.08	.13	.15	-.05	-.05	-.20	-.24	-.23	-.21	-.16	-.11	.19
17. Milk dry matter	.16	.21	.11	-.31	.15	.11	.15	-.25	.25	.08	-.19	.24	.26	.36	.42	.81		-.30	.24	.05	-.13	-.15	-.11	.01	-.22	-.32	-.33	-.32	-.28	-.23	-.16	.26
18. Average milk intake	.36	.33	-.01	.84	-.26	.60	-.26	.34	-.09	.27	.32	-.14	.31	-.14	.03	-.23	-.20		.06	.31	.44	.49	.49	.15	.72	.90	.96	.99	.98	.91	.80	-.45
19. Age	.35	.38	-.29	-.09	-.09	.14	-.09	-.12	.26	-.11	-.14	.08	.07	.30	.01	.29	.26	.06		-.03	.18	.04	-.06	-.23	-.09	-.03	.02	.06	.10	.13	.15	.13
20. Weight at birth	.44	.41	.05	.25	.28	.18	.28	-.24	.16	1.00	.17	.02	.45	.27	.03	.06	.08	.27	-.11		.07	.15	.21	.24	.37	.21	.16	.15	.15	.16	.17	.01
21. Weight at peak height	.02	.01	.97	-.17	.40	.13	.40	-.19	.21	.08	.08	.03	.09	.02	.12	.03	.10	-.01	-.28	.08		.18	-.03	.02	.16	.27	.35	.42	.48	.52	.54	.08
22. Change in weight at birth	.30	.28	-.03	.41	.31	.01	.31	-.19	-.02	.18	1.00	-.77	.26	.19	-.31	.01	-.19	.32	-.14	.17	.08		.91	-.18	.80	.55	.45	.41	.37	.33	.28	-.29
23. Change in weight at peak height	.61	.60	.30	.31	.23	.16	.23	-.15	.06	.26	.60	-.13	.54	.34	-.05	.04	.01	.31	-.07	.26	.46	.61		.15	.80	.57	.47	.41	.37	.31	.24	-.36
24. Change in weight at weaning	.65	.66	.10	-.07	-.05	.21	-.06	.03	.08	.21	-.38	.87	.44	.34	.22	.11	.24	.03	.04	.21	.10	-.38	.25		.06	.16	.18	.17	.15	.12	.06	-.19
25. Milk intake-day 30	.31	.29	-.13	.75	-.02	.04	-.02	.10	-.25	.50	.79	-.58	.34	.11	-.17	-.12	-.22	.60	-.20	.49	-.04	.79	.52	-.26		.86	.75	.66	.56	.43	.30	-.65
26. Milk intake-day 60	.21	.18	-.13	.98	-.41	.10	-.41	.60	-.55	.27	.47	-.32	.20	.15	-.09	-.27	-.31	.83	-.15	.27	-.09	.47	.33	-.13	.81		.98	.91	.80	.65	.47	-.77
27. Milk intake-day 90	.23	.19	-.08	.96	-.45	.28	-.45	.64	-.46	.19	.31	-.18	.19	-.22	-.02	-.30	-.29	.92	-.06	.19	-.07	.31	.26	-.03	.64	.96		.97	.91	.78	.62	-.67
28. Milk intake-day 120	.29	.26	-.02	.87	-.38	.51	-.38	.50	-.22	.18	.22	-.07	.23	.23	.04	-.28	-.24	.98	.05	.18	-.03	.22	.23	.05	.51	.84	.95		.97	.89	.77	-.51
29. Milk intake-day 150	.35	.32	.04	.68	-.24	.73	-.24	.26	.07	.19	.14	.01	.27	-.18	.10	-.22	-.14	.96	.16	.19	.02	.14	.22	.12	.37	.65	.82	.95		.97	.89	-.30
30. Milk intake-day 180	.38	.35	.10	.47	-.07	.88	-.08	.02	.34	.19	.08	.06	.30	-.11	.14	-.14	-.04	.87	.23	.19	.07	.08	.20	.17	.23	.43	.68	.82	.96		.97	-.07
31. Milk intake-day 210	.38	.36	.15	.29	.06	.95	.06	-.16	.52	.19	.03	.10	.31	-.05	.16	-.05	.05	.75	.27	.19	.10	.03	.17	.19	.12	.25	.45	.68	.87	.97		.16
32. Persistency	.09	.12	.23	-.70	.56	.58	.56	-.80	.93	-.01	.24	.21	.08	.21	.14	.28	.34	-.24	.30	.01	.18	-.24	-.09	.16	-.50	-.71	-.60	-.35	-.04	.24	.44	

†Constitutes predicted values.
Coefficients below the diagonal = Treatment 1; above the diagonal = Treatment 2.
$R > .26$ ($P < .01$)
$.20 \leq R \leq .26$ ($P < .05$)

(milk intake at weaning-peak lactation)/(age-peak lactation), B_1, average milk intake and milk intake at days 60, 90 and 120. The late period of growth would contain the variables such as weaning weight, weight at weaning (predicted), milk intake at weaning, B_2, change in weight at weaning and milk intake at days 150, 180 and 210.

Milk intake at birth for Treatment 1 calves displayed positive correlations for weight variables at birth (.31) and at peak lactation of lactation (.39) with persistency of lactation highly correlated (.56). This is reasonable to assume since weight at peak height depends largely on early milk consumption and persistency is dependent on early lactation (Neville, 1962; Spike and Freeman, 1967). Reasonably high negative correlations were shown for milk intakes after 60 days. Causes for the negative values are that milk intake after 60 days generally occurring after peak lactation occurs. Correlations for milk intake at birth for Treatment 2 calves are similar, but higher correlations are present for persistency (.68) and milk intakes past 60 days. It should be noted that the variables A, B and C associated with description of the lactation curves were so highly correlated that their association will not be discussed in this particular section. B_0 or predicted birth weight was significantly correlated with weaning height (.45) and milk intake at day 30 (.49) indicating that calves in Treatment 1 with higher birth weights were generally taller at weaning and consumed more milk at an earlier age. Treatment 2 calves had the same positive correlations for weaning height and milk intake at day 30, but they were somewhat smaller at .37 and .37, respectively. Weight at birth was positively associated with weaning weight (.44), weaning height (.45) and milk intake at day 30 (.49) for

calves on Treatment 1. Again, Treatment 2 had the same general positive correlations, but to a lesser degree of association (.39, .37 and .37) for weaning weight, weaning height and milk intake at day 30, respectively. Dickey et al. (1970) reported a correlation of .52 between milk yield and calf weight at weaning while Hohenboken et al. (1973) reported a similar correlation of .56 between milk yield at early stages of lactation and weaning weight. Milk intake at day 30 with calves in Treatment 1 was highly correlated with peak height of lactation (.95), B_0 or birth weight (.49), B_1 or gain (.79), average milk intake (.60), change in weight at birth (.79), change in weight at peak height of lactation (.52) and positive but progressively declining positive values for the milk intake intervals after 60 days. A negative association occurred between milk intake at day 30 and persistency of -.50, an evident conclusion since an increase in milk intake at early stages will generally cause a decrease in persistency of production (Kellogg et al., 1977). Treatment 2 calves followed the same general pattern, but milk intake at day 30 was more highly correlated with factors directly associated with lactation (peak height of lactation, .85 and persistence, -.64). Neville (1962) reported that the relationship of milk with actual gain was not important at 30 to 60 days of calf age. Totusek et al. (1973) also reported high correlations between milk yield and the actual growth rate or gain of the calf.

The peak lactation factor (Table 3) was more highly correlated ($P < .01$) with milk intake at birth for Treatment 1 calves than with milk intake at weaning while it was more highly associated with milk intake at weaning than with milk intake at birth for Treatment 2 calves. This is possibly due to the calves on low quality pasture having a

greater need for milk later in lactation because of lack of forage quality. B, related to pre-peak curvature of the lactation curve, was negatively associated with both C (-.89) and persistency of lactation (-.80) for both treatments, factors that are associated with the decay rate of the curve. B was also positively associated with milk intake from day 60 to day 150 for both treatments. Average milk intake is highly correlated with peak height (.84 and .90), milk intake at weaning (.60 and .60) and all milk intake variables for Treatments 1 and 2, respectively. The association with peak height is in agreement with studies by Kellogg et al. (1977) who reported that an increase in mean milk consumption as an average of lactation was associated with higher peak production, but a more rapid decline after peak production was reached. Milk intakes at days 60, 90 and 120 for Treatments 1 and 2 were highly correlated with peak height, average milk intake and all other milk intakes, but, as lactation proceeded from day 60 to day 120, the correlations declined in magnitude with each variable. These particular variables were also negatively correlated with persistency.

Weaning weight correlations (Table 3) with other variables were similar across treatment, but Treatment 2 calves had higher correlations between weaning weight and milk intake variables from day 30 to day 180, suggesting milk was more important for growth on low quality pasture. A slight negative correlation with persistency was determined, concluding that calves on low quality pasture with heavier weaning weights nursed dams tending to have less persistent lactation curves. C, or the variable pertaining to post-peak lactation curvature, was negatively correlated ($P < .01$) with variables associated with peak height of lactation and persistency for both treatments. Change in weight at weaning was

associated ($P < .01$) with B_2 and weaning weight, but correlation values were higher in Treatment 1. As stated previously, milk intake variables from day 150 to 210 were more significantly correlated with variables associated with weaning traits with the calves on low quality pasture than with calves on high quality pasture.

Butterfat, solids-non-fat and milk dry matter were only slightly correlated with other variables with the only high correlation occurring between milk solids and milk dry matter (.81 for both treatments). There was a trend toward a moderate negative correlation for milk solids and milk dry matter with milk intake from day 30 to day 180. Melton et al. (1966) estimated that the correlation between total gain and milk butterfat, solids-non-fat and total solids with total milk production were relatively high. Totusek et al. (1973) also reported high correlations between total fat and total solids with calf weight and total milk production. Researchers concluded that there was little variation in the percentages of protein, total solids and fat present in milk (Rutledge et al., 1971; Totusek et al., 1973). This is similar to data presented in Table 1 (pg. 34) in which little variation occurs across treatment and trial for solids-non-fat and milk fat.

D. Pathway Coefficients

Standard partial b values are found in Table 4. All coefficients are corrected for the average effect of year, sex and birth date (Julian day). The pathway coefficients (Figure 8) are utilized for unbiased comparisons by time or treatment in relation to utilization of milk DE intake and forage DE intake for weight and change in weight.

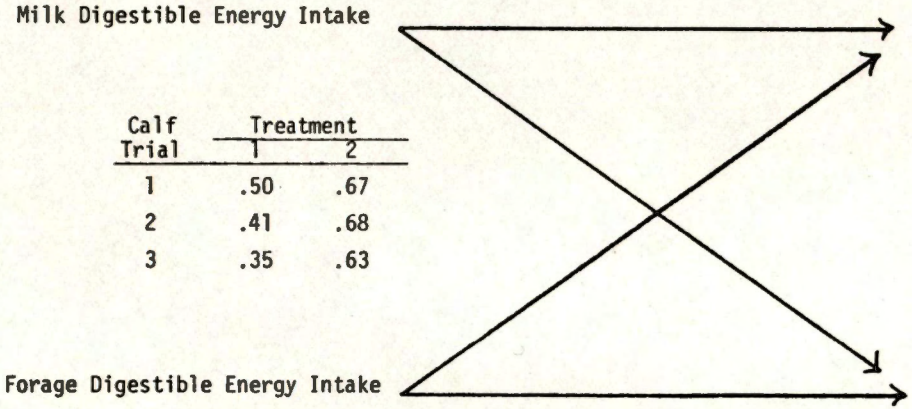
Table 4. Standard partial b values for the determination of pathway coefficients

	Treatment 1			Treatment 2		
	Calf trial					
	1	2	3	1	2	3
Weight = forage digestible energy intake (FDEI) and milk digestible energy intake (MLKDEI)						
FDEI	.2241292*	.3270358**	.4302373***	.2133400**	.2497455**	.2699502**
MLKDEI	.4813728****	.4409117****	.3058610***	.6756997***	.6508464****	.5634681****
Change in weight = forage digestible intake (FDEI) and milk digestible energy intake (MLKDEI)						
FDEI	.2458606*	.5006317****	.4152889***	.1705701†	.3566655****	.3281338**
MLKDEI	.4118995****	.2998172**	.1351319†	.6857563****	.5602119****	.3373829***

[a](Steele and Torrie, 1960).

†p<.10.
*p<.05.
**p<.01.
***p<.001.
****p<.0001.

Calf Trial	Treatment 1	2
1	.43	.68
2	.25	.60
3	.18	.41



Calf Trial	Treatment 1	2
1	.50	.67
2	.41	.68
3	.35	.63

Calf Trial	Treatment 1	2
1	.29	.15
2	.48	.43
3	.43	.40

Calf Trial	Treatment 1	2
1	.28	.19
2	.29	.33
3	.47	.40

Figure 8. Pathway coefficients for the utilization and milk DE intake for weight and change in weight.

[a]Determined through the use of standard partial b values (page 54).

Regarding comparison of path coefficients in Figure 8, milk DE intake for the calves on low quality pasture (Treatment 2) was almost twice as important for change in weight throughout lactation when compared with the calves on high quality pasture (Treatment 1). The difference among treatments increased dramatically as lactation progressed, although both treatments decreased in milk DE intake as lactation proceeded. Forage DE intake increased as lactation proceeded in both treatments, but the increase was greater for the calves in Treatment 1. Regarding the utilization of milk DE intake for weight, Treatment 2 calves had a noticeable advantage throughout lactation with only a slight decrease in relative value occurring during Trial 3. Treatment 1 calves decreased their utilization of milk DE intake for weight as lactation proceeded. Also, Treatment 1 calves had a higher utilization of forage DE intake for weight when compared to the calves in Treatment 2. Although calves in Treatment 1 had higher intakes associated with all milk and forage variables and higher weaning weights, the calves in Treatment 2 utilized more milk intake for weight and gain. Drewery et al. (1959) reported that calves nursing higher producing dams had greater total gains, but they had the least amount of gain from a given volume of milk. Lusby et al. (1976) studied milk productions of Holstein and Hereford cows and concluded that, although Holstein cows were higher in total milk production, the Hereford cows produced calves that were more efficient in converting milk to gain. Also, Wyatt et al. (1977) reported a substitution of milk for grass and that, as milk intake increased, forage intake decreased.

Least-square means (Table 5) of the percentages of milk and forage DE intake utilized for weight and change in weight revealed that calves in both treatments utilized more milk DE intake for weight rather than

Table 5. Least-squares means in the proportion for utilization of forage and milk DE intake to weight and change in weight

	Treatment 1			Treatment 2		
	Calf trial					
	1	2	3	1	2	3
Milk digestible energy intake to weight	2.443284 (54%)[b]	2.493268 (62%)	2.208492 (66%)	1.928950 (50%)	1.783450 (53%)	1.644240 (60%)
Milk digestible energy intake to change in weight	2.081316 (46%)	1.528132 (38%)	1.137708 (34%)	1.928950 (50%)	1.581550 (47%)	1.096160 (40%)
Forage digestible energy intake to weight	4.682832 (48%)	5.997350 (38%)	10.302708 (52%)	3.749144 (56%)	4.239356 (44%)	11.664113 (79%)
Forage digestible energy intake to change in weight	5.073068 (52%)	9.785150 (62%)	9.510192 (48%)	2.945756 (44%)	5.395544 (56%)	3.100587 (21%)

[a] Model Y = (year, sex, birth date (Julian day), trial) + all two-way interactions.
[b] The percentage of the independent variable partitioned to either weight or change in weight.

for change in weight. Treatment 2 calves tended to utilize milk DE intake more equally while the calves in Treatment 1 favored a higher utilization for actual weight. An inversion of these circumstances occurs in the comparison of forage DE intake between treatments. Treatment 2 calves utilized forage DE intake at a much higher rate for weight when compared to change in weight while Treatment 1 calves used more forage DE intake for change in weight.

Correlation coefficients were determined for the variables in Table 6 to evaluate the associations of the variables utilized with the pathway coefficients in addition to forage dry matter digestibility. Forage dry matter digestibility and forage DE intake are significantly correlated ($P < .001$) in both treatments with weight and change in weight also being highly associated ($P < .001$). Although not significant, forage dry matter digestibility and milk DE intake tended to be negatively associated for both treatments and all three trials. The correlation between milk DE intake and forage DE intake exhibited no discernible pattern.

E. Combination of Calf Trial and Treatment

An overview of total concept relating milk DE intake, forage DE intake and forage digestibility was accomplished through the use of proxy variables for treatment, trial and year.

A single three-dimensional graph was constructed with the variables milk DE intake and forage DE utilized to determine their effect on forage DE intake (Figure 9). Close inspection of the three-dimensional figures reveals that, at low concentrations of forage DE, there is an associative low value for forage DE intake while milk DE intake has a significantly

Table 6. Correlation coefficients associated with pathway coefficients

	Treatment 1			Treatment 2		
	Calf trial					
	1	2	3	1	2	3
Dry matter digestibility x milk digestibile energy intake	-.21332[†]	-.09612	-.09393	-.11672	-.16505	-.09859
Dry matter digestiblity x forage digestible energy intake	.58402***	.52451***	.44844***	.40949***	.61272***	.52776***
Milk digestible energy intake x forage digestible energy intake	.01344	-.05316	.06594	-.04265	.04711	.10542
Weight x change in weight	.70237***	.64279***	.60428***	.77068***	.67706***	.55402***

[†]P<.10.
***P<.001.

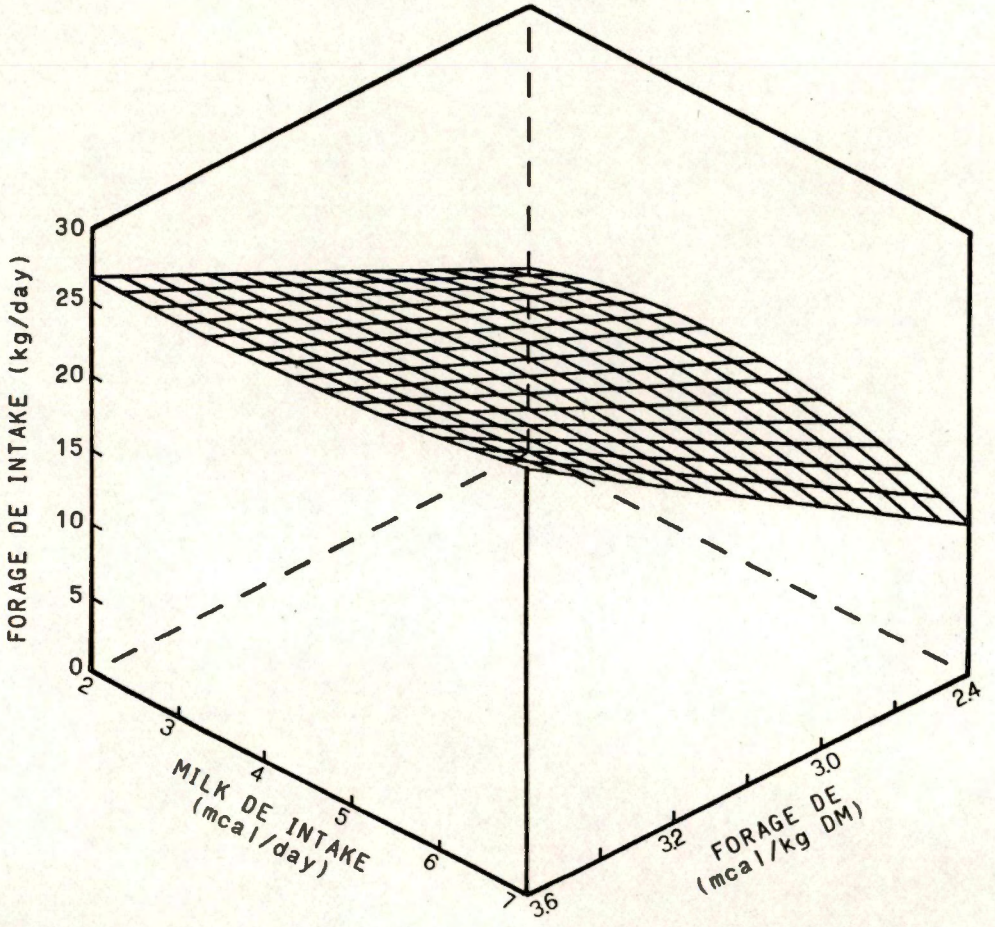


Table 9. Utilization of forage DE, milk DE intake and forage DE intake by calves grazing high and low quality pasture.

higher value. Thus, at low forage intake, calves consume more milk for growth utilization. In comparison, as forage DE level increases, an increase in forage DE intake occurs followed by a slight depression in milk DE intake. At peak forage DE concentration, an associated peak forage DE intake occurs while milk DE intake is also contributing to high forage DE intake values. Theoretically, it can only be assumed that as a calf becomes older, it can consume additional milk as well as additional forage. But, a more important position is carried by forage DE in relation to its effect upon forage DE intake. Burns et al. (1973) reported a high degree of correlation between forage pasture quality and calf gains with gain increasing as lactation progressed. Also, Wyatt et al. (1977) reported an increase in forage consumption as milk production decreased.

CHAPTER IV

RELATIONSHIP OF LACTATION CURVE TO PREWEANING PERFORMANCE OF ANGUS CALVES GRAZING HIGH OR LOW QUALITY PASTURES

I. SUMMARY

Lactation yields were estimated over a five-year period from 1976 through 1980 utilizing 200 lactating Angus cows to determine the association between lactation curve shape and preweaning calf performance.

Cows were bred to calve during January through March each year and were allotted to either high quality pastures, consisting of red and white clover, Korean and Kobe lespedeza, bluegrass and Kentucky-31 tall fescue, or low quality pastures comprised totally of tall fescue. Milk production estimates were taken monthly from April through October each year utilizing the calf suckle technique (2, 12-hour separations). Milk intakes prior to April were calculated from nutrient requirements for early preweaning growth. At weaning, calves were weighed, measured for height at the withers and ultrasonically probed for fatness at the 12th rib. Lactation yield for each calf was described by the equation: $MP = Ae^{-ct}t^{b}$ where, A, B and C are constants estimated from the data and t is calf age (days). Milk production at birth, lactation peak and weaning was estimated by the evaluation of these lactation functions. Also, functions were evaluated at 30-day intervals for milk intake and these estimates were then averaged to obtain an average milk production for each cow.

Mean milk production occurred at 67 days calf age with peak lactation for high and low quality pastures occurring at 80 and 68 days,

respectively. Average milk intake explained 53% of the variation in weaning weight (within year, sex and age basis) for calves on low quality pasture while it only explained 33% of the variation in weaning weight for calves on high quality pasture. Regression models containing milk production at peak and at weaning explained more variation (5-6% in sex and age corrected weaning weight, weaning height, weaning fat and average daily gain) than did models containing average milk intake. After the adjustment for average milk intake, milk production at birth, lactation peak and weaning accounted for 5 and 50% of the variation in average daily gain for high and low pasture qualities, respectively. Thus, lactation curve shape explained from 5 to 40% of the variation in average daily gain not explained by the average milk intake. In general, curve shape was more important for growth with calves on low quality pastures rather than high quality pasture. Desirable curves in this study were determined to be associated with high peaks and low persistence.

II. INTRODUCTION

Milk production is one of the more important factors influencing the growth rate and performance of beef calves during the preweaning period. Correlations ranging from .51 to .96 have been reported for the association of total milk production with calf average daily gain (Dawson et al., 1960; Rutledge et al., 1971; Totusek et al., 1973; Hohenboken et al., 1973). Hill et al. (1979) reported an additional increase in weaning weight and average daily gain of 22.1 kg and .10 kg/day, respectively, for calves grazing bluegrass pasture when compared to calves grazing straight fescue.

Much conflicting research has been reported in reference to factors associated with shape of lactation curves in beef cows and how it affects calf gains. Peak milk productions have been reported to occur from 20 days to five months postpartum (Dawson et al., 1960; Christian et al., 1965; Lamond et al., 1979; Holloway et al., 1975). Factors that have been reported to affect shape of lactation curves refer to parity, season of birth or lactation, age of dam and geographical area. Also, several models for dairy cows have been developed as aids in establishing lactation curves in regard to peak production, persistency of lactation and effect of milk composition on curve shape (Wood, 1969; Wood, 1974; Shaeffer and Burnside, 1976; Wood, 1976; Kellogg et al., 1977; Shaeffer et al., 1977). The purpose of this study was to determine the relationships between lactation curve shape and the various traits associated with the preweaning performance of Angus calves grazing high or low quality pasture.

III. MATERIALS AND METHODS

A. Pasture Management

In a five-year study from 1976 through 1980 involving about 200 cow-calf pairs, four pastures were managed to provide two levels of nutrition for mature Angus cows and their straightbred calves.

Four 8.0 ha pastures were managed to achieve two pastures of high quality forage and two pastures of low quality forage. During the five-year study, pastures were renovated four times with high quality pasture receiving an overseeding of red and regal ladino white clover. Fertilization of each pasture quality differed in that high quality pastures

received only phosphorous and potassium in early March while the low quality pastures were supplemented with nitrogen, phosphorous and potassium fertilization each spring. Water and mineral supplementation was provided for the animals, ad libitum. The high quality pastures were comprised of a fescue/legume concentration with an average percentage in the study of about 60 to 70% all fescue and 30 to 40% legume. Species of forage were regal ladino white clover (Trifolium repens L.), red clover (Trifolium pratense L.), Korean and Kobe lespedeza (Lespedeza stipulacea Maxim.), bluegrass (Poa pratensis L.) and Kentucky-31 tall fescue (Festuca arundinacea Schreb.). The low quality pastures were comprised totally of Kentucky-31 tall fescue with combination of dallisgrass (Paspalum dilatatum Poir) occurring during the summer months of 1980. Cows grazed the pasture treatments on a constant year-round basis with hay harvested in about June of each year and fed to the cows in their respective pastures during the winter months. Forage was managed in a manner as to keep the high quality pastures in an immature, vegetative state of production while the low quality pastures were allowed to mature and become less digestible.

B. Animal Management

Forty mature Angus cows ranging in age from 5 to 10 years were allotted to one of two pasture treatments each year (10 cow-calf pairs/pasture). Twenty to 40% of the cows were replaced each year with the remaining cows staying in their respective pastures. Cows were bred to calve in January, February and March each year and all bull calves were castrated in late April. Large cows were bred to large bulls to prevent confounding effects of calf weight/cow weight ratios in efficiency analysis.

C. Estimation of Milk Intake

Each year, monthly milk productions were taken from April through October, determined by a calf suckle technique. Six milk production estimates were measured in 1976, 1978 and 1979, while seven estimates were performed in 1977 and 1980. Calves were separated from their dams at about 1800 hr preceeding the day production estimates were made and cows were replaced to their respective pastures with calves placed in a central holding facility. At about 0600 hr the following day the calves were weighed and then individually paired with their dams to allow for nursing. Following completion of the pairing sequence of all 40 cow-calf pairs and the complete nursing of each, calves were then reweighed and the difference in weights assumed to be the 12-hour milk production estimate. This procedure was repeated at about 1800 hr of the same day and the two estimates were totaled to compile a 24-hour milk intake estimate. Calf urine and fecal loss was assumed to be negligible.

Each year, during the months of June, July and August (the middle third of lactation), milk sample estimates were performed to obtain measurements of milk constituents. Ten cows from each pasture treatment were subjected to toal machine milk-out procedures with the use of 20 I.U. of oxytocin (Pitocin, intramuscularly) after separation of at least 3 hours from their calves. On the following day, the remaining 20 cows were milked using the same procedure. Milk samples were analyzed for dry matter and butterfat (Mark III Milk-O-Tester).

D. Estimation of Forage Digestibility

Random forage samples were taken bi-weekly from April to October each year by either the cage-and-strip technique (Holloway et al., 1979)

or by hand-clipping procedures. These samples were dried in a 60°C oven and then ground in a Wiley Mill using a 40-mesh screen for the purpose of determination of dry matter (AOAC, 1970) acid detergent fiber and acid detergent lignin (Van Soest, 1963).

E. Estimation of Weaning Characteristics

At weaning age of about 240 days, calves were measured for height at the withers (cm), weight (kg) and fatness measured ultrasonically at the 12th rib (mm). Calves were then transported to another location for further studies.

IV. STATISTICAL ANALYSIS

A. Relation of Pasture Quality to Shape of Curve

The equation: milk production = $Ae^{-ct}t^{b}$ developed by Wood (1976) was used to describe the lactation curves developed during the five-year study with A, b and c being the parameters of measured milk production, t being equal to some form of time (days) and e equal to the logarithmic function. These coefficients were obtained by an iteration procedure in SAS 79.1 to obtain the values of A, b and c which were utilized in the graph construction with milk intake ranging from 0 to 10 kg/day.

Least-square means were calculated from the equation Y = year, pasture quality, birth day (Julian day), sex and all two- and three-way interactions for the variables associated with lactation curve and calf growth: average milk intake, milk intake at weaning, weaning weight, weaning fat, weaning height, peak of lactation curve, B_0, B_1 and B_2 (Table 7). For depicting calf growth across time (Figures 10-14), growth curves were developed using the equation calf weight (kg) = B_0 + (B_1 * time) +

Table 7. Least-squares means of variables associated with milk intake, weaning measurements and growth variables

	High quality					Low quality					Level of significance		
	Year					Year							
	1976	1977	1978	1979	1980	1976	1977	1978	1979	1980	Year	Pasture quality	Year by pasture quality
Weaning characteristics[a]													
1. Weight (kg)	245.5	227.0	237.7	242.5	198.6	224.1	215.9	212.1	211.0	199.8	.0001	.0001	.0957
2. Height (cm)	38.5	37.5	38.9	38.9	37.5	37.6	37.5	38.1	37.7	37.5	.0175	.1064	.3658
3. Fatness (mm)	4.6	2.2	2.7	4.6	2.5	3.9	2.2	2.7	3.6	2.9	.0001	.0483	.0040
Milk intake (kg/day)[a]													
1. Birth	4.2	.71	1.6	2.3	3.1	3.3	.63	1.4	1.9	4.7	.0001	.9691	.9147
2. Day 30	6.4	6.8	6.1	6.5	7.8	7.2	6.8	6.1	6.0	6.3	.0046	.4358	.0129
3. Day 60	6.2	9.3	7.5	7.2	8.4	7.0	8.7	7.2	6.6	6.7	.0001	.1143	.0510
4. Peak	81.4	85.4	70.2	61.8	82.8	84.8	76.7	71.7	67.9	78.6	.9000	.5610	.8289
5. Day 90	5,6	9.5	7.9	7.1	7.9	6.3	8.8	7.1	6.3	6.6	.0001	.0369	.1795
6. Day 120	4.9	8.7	7.8	6.6	7.0	5.3	8.0	6.7	5.7	6.3	.0001	.0137	.2372
7. Day 150	4.3	7.5	7.3	6.1	6.1	4.5	7.8	6.0	5.1	6.0	.0001	.0069	.0977
8. Day 180	3.8	6.3	6.8	5.5	5.3	3.7	7.3	5.3	4.4	5.6	.0001	.0055	.0163
9. Day 210	3.3	5.2	6.3	5.1	4.5	3.0	6.8	4.6	3.9	5.3	.0001	.0065	.0026
10. Day 240	2.9	4.2	5.7	4.7	3.9	2.5	4.7	4.0	3.4	5.0	.0001	.0095	.0007
11. Weaning	2.7	4.1	5.6	4.6	3.8	2.3	3.7	3.9	3.1	4.9	.0001	.0251	.0002
12. Average milk intake	4.8	6.5	5.8	5.8	6.1	4.6	6.0	5.8	4.7	5.7	.0001	.0124	.1568
Calf growth[b]													
1. B_0 (kg)	31.7	28.38	32.00	30.90	32.78	28.61	28.03	31.11	30.70	31.73	.0008	.1538	.3821
2. B_1 (kg/day)	.81	.77	.59	.72	.87	.92	.73	.61	.68	.77	.0001	.8421	.1080
3. B_2 (kg/day^2)	.0002	.0006	.0007	.0003	- .0008	- .0005	- .0006	.0004	- .0001	- .0004	.0001	.0004	.0001
Lactation curve													
1. A	4.24	.72	1.16	2.37	3.13	3.40	.64	1.49	1.92	4.72	.0001	.9683	.0192
2. b	.18	.97	.56	.45	.41	.34	.83	.53	.47	.18	.0001	.3622	.0383
3. c	- .005	- .012	- .006	- .007	- .007	- .008	- .011	- .007	- .008	- .003	.0001	.7776	.0047

[a] $\tilde{y}$ = b (year, sex, birth date (Julian day), pasture quality + all two- and three-way interactions.

[b] Developed from: calf weight = B_0 + (B_1 * time) + (B_2 * time * time).

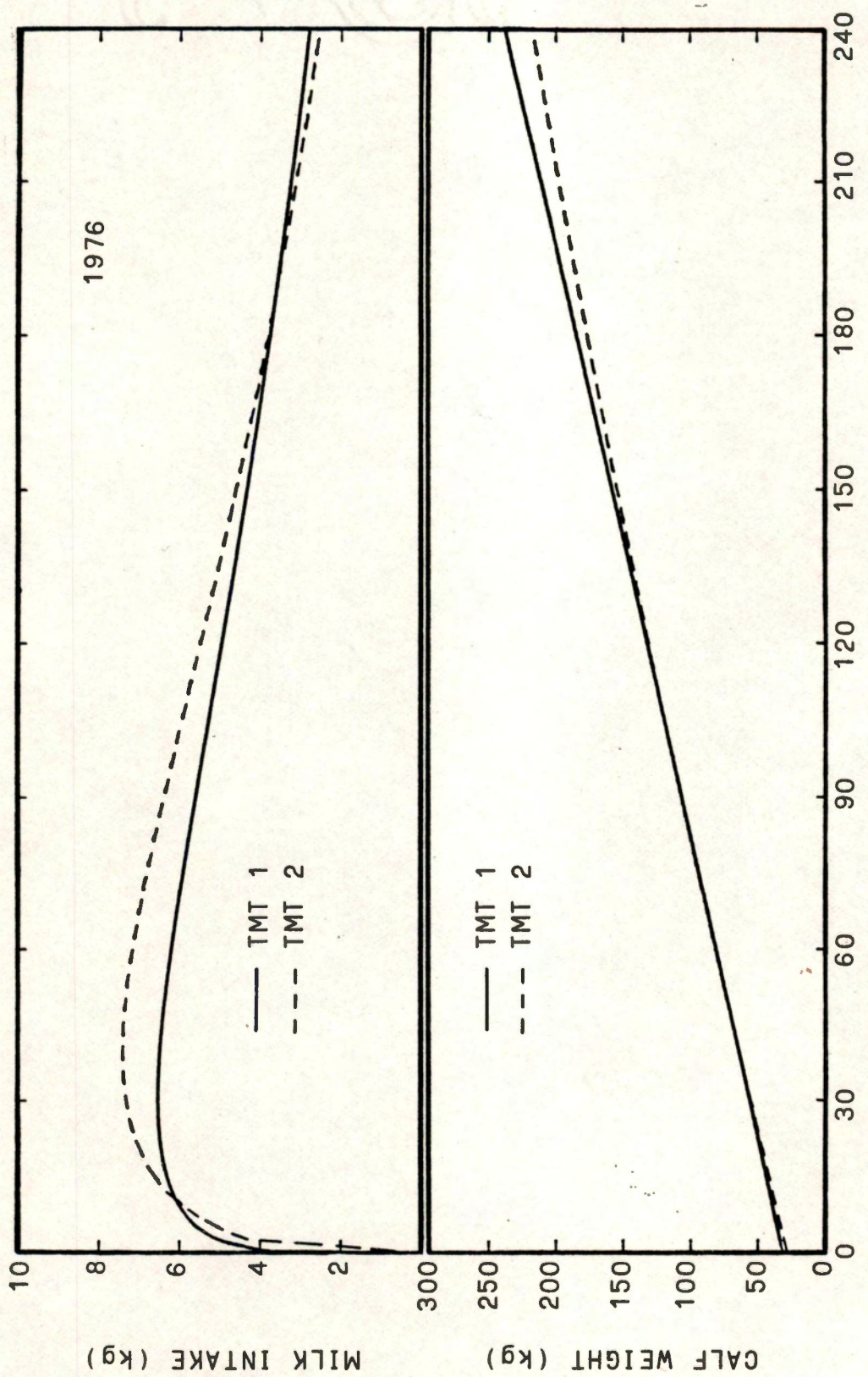


Figure 10. Effect of pasture quality on lactation curve shape and preweaning growth (1976).

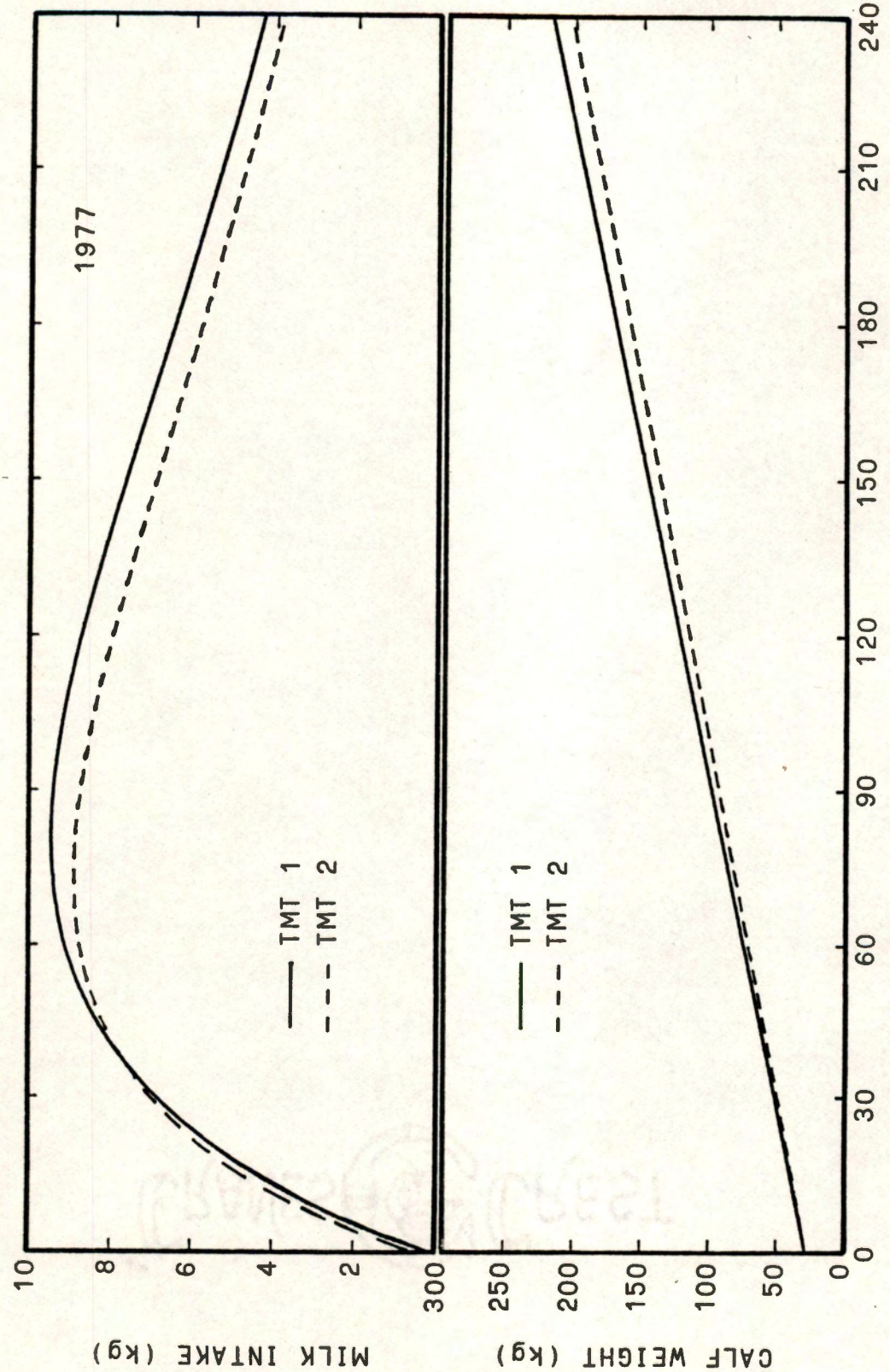


Figure 11. Effect of pasture quality on lactation curve shape and preweaning growth (1977).

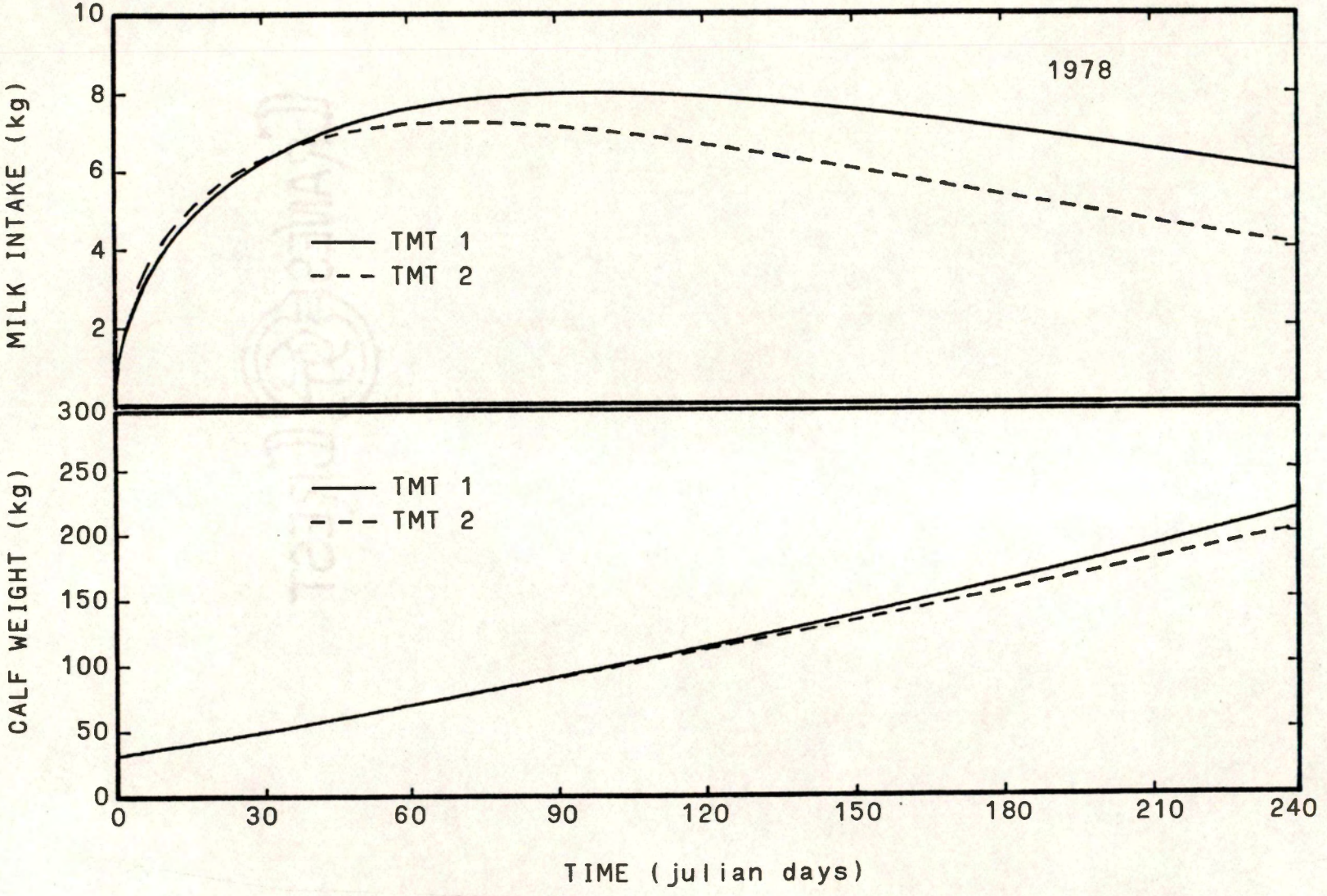


Figure 12. Effect of pasture quality on lactation curve shape and preweaning growth (1978).

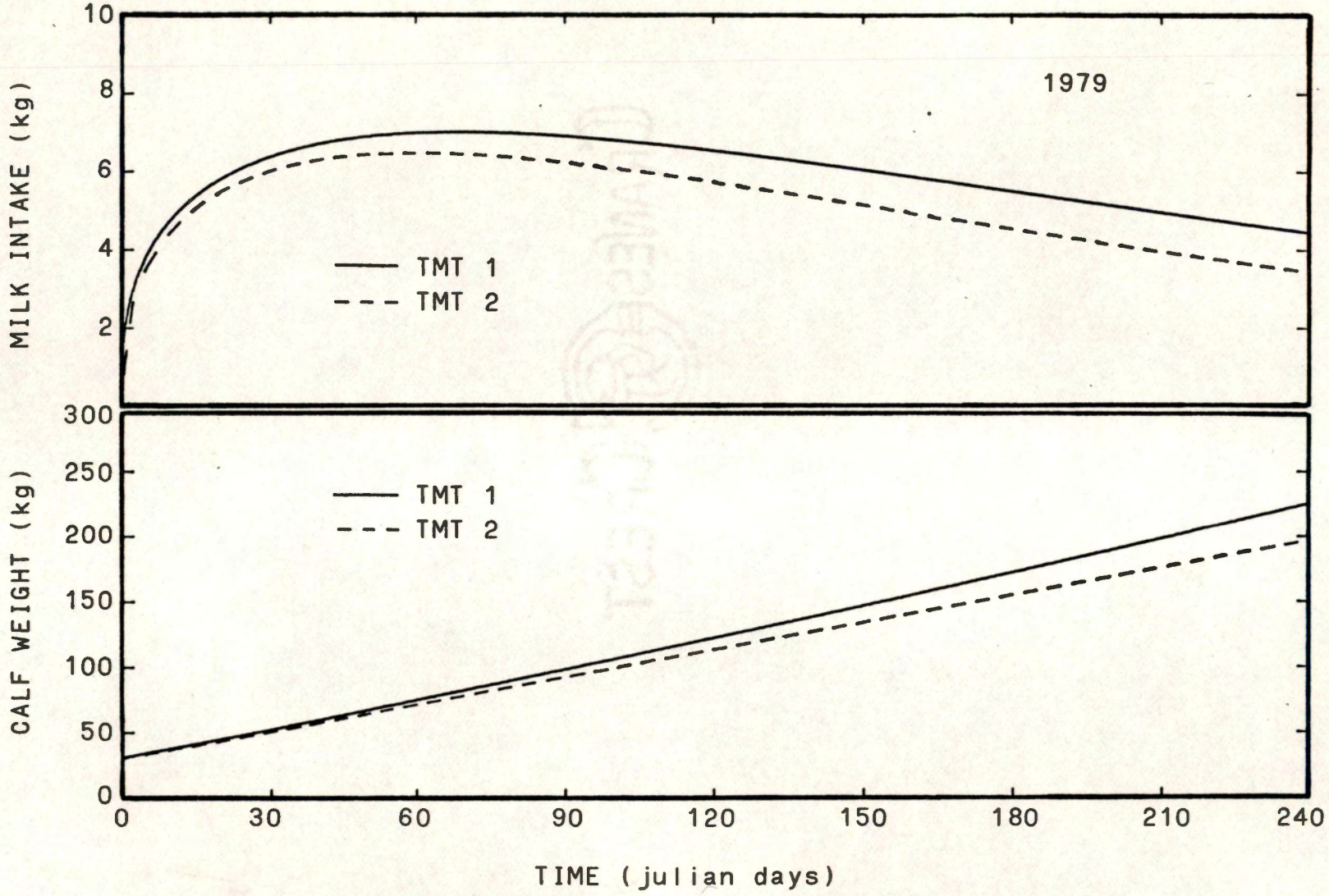


Figure 13. Effect of pasture quality on lactation curve shape and preweaning growth (1979).

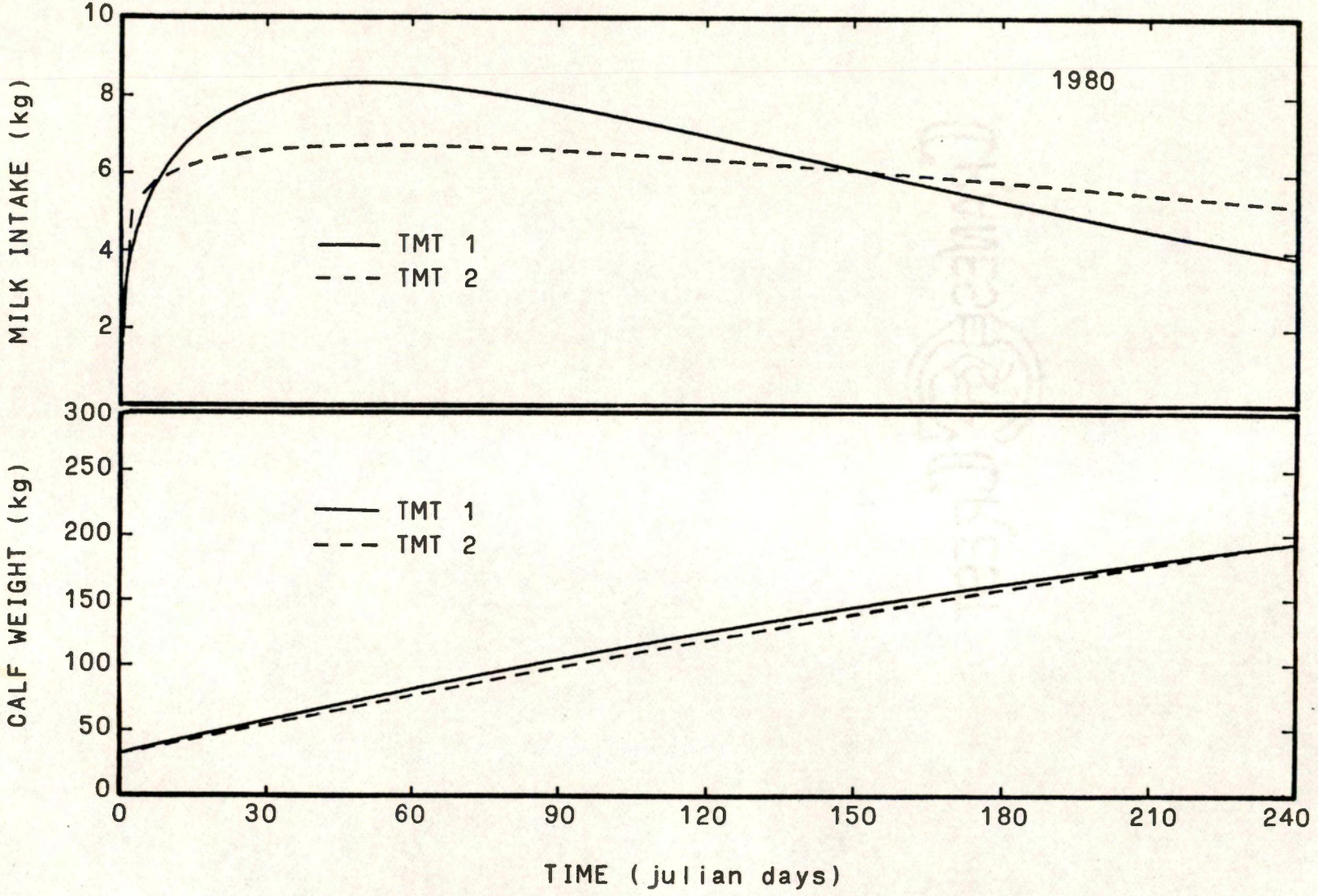


Figure 14. Effect of pasture quality on lactation curve shape and preweaning growth (1980).

(B_2 * time * time). Effect of pasture quality on shape of lactation curve was determined through a series of graphs of composite lactation curves from each year of the study with high and low quality pastures depicted separately (Figures 10, pg. 65, through 14). In addition, lactation curves from 1976-1979 were combined to determine the differences which occurred between 1980 and the previous four years (Figure 15).

B. Relation of Shape and Average Production

To facilitate the study of the relative pattern of milk production and average milk intake, a series of milk intakes were calculated (Table 8) at 30-day intervals using the model Y (milk intake) = b_0 (year, sex, birth date (Julian day) + b_1 (average milk intake). This method was utilized to determine how average milk intake affects the lactation curve and to what extent an increase in average milk intake affects the shape (Figure 16).

C. Relation of Sahpe and Weaning Weight Above Average Production

Methods were developed to determine how milk intake above and beyond average milk intake is utilized for maximum weaning weight by calves in both high and low quality pastures. Predicted b values were calculated from regression analysis utilizing the model Y = year, sex, birth date (Julian day), average milk intake for the variables, weaning weight, height and fatness, milk intake at day 30 to 240 (30-day intervals) and peak height (Table 9). These b values were then corrected for average milk intake and plotted (milk intake variables only) across age. These values were plotted (Figure 17) at 30, 90, 150 and 240 days of age and at peak lactation of the curve (80 days for high quality pastures and

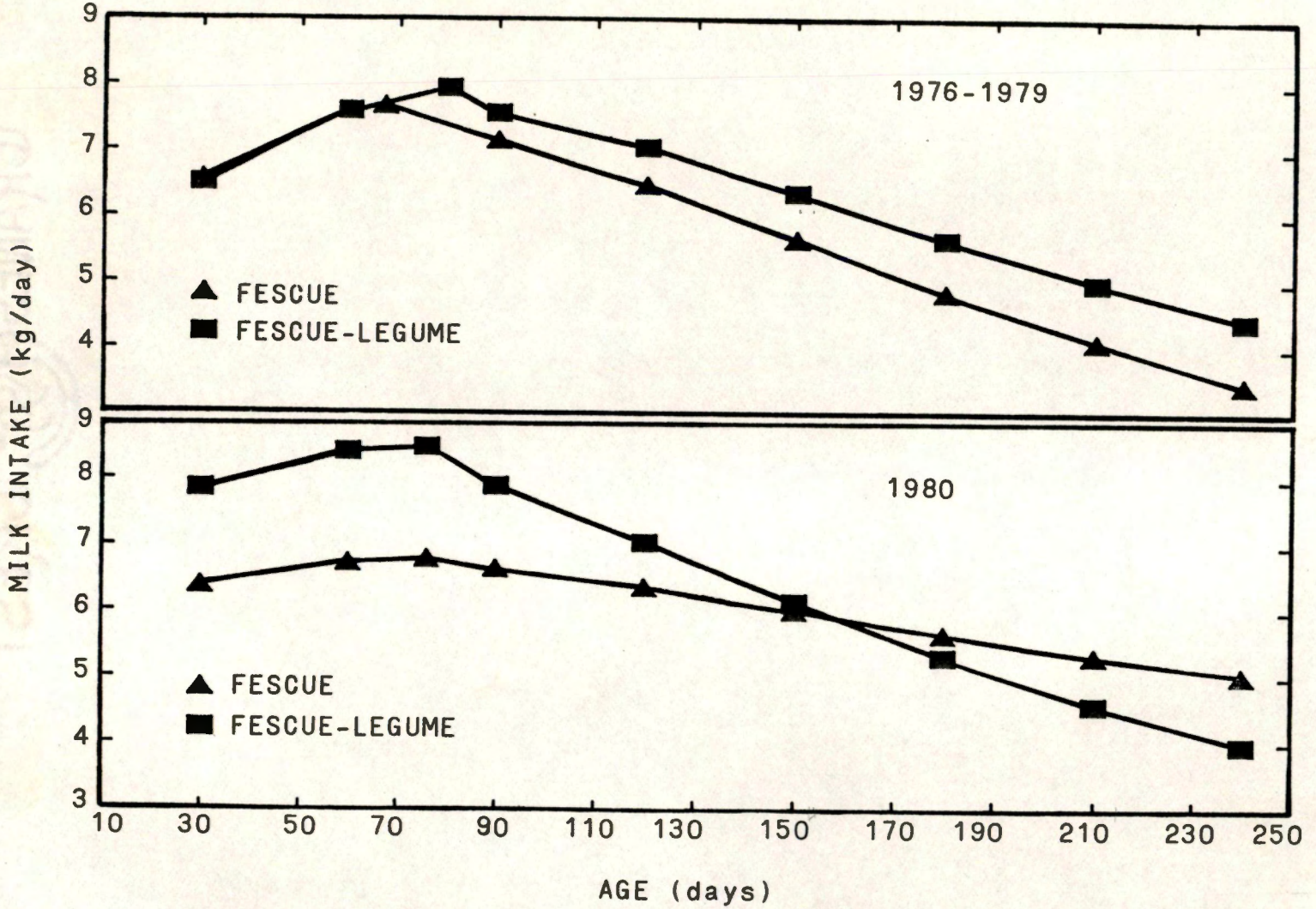


Figure 15. Comparison of lactation curves as affected by pasture quality differences between 1976-1979 and 1980.

Table 8. Partial b values utilized to determine the effect of average milk intake on shape of curve

Intake	High Quality				Low Quality			
	B_0	RSD	(R^2)	B_1	B_0	RSD	(R^2)	B_1
Milk Intake Day 0	.3024867	.2953	(.50)	.02303865	.6970258	.3103	(.41)	-.04307929
Milk Intake Day 30	1.4989329	.1819	(.54)	-.06595882	1.6753633	.1791	(.54)	-.08633645
Milk Intake Day 60	1.6239707	.2167	(.28)	-.06695065	1.6404645	.1859	(.40)	-.05413114
Milk Intake Day 90	1.5010085	.1777	(.28)	-.04481942	1.3954116	.1465	(.38)	-.01606973
Milk Intake Day 120	1.2858131	.1040	(.46)	-.01628995	1.1282054	.0959	(.46)	.01456630
Milk Intake Day 150	1.051783	.0584	(.75)	.01069120	.8926830	.0710	(.58)	.03526376
Milk Intake Day 180	.8302088	.0947	(.62)	.03333294	.7036425	.0894	(.55)	.04720653
Milk Intake Day 210	.6325536	.1454	(.49)	.05140846	.5837680	.1233	(.49)	.05260447
Milk Intake Day 240	.2737900	.2069	(.34)	.07554759	.31330620	.1662	(.42)	.04997554

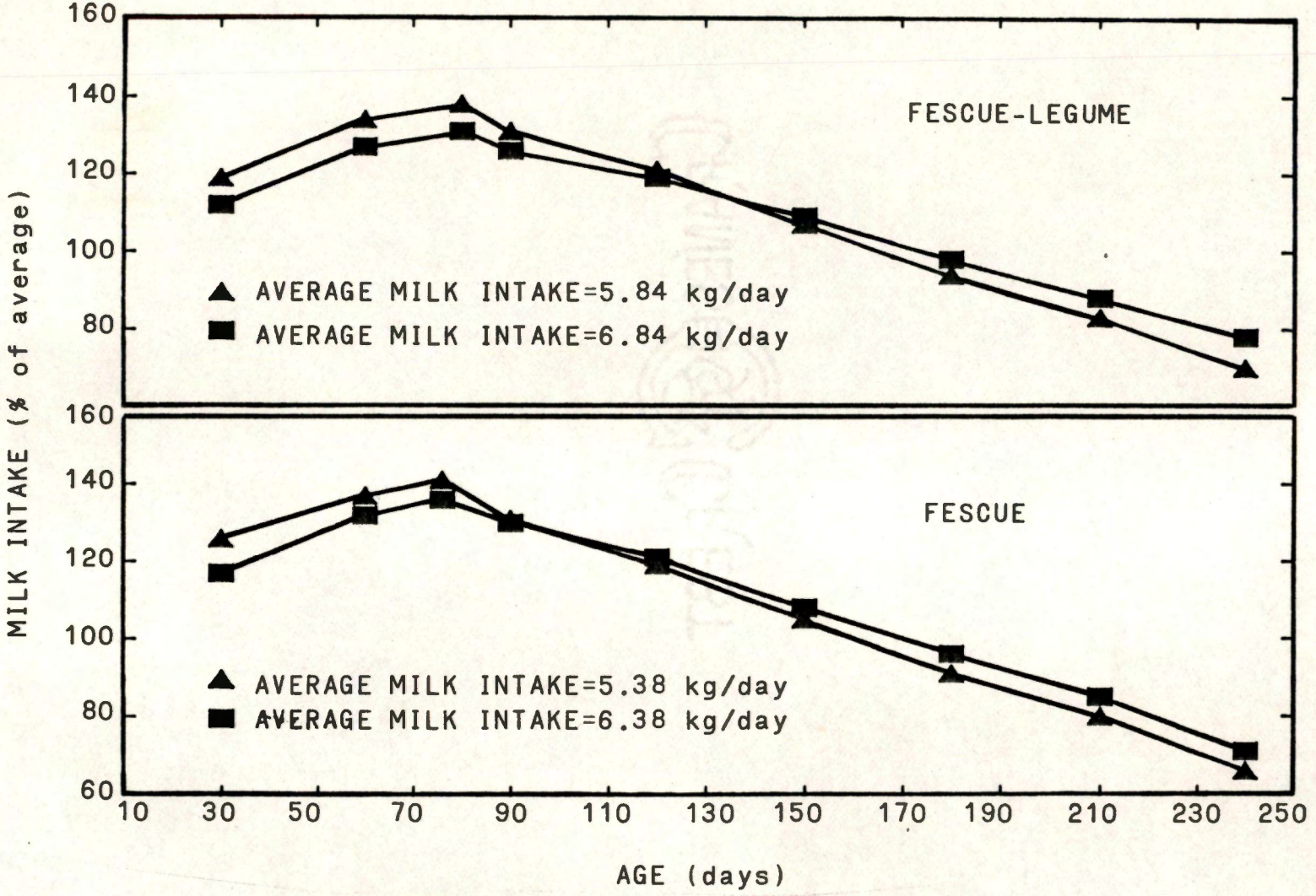


Figure 16. Effect of average milk intake on shape of lactation curve.

Table 9. Coefficients of simple correlation among weaning traits and milk intakes estimated at various times (average milk intake included)

	1	2	3	4	5	6	7	8	9	10	11	12
1. Weaning weight		.46[c]	.47	.47	.16	.16	-.01	-.16	-.33	-.10	-.11	-.13
2. Weaning height	.48[c]		.32	.22	.01	.03	-.08	-.15	-.19	-.04	-.03	-.03
3. Weaning fat	.35	.22		.10	-.01	-.01	-.03	-.01	.02	.01	.01	-.01
4. Milk intake-day 30	.45	.24	.29		.79	.74	.55	.23	-.37	-.24	-.37	-.48
5. Milk intake-day 60	.31	.12	.20	.82		.97	.94	.75	.16	-.62	-.89	-.95
6. Peak height	.29	.10	.17	.75	.97		.93	.75	.20	-.16	-.36	-.54
7. Milk intake-day 90	.21	.04	.13	.64	.96	.95		.92	.47	-.10	-.31	-.50
8. Milk intake-day 120	.08	-.05	.04	.42	.83	.84	.94		.77	.03	.43	-.63
9. Milk intake-day 150	-.26	-.24	-.22	-.31	.04	.11	.26	.56		.19	.10	-.01
10. Milk intake-day 180	-.37	-.20	-.28	-.80	-.82	-.76	-.70	-.43	.50		.88	.73
11. Milk intake-day 210	-.34	-.13	-.24	-.81	-.94	-.90	-.89	-.70	.17	.94		.76
12. Milk intake-day 240	-.31	-.10	-.22	-.80	-.96	-.91	-.93	-.79	.01	.86	.98	

[a]All variables are residuals from the model $\hat{Y}$ = year, sex, birth date (Julian day).

[b]Average milk intake included.

[c]Coefficients above the diagonal = Treatment 1; coefficients below the diagonal = Treatment 2.

$R > .26$ ($P < .01$)
$.20 \leq R \leq .26$ ($P < .05$)

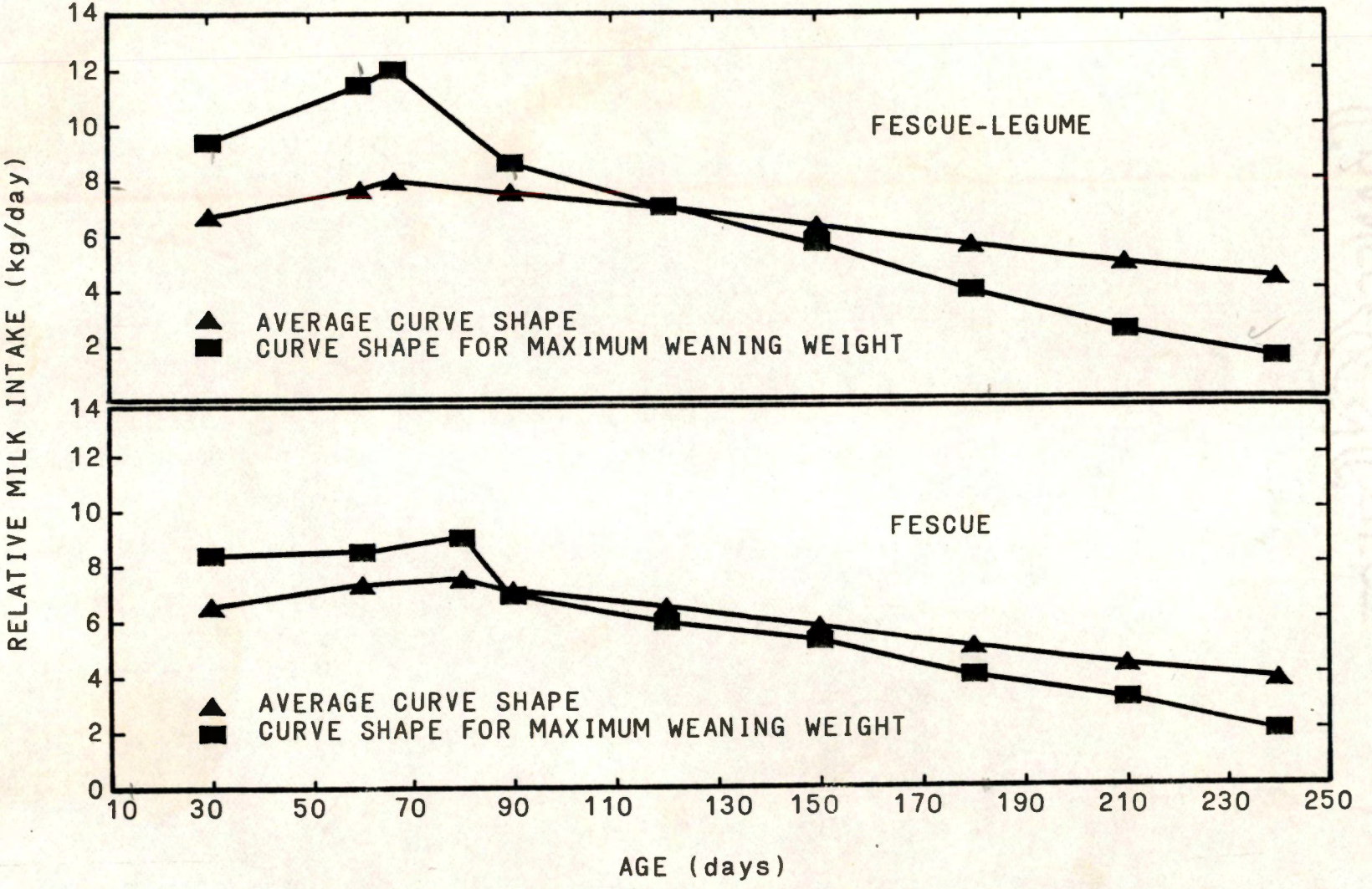


Figure 17. Milk intake above average milk intake associated with maximum weaning weight.

68 days for low quality pastures). In addition, correlation coefficients (Table 10) were calculated between milk intake variables and various weaning traits (weight, height, fatness) using the model Y = year, sex, birth date (Julian day) and average milk intake. These values were then corrected for average milk intake and correlation coefficients were recalculated to determine what effect average milk intake has upon the association of various milk intakes with weaning traits (Table 11, Figure 17).

Table 10. Coefficients of simple correlation among weaning traits and milk intakes estimated at various times (corrected for average milk intake)

	1	2	3	4	5	6	7	8	9	10	11	12
1. Weaning weight		.63[c]	.62	.78	.69	.69	.68	.68	.68	.66	-.61	.54
2. Weaning height	.61[c]		.47	.50	.42	.43	.41	.42	.43	.44	.42	.37
3. Weaning fat	.51	.32		.40	.38	.38	.40	.43	.45	.45	.42	.36
4. Milk intake-day 30	.69	.44	.46		.92	.90	.84	.77	.69	.58	.46	.32
5. Milk intake-day 60	.61	.35	.39	.89		.99	.98	.92	.84	.71	.56	.39
6. Peak height	.60	.34	.37	.85	.98		.98	.93	.85	.73	.58	.41
7. Milk intake-day 90	.62	.34	.38	.81	.97	.96		.98	.92	.82	.68	.52
8. Milk intake-day 120	.65	.36	.37	.72	.85	.86	.95		.98	.91	.80	.66
9. Milk intake-day 150	.62	.36	.33	.57	.63	.63	.77	.93		.98	.91	.79
10. Milk intake-day 180	.55	.33	.28	.40	.38	.38	.55	.77	.95		.97	.90
11. Milk intake-day 210	.47	.30	.22	.25	.19	.19	.35	.62	.86	.97		.98
12. Milk intake-day 240	.40	.28	.18	.13	.06	.06	.21	.49	.76	.92	.99	

[a]All variables are residuals from the model $\hat{Y}$ = year, sex, birth date (Julian day).

[b]Corrected for average milk intake.

[c]Coefficients above the diagonal = Treatment 1; coefficients below the diagonal = Treatment 2.

$R > .26$ ($P < .01$)
$.20 \leq R \leq .26$ ($P < .05$)

Table 11. Regression equations showing relationship of weaning traits, average milk intake and milk intakes estimated at various times

	High quality				Low quality			
	b_0	b_1	RSD	(R^2)	b_0	b_1	RSD	(R^2)
Weight at weaning	166.64073	13.92511205	17.5211	(.75)	147.35867	15.08228615	16.6375	(.72)
Weaning height	347.12552	6.34088422	16.2709	(.41)	359.31842	5.83280364	13.2648	(.44)
Weaning fat	2.0507600	.30391509	.8252	(.66)	1.6356313	.31163099	.7756	(.48)
Milk intake-day 30	2.0324516	.7361895	1.0328	(.56)	1.9622338	.8077755	.8607	(.64)
Milk intake-day 60	1.9649554	.8891194	1.2803	(.60)	.9971801	1.1414988	.9479	(.76)
Peak height	2.5681891	.9294202	1.3710	(.58)	.8329823	1.2059503	.9687	(.77)
Milk intake-day 90	1.3691478	1.0085599	1.0702	(.74)	.1201784	1.2965456	.8063	(.86)
Milk intake-day 120	.5959855	1.0984028	.6464	(.90)	- .4899540	1.3094330	.5654	(.92)
Milk intake day 150	- .173027	1.1564779	1.0702	(.97)	- .8394121	1.2568238	.3908	(.96)
Milk intake-day 180	- .8608405	1.1869759	.5379	(.92)	- .9887656	1.1623721	.4319	(.94)
Milk intake-day 210	- 1.4497906	1.1977325	.8554	(.83)	- 1.0054457	1.0493521	.6162	(.87)
Milk intake-day 240	- 1.9496106	1.1967891	1.1398	(.73)	- .9468444	.9330399	.8330	(.76)

[a]Includes effects of year, sex, birth date (Julian day).

V. RESULTS AND DISCUSSION

A. Pasture Quality Difference in Lactation Curve

Least-square means were compared by year and treatment to determine pasture quality differences in variables associated with lactation curve description, milk intake at various times, weaning traits and calf growth (Table 7, pg. 65).

The lactation variables such as average milk intake, milk intake at birth to day 240, milk intake at weaning and milk intake at peak of lactation were compared to show trends in curve shape during the five-year study. Average milk intake was highest for 1977 with calves on high quality pastures consuming 6.74 kg/day and calves on low quality pastures consuming 6.36 kg/day. Average milk intake was also the lowest in 1976 for both treatments with calves on high quality pastures consuming 4.27 kg/day and calves on low quality pastures consuming 4.6 kg/day. Significant differences were found for year ($P < .001$) and pasture quality ($P < .01$), but not for year by pasture quality ($P > .05$) in respect to average milk intake. In each year except 1976, of calves grazing high quality pastures, milk intakes were higher than for calves grazing low quality pastures, possibly because of factors relating to initiation of the project in regard to legume establishment. Milk intake at weaning was highest for the high quality pastures in 1978 (5.31 kg/day), but was highest for the low quality pastures in 1980 (4.79 kg/day) with the lowest values occurring in 1976 for both pasture qualities (2.34 and 1.95 kg/day), respectively. Milk intake at weaning had a significant difference with year ($P < .001$), pasture quality ($P < .03$) and year * pasture quality

($P < .0002$). Largest values for peak of lactation occurred in 1977 for the high quality pastures (85.46) and in 1980 for the low quality treatment (78.69) while the lowest values occurred in 1979 (61.90) and 1976 (34.86) for the high and low quality pastures, respectively. High values for 1977 were the results of high milk intake during the year while high peak values in 1980 for low quality pastures were the results of drought and small differences in pasture quality. Milk intake at various times resulted in a general pattern for each year in which lactation increased to about day 60 after which a decrease in lactation occurred.

Highest B_0 values (birth weight) occurred during 1980 (Table 7, pg. 65) for both high and low quality pastures (32.78 and 31.74 kg, respectively) while lowest birth weights occurred in 1976 for both pasture qualities (28.38 and 28.03 kg, respectively). Highest values for B_1 occurred in 1980 (.87 kg/day) for the high quality pastures and in 1976 (.93 kg/day) for the low quality pastures while the lowest values occurred during 1978 (.59 kg/day) for the high quality pastures and in 1978 (.62 kg/day) for the low quality pastures. Significant differences for year ($P < .0001$), pasture quality ($P < .0004$) and year by pasture quality ($P < .0001$) were detected for B_2 with minimum values occurring in 1980 (-.0008 kg/day^2, high quality) and 1976 (-.0005 kg/day^2, low quality) and (.0004 kg/day^2, low quality). Significant differences (Table 7, pg. 65) were detected for year ($P < .0001$) and pasture quality ($P < .02$) with reference to weaning weight and fat. The only significant difference for year * pasture quality interaction occurred with weaning fat ($P < .004$).

Lactation and growth curves (Figures 10-14) were constructed in an effort to evaluate differences across years in patterns of lactation and growth. These differences were visually appraised to determine trends in milk intake as utilized for calf growth.

Patterns of lactation in respect to pasture quality were very similar for the years 1977, 1978 and 1979 (Figures 11-13, pgs. 67-69). In each year the calves on high quality pasture consumed more milk and had higher peak levels. Also, in each year, the calves on high quality pasture had significantly higher ($P < .0001$) average milk intakes and milk intakes at weaning. These advantages correspond to heavier weaning weights at 240 days for the calves on high quality pasture. Dawson et al. (1960) reported correlations of .51 and higher for average daily gain and total milk intake. The general trend for these three years was that the higher average milk intake was associated with a heavier weaning weight. The growth curves for the three respective years did show a trend toward more curvilinearity as they approached weaning, possibly due to the larger calves' ability to consume and utilize more milk and forage dry matter. In 1976 (Figure 10, pg. 66), a different lactation pattern occurred with the calves on low quality pasture having a higher peak lactation, higher average milk intake and higher average daily gain or B_1 values when compared to calves on high quality pasture. But, at weaning, the high quality pasture calves had a significantly higher milk intake at weaning ($P < .03$) and weaning weight ($P < .0001$). In 1980 (Figure 14, pg. 70), the average milk intake was significantly higher ($P < .01$) for the calves on high quality pasture, but the calves on low quality pasture were consuming more milk ($P < .03$) at weaning.

To obtain a more precise understanding of the differences among years, lactation curves were combined for the years 1976-1979 (Figure 15, pg. 72) for two reasons: (1) although differences in lactation curves were evident between 1976 and 1977-1979, weaning weights were in general agreement with the calves on high quality pasture being significantly higher ($P < .0001$) and (2) differences were experienced outside of normal environmental conditions which warranted the separation of the lactation curve representing 1980 from the preceeding four years. After combining the lactation curves representing 1976-1979 the results tended to agree with the values of least-square means with the high quality pasture calves exhibiting higher peak lactations and maintaining their advantages in milk intake throughout lactation, an advantage explained by significant differences in weaning weights between pasture qualities.

Some general hypotheses can be made regarding the non-significant differences in weaning data concerning the two pasture qualities in 1980. First, early and more rapid growth due to residual nitrogen from previous years in the high quality pastures predisposed the pastures to faster maturing of the forage present. Secondly, and perhaps more importantly, during the drought conditions experienced in 1980 the cattle on low quality pasture qualities were able to graze forage of a more immature stage caused by the lack of an abundant source of forage. Pastures were kept at a more vegetative stage of growth in relation to the high quality pastures and the animals were obtaining forage of a more digestible or usable variety. Also, a measurable amount of dallisgrass was available for grazing in the low quality pastures which probably was utilized for grazing.

Regression procedures were utilized through the model Y = year, sex, pasture quality, A, b, c and all two-way interactions to determine how the variables that describe lactation curves (A, b and c) affect the calf growth variables (weaning weight, height and fatness, B_0, B_1 and B_2). It was determined that weaning weight was highly related to all three characters of the lactation curve ($P < .01$). In addition, weaning height and fatness were related to A, b and c with differences by year being significant ($P < .01$). B_0 or birth weight was highly related to A and b ($P < .01$) with significant interactions occurring for A, b and c with pasture quality. B_2 was also highly related ($P < .01$) to A and c with interactions with pasture quality being significant ($P < .01$). Therefore, curve shape or the characters depicting curve shape are apparently influential upon the variables associated with weaning traits and growth during lactation.

B. Relative Patterns of Milk Intake at Monthly Levels During Lactation

Average Milk Intake

Preliminary analysis indicated that average milk intake was significantly affecting all variables relating to depiction of the lactation curves. In regard to this association between shape of lactation curve and average milk intake, an equation was developed regressing milk intake at monthly intervals as a percent of the average or average milk intake (Table 8, p. 73). Through the utilization of the model $Y = b_0$ (year, sex, birth date (Julian day) + b_1 (average milk intake) to provide average milk intake for both treatments, it was determined that the average milk intake values were 5.84 kg/day for the calves on high quality pasture and 5.38 kg/day for the calves on low quality pasture.

Utilizing b values calculated in Table 8, pg. 73, a lactation curve was constructed denoting milk intakes at various times expressed as a percentage of average milk intake (Figure 16, pg. 74).

Hypothetical values of 1 kg/day above the average milk intake (5.84 and 5.38 kg/day, respectively) were added to the average milk intakes of both high and low quality pastures in an effort to determine how an increase in average milk intake would affect lactation trends and trends in calf performance (Figure 16, pg. 74). In general, an increase in average milk intake, though not dramatically expressed here, was associated with a relative increase in weaning weight. Also, as the average milk intake was increased, the lactation curves tended to become flatter. Thus, it can be theorized that the shape of the lactation curve is affected by an increase or decrease in average milk intake.

C. Relative Patterns of Milk Intake at Various Times Above Average Milk Intake

In order to study the pattern of milk intake above the average intake, correlation coefficients (Table 9, pg. 75) were calculated for the model: Y = year, sex, birth date (Julian day), average milk intake using weaning weight, height and fat, peak of lactation and milk intake from day 30 to 240 as dependent variables. These coefficients were compared across pasture quality only.

Weaning weight was high correlated (P .0001) with all weaning traits and peak lactation, but as lactation progressed, the correlations with milk intake at various times decreased and became negatively correlated during the later stages of lactation. The same pattern occurred for the low quality pasture, but negative correlations tended to not be

as significant ($P < .05$). The correlations with weaning height and fat, in general, were similar in pattern for both pasture qualities. Milk intake at day 30 for both pasture qualities was highly correlated with milk intake at day 60 and day 90 with the correlations with peak lactation also being significant ($P < .0001$). A negative correlation was attained between milk intake at day 30 and the latter milk intakes past day 120. The negative correlations were much higher for the high quality pastures, possibly explained by a higher milk intake early in life being associated with a more rapid decline during the later stages of lactation. In general, milk intakes at day 80 or greater were negatively associated with all milk intakes early in lactation and with weaning traits, but the correlations were more significant for the high quality pastures. Correlations for peak lactation and all weaning traits tended to be non-significant for both pasture qualities.

A second group of correlations were calculated with the omission of average milk intake from the model to determine the effect average milk intake had on the association of the various traits (Table 10, pg. 78). The correlations of the weaning traits with the remaining variables were higher in value than in the correlations with average milk intake in the model, though the correlations between weaning weight and milk intake at various times decreased as lactation proceeded. But more importantly, these correlations did not decrease for the low quality treatments. It would be reasonable to assume that the calves on low quality pasture were more dependent or made better utilization of that portion of milk intake above and beyond average milk intake. These comparisons are similar to data reported by Neville (1962) in which the researcher suggested that the relationship of milk to calf gain was

most important in the first 60 days of age. Kress et al. (1974) reported correlations of milk production with calf weight and future calf weight to be .49 and .59, respectively, which indicates that milk yield at a certain period of time is a good indicator of future calf gain in relation to weaning weight.

A series of regression equations were developed predicting weight, height and fatness at weaning from milk intake estimated at various times during lactation with all variables corrected for average milk intake. This was done to provide evidence as to the importance of curve shape to weaning traits. Using the model Y = year, sex, birth day (Julian day), peak lactation and milk intake at weaning, b values calculated and then compared with an additional set of b values calculated by the same model with average milk intake replacing peak lactation and milk intake at weaning. R^2 values for the models containing peak of lactation and milk intake at weaning and (average milk intake) were, respectively: weaning weight .74 (.69); weaning fatness .65 (.60) and weaning height .47 (.38). Therefore, in the above equations, the models containing peak lactation and milk intake at weaning explained 5-9% more variation in the above growth characteristics than did models containing average milk intake.

Regression equations predicting weaning traits and milk intakes at various times and average milk intake are shown in Table 11, pg. 79 and Figure 17, pg. 76, with comparisons made across pasture quality. More variation was explained in the low quality pastures when observing the R^2 values for milk intake at day 30 (.64, low quality; .56, high qualiyt), milk intake at day 60 (.76, low quality; .60, high quality),

milk intake at day 90 (.86, low quality; .75, high quality) and peak of lactation (.77, low quality; .58, high quality). Therefore, it can be stated that the shape of the lactation curve was more important for the growth of calves on low quality pasture than for the calves on high quality pasture.

In general, it can be stated that a decrease in peak lactation can be associated with a decrease in weaning weight given the same average milk intake. More importantly, the desirable lactation curves determined in this study were ones with higher peak lactations occurring at an early stage of lactation. These characteristics were deemed important in relation to preweaning performance of the calves during the entire lactation progression.

D. Relationship of Milk Constituents to Lactation and Calf Growth

In regard to the association of milk composition to various lactation and growth variables, the only significant ($P < .05$) correlation coefficients were the associations of B_1 with milk butterfat and solids-non-fat variables, values determined to be -.31 and .20, respectively. All other correlations with lactation and calf growth were small and non-significant.

LITERATURE CITED

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AOAC. 1970. Official Methods of Analysis (11th Ed.). Association of Official Agricultural Chemists. Washington, D.C.

Boggs, D.L., D.F. Smith, R.R. Schalles, B.E. Brent, L.R. Corah and R.J. Pruitt. 1980. Effects of milk and forage intake on calf performance. J. Anim. Sci. 51:550.

Brown, C. J. 1960. Influence of year and season of birth, sex, sire and age of dam on weights of beef calves at 60, 120, 180 and 240 days of age. J. Anim. Sci. 19:1062.

Burns, J.C., L. Goode, H.D. Bross and A.C. Linnerud. 1973. Cow and calf gains on ladino clover-tall fescue and tall fescue, grazed alone and with coastal bermudagrass. Agron. J. 65:877.

Christian, L.L., E.R. Hauser and A.B. Chapman. 1965. Association of preweaning and postweaning traits with weaning weight in cattle. J. Anim. Sci. 24:652.

Crampton, E.W. and L.E. Harris. 1961. Applied Animal Nutrition (2nd Ed.). W.H. Freeman and Co., San Francisco.

Crosthwait, G.L., L.D. Ridenour, R.D. Wyatt, L. Knori and R. Totusek. 1978. Effects of creep feeding on preweaning and postweaning performance of Angus x Hereford calves. Oklahoma Agri. Exp. Sta. MP103:35.

Dawson, W.M., A.C. Cook and Bradford Knapp, Jr. 1960. Milk production of beef Shorthorn cows. J. Anim. Sci. 19:502 (Abstr.).

Dickey, James R., M. Koger, Donald E. Franke and W.C. Burns. 1970. Milk production in beef cattle. J. Anim. Sci. 30:317 (Abstr.).

Drewery, K.J., C.J. Brown and R. S. Honea. 1959. Relationships among factors associated with mothering ability in beef cattle. J. Anim. Sci. 18:938.

Garrigus, R.R., H.W. Foutch and T.C. Bigger. 1975. Orchardgrass vs fescue for cow-calf production. J. Anim. Sci. 40:182 (Abstr.).

Hardison, W.A., J.T. Reid, C.M. Martin and P.G. Woolfolk. 1954. Degree of herbage selection by grazing cattle. J. Dairy Sci. 37:89.

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

Hill, G.M., N.W. Bradley and J.A. Boling. 1979. Cow and calf performance on tall fescue- o.e. Kentucky bluegrass-ladino clover forages. J. Anim. Sci. 49:44.

Hohenboken, W.D., E.R. Hauser, A.B. Chapman and L.V. Cundiff. 1973. Phenotypic correlations between dam traits expressed during development and lactation and traits of progeny in cattle. J. Anim. Sci. 37:1.

Holloway, J.W., D.F. Stephens, J.V. Whiteman and Robert Totusek. 1975. Performance of 3-year-old Hereford, Hereford x Holstein and Holstein cows on range and in drylot. J. Anim. Sci. 40:114.

Holloway, J.W., W.T. Butts, Jr., J.D. Beaty, J.T. Hopper and N.S. Hall. 1979. Forage intake and performance of lactating beef cows grazing high or low quality pastures. J. Anim. Sci. 48:692.

Horn, F.P., J.P. Telford, J.E. McCroskey, D.F. Stephens, J.V. Whiteman and Robert Totusek. 1979. Relationship of animal performance and dry matter intake to chemical constitutents of grazed forage. J. Anim. Sci. 49:1051.

Jeffery, H.B., R.T. Bert and R.T. Hardin. 1971. Factors influencing milk yield of beef cattle. Can. J. Anim. Sci. 51:551.

Kellogg, D. Wayne, J. Scott Urquhart and A.J. Ortega. 1977. Estimating Holstein lactation curves with a Gamma curve. J. Dairy Sci. 60:1308.

Kress, D.D. and D.C. Anderson. 1974. Production in Hereford cattle. J. Anim. Sci. 38:1320 (Abstr.).

Lammond, D.R., J.H.G. Holmes and K.P. Haydock. 1969. Estimation of yield and composition of milk produced by grazing beef cows. J. Anim. Sci. 29:606.

Lusby, K.S., D.F. Stephens, Leon Knori and Robert Totusek. 1976. Effects of milk intake by calves on feed intake and digestibility. Oklahoma Agr. Exp. Sta. MP93:33.

Marlowe, Thomas J. and James A. Gaines. 1958. The influence of age, sex and season of birth of calf and age of dam on preweaning growth rate and type score of beef calves. J. Anim. Sci. 17:706.

Marshall, D.A., W.R. Parker and C.A. Dinkel. 1976. Factors affecting efficiency to weaning in Angus, Charolais and reciprocal cross cows. J. Anim. Sci. 43:1176.

Melton, A.A., J.K. Riggs, L.A. Nelson and T.C. Cartwright. 1966. Milk production, composition and calf gains of Angus, Charolais and Hereford cows. J. Anim. Sci. 26:804.

Neville, W.E., Jr. 1962. Influence of dam's milk production and other factors on 120- and 240-day weight of Hereford calves. J. Anim. Sci. 21:315.

NRC. 1976. Nutrient requirements of domestic animals, No. 4. Nutrient requirements of beef cattle. National Academy of Sciences--National Research Council, Washington, D.C.

Rahnefeld, G.W., R.J. Parker, S. Yodseranee and E.W. Stringam. 1980. Influence of body weight and changes in body weight of the cow on preweaning traits of the calf. Can. J. Anim. Sci. 60:599.

Reynolds, W.L., T.M. Derouen and R.A. Bellows. 1978. Relationships of milk yield of dam to early growth rate of straightbred and cross-bred calves. J. Anim. Sci. 47:584.

Rollins, W.C. and H.R. Guilbert. 1954. Factors affecting the growth of beef calves during the suckling period. J. Anim. Sci. 13:517.

Rutledge, J.J., O.W. Robison, W.T. Ahlschwede and J.E. Legates. 1971. Milk yield and its influence on 205-day weight of beef calves. J. Anim. Sci. 33:563.

Schaeffer, L.R., C.E. Minder, I. McMillan and E.B. Burnside. 1977. Nonlinear techniques for predicting 305-day lactation production of Holsteins and Jerseys. J. Dairy Sci. 60:1636.

Schaeffer, L.R. and E.B. Burnside. 1976. Estimating the shape of the lactation curve. Can. J. Anim. Sci. 56:157.

Smith, W.H., V.L. Lechtenbery, D.C. Peritz and K.G. Hawkins. 1976. Cows grazing orchard, fescue or grass-legume. J. Anim. Sci. 41:339 (Abstr.).

Spike, P.W. and A.E. Freeman. 1967. Environmental influences on monthly variation in milk constitutents. J. Dairy Sci. 50:1897.

Steel, R.G.D. and J.H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., New York.

Stricker, J.A., A.G. Matches, G.B. Thompson, V.E. Jacobs, F.A. Martz, H.N. Wheaton, H.D. Currence and G.F. Krause. 1979. Cow-calf production on tall fescue-ladino clover pastures with and without nitrogen fertilization or creep feeding: spring calves. J. Anim. Sci. 48:13.

Thompson, N.R. and C.W. Holdaway. 1954. Alfalfa-orchardgrass, ladino clover-orchardgrass and ladino clover-Kentucky-31 fescue pastures for milk production. J. Dairy Sci. 37:666 (Abstr.).

Totusek, Robert. 1968. Early weaning vs normal weaning vs creep feeding of heifer calves. Oklahoma Agr. Exp. Sta. MP80:72.

Totusek, Robert, Dudley W. Arnett, G.L. Holland and J.V. Whiteman. 1973. Relation of estimation method, sampling interval and milk composition to milk yield of beef cows and calf gain. J. Anim. Sci. 37:153.

Tyrrell, H.F. and J.T. Reid. 1965. Prediction of the energy value of cow's milk. J. Dairy Sci. 48:1215.

Van Soest, P.J. 1963. Use of detergents in the analysis of fibrous feeds. II. A rapid method for the determination of fiber and lignin. J. Assoc. Official Agr. Chem. 46:825.

Van Soest, P.J. 1965. Symposium on factors influencing the voluntary intake of herbage by ruminants: voluntary intake in relation to chemical composition and digestibility. J. Anim. Sci. 24:834.

Wood, P.D.P. 1969. Factors affecting the shape of the lactation curve in cattle. Anim. Prod. 11:307.

Wood, P.D.P. 1974. A note on the estimation of total lactation yield from production on a single day. Anim. Prod. 19:393.

Wood, P.D.P. 1976. Algebraic models of the lactation curves for milk, fat and protein production, with estimates of seasonal variation. Anim. Prod. 22:35.

Wood, P.D.P. 1977. The biometry of lactation. J. Agr. Sci. (Camb.) 88:333.

Wyatt, R.D., M.B. Gould, J.V. Whiteman and Robert Totusek. 1977. Effect of milk level and biological type of calf growth and performance. J. Anim. Sci. 45:1138.

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