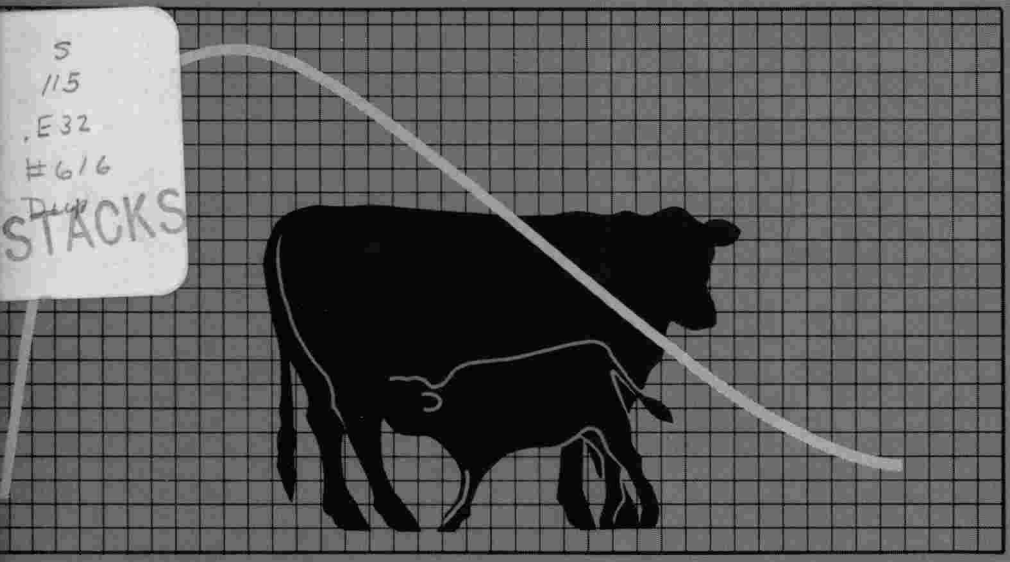
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Lactation Curves of Angus Cows Grazing Fescue-Legume or Fescue Pastures

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Lactation Curves of Angus Cows Grazing Fescue-Legume or Fescue Pastures

J. W. Holloway[1], T. L. Worley[1], and W. T. Butts, Jr.[2]

SUMMARY

One hundred and ninety-seven lactation curves of mature Angus cows grazing fescue-legume or fescue pastures were described by a "gamma" model (average R^2 of .903, with no lack-of-fit detected). The curves were based on milk intake of Angus calves as determined by the weigh-suckle-weigh method. Milk intake curves of calves grazing fescue-legume pastures generally had similar levels at peak intake, but were more persistent than those of calves grazing fescue, reflecting a difference in forage quality ingested by their dams during the summer. Calves consuming larger amounts of milk as an average of lactation were heavier, taller and fatter at weaning. The relationship of milk intake and weaning traits was more pronounced for calves grazing fescue ($r = .46$ to $.76$) than for those grazing fescue-legume ($r = .39$ to $.69$). Calves that consumed larger amounts of milk had more even distributions of milk intake than calves consuming less milk as an average of lactation. Also, for calves consuming similar amounts of milk as an average of lactation, the most desirable pattern of milk intake for calf growth was one described by a high peak and low persistency. Calves consuming similar amounts of milk as an average of lactation that consumed milk in this distribution grew more rapidly early. They were subsequently able to consume relatively large quantities of forage late in lactation, when forage quality was high, and thus were heavier at weaning. The correlation between weaning weight and average milk intake through lactation would have been higher, except for the partial counterbalancing association between high average milk intake and relatively flat milk intake curves.

(Key Words: Beef Cattle, Milk Production, Preweaning Nutrition, Growth).

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INTRODUCTION

Amount of milk consumed by beef calves has been shown to be an important determinant of growth (Knapp and Black, 1941; Drewry *et al.*, 1959; Neville, 1962; Brumby *et al.*, 1963; Furr and Nelson, 1964; Christian *et al.*, 1965; Klett *et al.*, 1965; Melton *et al.*, 1967). The importance of milk to calf growth, however, is generally thought to change as lactation progresses and as the calf gets older. Most researchers have reported that the correlation between milk consumption and rate of growth decreases as lactation progresses (Neville, 1962; Brumby *et al.*, 1963; Gleddie and Berg, 1968), although some workers have reported increasing correlations (Gifford, 1953; Drewry *et al.*, 1959). These results give some evidence that shape of the lactation curve might be related to the rate of calf growth. Differences among beef breeds in amount and distribution of milk produced during lactation have been reported (Kropp *et al.*, 1973b; Holloway *et al.*, 1975; Gaskins and Anderson, 1980; Chenette and Frahm, 1981).

The purpose of this study was to estimate relationships between patterns of milk intake (amount and distribution) and weaning traits of calves grazing fescue-legume or fescue pastures.

EXPERIMENTAL PROCEDURE

Animal Management. One hundred and ninety-seven lactations of mature (5- to 12-yr-old) Angus cows grazing either fescue-legume or fescue pastures were observed over a 5 yr period (1976 to 1980). All cows nursed straightbred calves born from January through March and weaned in October of each year (average calf age of about 240 d).

Cows were randomly allotted to either fescue-legume or fescue pastures at calving time. Fescue-legume pastures consisted of about 60 to 70% Kentucky-31 tall fescue (*Festuca arundinacea* Schreb., IFN 2-01-434) and 30 to 40% legume, consisting of red clover (*Trifolium pratense* L., IFN 2-01-434), Korean and Kobe lespedeza (*Lespedeza stipulacea* Maxim., IFN 2-02-598) and white clover (*Trifolium repens* L., IFN 2-01-383). Fescue pastures were almost homogeneous stands of tall fescue. Both types of pasture were mowed for hay in June of each year. Within each pasture type, cows were allotted to two 8.1-ha pastures (10 cows with calves/pasture/yr). Cows and calves were rotated between the two pastures within pasture type each week. These procedures generally resulted in large quality differences between pasture types, especially during the summer (Holloway *et al.*, 1979). A drought was experienced during 1980, resulting in poor legume growth; the quantity of forage available, however, was greater for fescue-legume than for fescue pastures during the summer, possibly a result of residual nitrogen from previous legume growth. Although more forage was available, it was low in quality when compared to other years.

Twenty to 40% of the cows were replaced each fall. A few animals died during the 5 yr. of the project, and all data dealing with them were omitted.

Estimation of Milk Intake. Twenty-four h. milk consumption was estimated by the weigh-suckle-weigh technique (seven estimates per year) at monthly intervals beginning in April of each year. Each year, the first estimates were made before many of the cows had reached peak lactation. Calves were confined with their dams at 1700 h and then separated from them at 1800 h for a 12-h period. They were then weighed before and after nursing the next morning at 0600 h. They were again separated from the dams until 1800 h at which time the weigh-suckle-weigh procedure was repeated. Some researchers have suggested the need for a period of separation at the beginning of the procedure so that the udder will be "empty" at the beginning of the 24-h period (Drewry *et al.*, 1959). This was not done in this study, because a preliminary 48-h grazing behavior study (Hopper *et al.*, 1978) indicated that calves normally nursed at 1800 h. This agreed with other observations made during the experiment and with the results of Kropp *et al.* (1973a). The calves were observed during the hour that they were confined before the first 12-h separation, and nearly all nursed at that time.

Calf Growth. Quadratic polynomials ($R^2 > .90$) were fitted through a series of each calf's weights taken at monthly intervals (with overnight shrinks) from birth to weaning. These polynomials were evaluated at monthly intervals in order to describe the nature of growth.

Wither height and fatness were measured for each calf at weaning. Fatness was measured ultrasonically[3] at the 12th rib. The sample of experimental animals is described in table 1.

Description of Lactation Curve. The shape of the lactation curve for each cow (milk intake curve for each calf) was described with the equation of Wood (1977):

$$\hat{Y}_n = an^b e^{cn}, \quad (1)$$

where $\hat{Y}_n$ is the milk consumption at time n, n is the day of lactation (calf age), e is the base of natural logarithms and a, b and c are coefficients defining the lactation curve (a is the scaling factor, b is curvilinearity before peak and c is curvilinearity after peak; Wood, 1976). The lactation peak (turning point, days) was calculated as follows:

$$n_p = -(b/c), \quad (2)$$

Nonlinear procedures of the Statistical Analysis System (Barr *et al.*, 1979) were used in fitting this model. Nonlinear procedures were used instead of

[3]Ultrasonic Animal Tester-Sonoray® , Model 12, Bronson Instruments, Inc. Bethel, Conn.

linear regressions of Log_e transformations because these transformations result in lack-of-fit (Cobby and LeDu, 1978). In preliminary analyses, difficulty was experienced in obtaining convergence. We found that although milk intake estimates were obtained for all calves before peak consumption (observed in preliminary plots), not enough early points were available for convergence to occur within the 50 iterations deemed reasonable. Therefore three early milk intakes (at 10, 20 and 30 d of age) were calculated from nutrient requirements of the calves. This seemed to be justified since at this time (10 to 30 d of age) beef calves consume very little nonmilk nutrients. When these early calculated points were added to the data set, convergence was easily obtained and the resultant curves fit the observed milk consumptions well (average $R^2 = .903$). Residual plots were inspected and no indication of lack-of-fit (systematic bias) was noted for either the observed or calculated points. Since the section of the curves of primary interest was from peak consumption to weaning, and since no trends were noted in the residual plots (either for individual cows or when data from all 197 cows were plotted), we concluded that the only apparent effect of the addition of calculated points to the data set was to make convergence possible. The term "lactation curve" will denote that part of lactation estimated from the weigh-suckle-weigh technique (30 to 240 d of calf age). Any three milk intakes provide all the information available (since there are three parameters in the model). Analysis of monthly intakes are presented, however, to graphically illustrate shape of curve. Average daily milk intake was estimated by evaluating each calf's milk intake curve at monthly intervals and then averaging these values.

Calf nutrient requirements were calculated by evaluation of the quadratic polynomials describing calf growth in weight for 10, 20 and 30 d of age. These evaluated weights and growth rates were used to calculate net energy for maintenance (NE_M) and net energy for gain (NE_G) requirements for each calf at 10, 20 and 30 d of age (NRC, 1976). NE_M and NE_G values for the milk consumed by the calf were calculated from the fat and total solids content of milk obtained by a total milk-out procedure (Tyrrell and Reid, 1966). Three milk samples were obtained for fat and total solids analysis during the fourth, fifth and sixth months of lactation. These samples were taken by total milk-out with a milking machine after 3-h calf separations and IM injections of 10 IU of oxytocin. Fat content was determined by a turbidometric method.[4]

Forage Intake. Three forage intake and digestibility trials were conducted with the calves born during the last 4 yr. of the experiment. The trials began when the calves were 109 (trial 1), 142 (trial 2) and 192 d of age (trial 3). An internal (permanganate acid detergent lignin; Van Soest, 1963), external (Cr_2O_3) indicator method was used (Crampton and Harris, 1969). Each trial consisted of a 5-d preliminary and a 5-d collection period. Forage

[4]Mark III Milk-O-Tester, A/S N. Foss Electric Hillerod Denmark

samples were obtained by selective clipping forage the calves were observed to be consuming. During each trial, calves were bolused with 2.5g Cr_2O_3 at 0800 and 1700 h. During the collection periods, fecal grab samples were also taken at 0800 and 1700 h. Fecal samples were composited on wet weight basis and dried at 60 C before analysis. Forage samples were also dried at 60 C. Digestible energy (DE) was calculated from dry matter (DM) digestibility by the equations of Heany and Pigden (1963).

Statistical Analyses. Preliminary analyses consisted of determining simple linear correlations among weaning and growth traits, lactation curve coefficients and milk composition data. These analyses indicated that the lactation curve coefficients were correlated ($r > .60$, $P < .01$) with each other and, therefore, that each coefficient could not be described independently. Subsequent analysis of the nature of the curve consisted of calculating from the coefficients certain graphically depictable characteristics of the curve (age and milk intake at peak, persistence and milk intake at monthly intervals during lactation), and then relating these to weaning and growth traits. These curve characteristics were then regressed on average milk intake to determine the relationship between the shape of the curve and the level of milk intake.

Monthly estimates of milk intake were also used in analyses designed to determine the relationship between the shape of the curve and weaning characteristics, independent of level of milk intake. First, all weaning characteristics and the monthly milk intakes were corrected for year, sex, birth date and average milk intake by regression procedures:

$$\hat{Y} = \text{year, sex, birth date, average milk intake} \quad (3)$$

Preliminary plots indicated that the characteristics of interest (weight, height and fatness at weaning and monthly estimates of milk intake) were linearly related to birth date and average milk intake, and, therefore, quadratic terms for these variables were not included in this model. Residuals from the model contained the variation in the characteristics of interest free from variation in year, sex, birth date and average milk intake. Therefore, subsequent analyses were designed to determine the relationship between weaning characteristics and the shape of the curve independent of variation in levels of milk intake. Preliminary plotting indicated nonlinear relationships, so the following expression was fitted:

$$\hat{Y} = b_0 + b_1 x + b_2 x^2, \quad (4)$$

where $\hat{Y}$'s were data sets of residuals from models (equation 3) with weight, fatness and wither height measured at weaning as dependent variables, and x's were residuals from models (equation 3) with estimates of milk intake made at monthly intervals (30 d of age to weaning) as dependent variables.

RESULTS AND DISCUSSION

Patterns of Milk Intake of Calves Grazing Fescue-Legume or Fescue Pastures. Least-square means for curve coefficients are presented in table 1. These coefficients are different from those reported for dairy cattle by Wood (1969). He reported means of 3.74, .20, and -.04 for a, b and c, respectively. Since a is the scaling factor, estimates for dairy cattle should be greater than those for Angus under pasture conditions, but the large differences noted in b and c reflect large differences in shape. A large amount of variation among animals was noted in a, b and c (coefficients of variation $> 50\%$). Year x pasture type interactions were noted ($P < .04$) for all three coefficients. Therefore, means for year and pasture type are shown in table 1, and all subsequent results are reported separately for each pasture type. Year differences ($P < .05$) were detected for both a and b, whereas pasture type differences ($P < .06$) were detected for c.

As shown by the estimated milk intakes at the various times during lactation (table 1), pasture type differences were not detected ($P > .05$) until calves were 60 d of age. As lactation progressed, the difference between pasture type in milk intake became greater (figure 1, 1976 to 1979). A preliminary report on forage digestibility of these pastures indicated that the pastures did not vary greatly in quality until summer (Holloway *et al.*, 1979). Thus, differences in milk intake (milk production) during mid to late lactation appear to be related to quality of forage available at that time. Also, Holloway *et al.* (1979) reported that midsummer differences in forage quality did not influence average milk production. Analysis of data collected over a 5-yr period indicated a marked year x pasture type interaction ($P < .01$, table 1, figure 1). This interaction appeared to be due largely to differences between 1980 and 1976 to 1979. The largest pasture type differences in shape were noted in 1978 and 1979, and, these were associated with large differences in summer pasture qualities. A drought was experienced in 1980, resulting in poor legume stands and relatively "stemmy" growth on the fescue-legume pastures, and, consequently, the calves on the pasture type held only a 1.8 kg (4.0 lb) advantage in weaning weight over calves grazing fescue pastures. A mean advantage of 22 kg (48.5 lb) for calves grazing fescue-legume pastures was noted for the other 4 years. The pasture-type effect was probably due in part to differences in forage quality and quantity consumed by the calves, but it was also a result of differences in average milk intake and differences in distribution of that intake.

The average calf age at peak milk intake was 78.4 d, but considerable variation among animals (c.v. = 122%) was noted, with a tendency for calves grazing fescue-legume to peak about 10.5 d later than those grazing fescue pastures. Harris *et al.* (1963) also found that peak milk yield of beef cows occurred between 30 and 90 d postpartum.

Relationship Between Level of Milk Intake and Shape of Lactation Curve. The influence of level of milk intake on shape of lactation curve is

presented as the regression of milk intake at monthly intervals expressed as a percent of average milk intake on average milk intake (table 2 and figure 2). For a graphic illustration of these relationships, the equations in table 2 were evaluated for average milk intake and an intake of 1 kg (2.2 lb) above average (for each pasture type), and these were plotted (figure 2). Milk intake as a proportion of the average was negatively related ($P < .01$) to the average early in lactation and positively related ($P < .01$) to the average later in lactation (table 2). The demarcation point was about 120 d of age for calves grazing fescue-legume pastures and 90 d of age for calves grazing fescue pastures. These data provide evidence that cows averaging larger amounts of milk during lactation (calves consuming larger amounts) have flatter (more persistent) lactation curves.

Influence of Level of Milk Intake on Weaning Traits. At weaning, calves grazing fescue-legume pastures were 17.9 kg (39.5 lb) heavier ($P < .01$), .24 mm (.01 in) fatter ($P < .05$) and .44 cm (.17 in) taller ($P < .07$) at the withers than calves grazing fescue pastures (table 1). These differences were not consistent across years, resulting in year x pasture type interactions ($P < .06$; table 1) for all traits except wither height. The differences in weaning traits due to pasture type appeared to parallel differences in average milk intake, although other factors such as differences in distribution of milk intake and differences in forage intake were undoubtedly involved.

Correlations within pasture type, sex, year and birth date (table 3) indicated that milk intake was positively related to all weaning traits. Magnitude of the coefficients of correlation declined as lactation progressed, except in the case of fatness for calves grazing fescue pastures. Coefficients were higher for fescue than for fescue-legume pastures, indicating that calves grazing the lower quality fescue pastures were more dependent upon milk for growth than calves grazing the higher quality fescue-legume pastures.

This effect of pasture type on the correlation between weaning traits and level of milk intake has not been reported previously, and perhaps explains some of the variation in this correlation that exists in the literature. The correlations (table 3) between milk intake and weaning traits for calves grazing fescue-legume pastures may be overestimated because of the confounding between peak milk intake and forage intake during late lactation (table 4). Among calves grazing fescue-legume, those that consumed more milk at peak lactation tended to consume more forage DE, although this relationship was significant only during the third trial (table 4). Calves allotted to fescue-legume pastures consumed an additional .67 Mcal DE more forage kg (.3 Mcal DE/lb) increase in peak milk intake at 192 d of age. Calves that grazed fescue pastures and consumed large amounts of milk at peak lactation did not consume larger quantities of forage later in lactation (table 4). Evidently, when the calf is young and depends largely on milk as a nutrient source, ability to consume large amounts of milk is conducive to growth, making the calf capable of consuming large quantities of forage in later lac-

tation if forage quality is adequate. An alternate explanation is that calves with large appetites for milk also have large appetites for forage.

Influence of Distribution of Milk Intake, Independent of Level of Milk Intake, on Weaning Traits. Since both shape of the lactation curve and weaning traits were related to the level of milk intake, (average of lactation), to study the relationship between weaning traits and shape of the lactation curve, we removed the confounding effect of the level of milk intake. We accomplished this by performing an analysis with data sets that were previously corrected for the effect of level of milk intake (table 3 and figure 3). Shape of the lactation curve was more related to weaning weight than to either wither height or fatness at weaning, although the same general trends were noted for all three weaning traits. Multiple regression procedures indicated that within year, sex, birth date and level of milk intake, about 40% of the variation in weaning weight among calves grazing fescue was explained by variation in shape of the lactation curve. For calves grazing fescue-legume pastures, about 15% of the variation in weaning weight was explained.

Milk intake early in lactation was positively correlated ($P < .01$) with weaning traits, whereas, later in lactation, the correlations were negative ($P < .01$; table 3). Figure 3 also indicates that, regardless of pasture type, calves that were heaviest at weaning were those that consumed a large proportion of their milk early in life, and the most desirable shape was one of high peak and low persistence. This may have resulted in part from rapid early growth associated with high milk production causing the calves to be well developed when milk no longer met their requirements. These calves were then able to consume large quantities of forage when forage quality was high (table 4). Even though calves grazing fescue depended more upon level of milk intake for growth than calves grazing fescue-legume pastures, the shape of lactation curve conducive to growth was the same regardless of pasture type.

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Table 1. Least-Squares Means for Weaning Traits and Milk Intake[a]

Item	Year	Pasture type: Fescue-legume 1976	1977	1978	1979	1980	Fescue 1976	1977	1978	1979	1980	Level of significance[c]: RSD[b]	Pasture type	Year	Year x pasture type
Weaning and growth traits															
Weights, kg[d] (lb)		248.1 (547)	219.9 (485)	229.3 (506)	242.0 (534)	199.5 (440)	224.4 (495)	209.9 (463)	208.3 (459)	209.2 (461)	197.7 (436)	24.68 (544)	<.0001	<.0001	<.06
Fatness, mm (in)		4.7 (.2)	2.2 (.1)	2.6 (.1)	4.6 (.2)	2.6 (.1)	3.9 (.2)	2.2 (.1)	2.8 (.1)	3.6 (.1)	3.0 (.1)	.91 (.04)	<.05	<.0001	<.002
Wither height, cm (in)		98 (38.7)	95 (37.4)	99 (38.8)	98 (38.7)	96 (37.7)	96 (37.9)	96 (37.7)	97 (38.1)	96 (37.7)	96 (37.7)	4.3 (1.70)	<.07	<.09	>.20
Daily gain from birth to weaning, kg/d[d] (lb/d)		.86(1.9)	.78(1.7)	.79(1.7)	.83(1.8)	.67(1.5)	.78(1.7)	.73(1.6)	.72(1.6)	.69(1.5)	.67(1.5)	.092(.20)	<.01	<.01	<.04
Lactation curve shape coefficients															
a		4.309	.756	1.316	2.304	3.039	3.052	.762	1.517	1.929	4.532	1.8170	>.20	<.01	<.02
b		.192	.969	.548	.442	.421	.353	.828	.532	.461	.201	.2846	>.20	<.0001	<.04
c		−.0058	−.0121	−.0057	−.0066	−.0075	−.0084	−.0115	−.0074	−.0079	−.0031	.00435	<.06	<.10	<.007
Lactation characteristics															
Age at peak, d[d]		83.4	90.2	109.2	85.5	75.9	35.1	76.1	70.2	70.8	87.4	95.63	<.13	>.20	>.20
Milk intake at 30 d age, kg/d[d] (lb/d)		6.44 (14.2)	6.79 (15.0)	6.21 (13.7)	6.43 (14.2)	7.83 (17.3)	7.10 (15.7)	7.10 (15.7)	6.16 (13.6)	6.03 (13.3)	6.43 (14.2)	1.346 (2.97)	>.20	<.005	<.01
Milk intake at 60 d age, kg/d[d] (lb/d)		6.20 (13.7)	9.23 (20.4)	7.63 (16.8)	7.17 (15.8)	8.41 (18.5)	7.04 (15.5)	8.94 (19.7)	7.18 (15.8)	6.56 (14.5)	6.86 (15.1)	1.780 (3.93)	<.05	<.0001	<.05
Milk intake at peak, kg/d[d] (lb/d)		6.48 (14.3)	9.66 (21.3)	8.12 (17.9)	7.31 (16.1)	8.49 (18.7)	7.36 (16.2)	9.18 (20.2)	7.32 (16.1)	6.72 (14.8)	6.94 (15.3)	1.695 (3.74)	<.09	<.0001	<.05
Milk intake at 90 d kg/d[d] (lb/d)		5.64 (12.4)	9.52 (21.0)	8.01 (17.7)	7.04 (15.5)	7.91 (17.4)	6.30 (13.9)	8.91 (19.6)	7.15 (15.8)	6.28 (13.8)	6.79 (15.0)	1.717 (3.79)	<.03	<.0001	<.17
Milk intake at 120 d age, kg/d[d] (lb/d)		5.02 (11.1)	8.74 (19.3)	7.88 (17.4)	6.62 (14.6)	7.06 (15.6)	5.41 (11.9)	8.08 (17.8)	6.67 (14.7)	5.72 (12.6)	6.51 (14.4)	1.612 (3.55)	<.01	<.0001	>.20
Milk intake at 150 d age, kg/d[d] (lb/d)		4.42 (9.7)	7.57 (16.7)	7.50 (16.5)	6.11 (13.5)	6.17 (13.6)	4.56 (10.1)	6.96 (15.3)	6.02 (13.3)	5.10 (11.2)	6.16 (13.6)	1.533 (3.38)	<.007	<.0001	<.11
Milk intake at 180 d age, kg/d[d] (lb/d)		3.88 (8.6)	6.39 (14.1)	7.00 (15.4)	5.63 (12.4)	5.35 (11.8)	3.79 (8.4)	5.82 (12.8)	5.33 (11.8)	4.50 (9.9)	5.80 (12.8)	1.521 (3.35)	<.007	<.0001	<.02
Milk intake at 210 d age, kg/d[d] (lb/d)		3.39 (7.5)	5.28 (11.6)	6.44 (14.2)	5.21 (11.5)	4.63 (10.2)	3.14 (6.9)	4.77 (10.5)	4.66 (10.3)	3.95 (8.7)	5.46 (12.0)	1.563 (3.45)	<.008	<.0001	<.004
Milk intake at 240 d age, kg/d[d] (lb/d)		2.99 (6.6)	4.34 (9.6)	5.88 (13.0)	4.86 (10.7)	4.03 (8.9)	2.59 (5.7)	3.86 (8.5)	4.04 (8.9)	3.47 (7.7)	5.17 (11.4)	1.640 (3.62)	<.01	<.0001	<.011
Persistence, kg/d[e] (lb/d)		-.017(-.04)	-.034(-.08)	-.016(-.04)	-.014(-.03)	-.024(-.05)	-.024(-.05)	-.032(-.07)	-.019(-.04)	-.018(-.04)	-.010(-.02)	.0120 (.026)	>.20	<.0001	<.002
Average milk intake, kg/d[d,f] (lb/d)		4.67 (10.3)	6.50 (14.3)	6.42 (14.2)	5.70 (12.6)	6.02 (13.3)	4.75 (10.5)	6.11 (13.5)	5.40 (11.9)	4.81 (10.6)	5.96 (13.1)	1.232 (2.72)	<.01	<.0001	<.19

[a]Least-squares means from the model $\hat{Y}$ = year, pasture quality, sex, birth date, year x pasture quality.

[b]Residual standard deviation.

[c]Probability of a greater F as calculated from partial sums of squares.

[d]Evaluated from equations developed for each calf: milk intake = an^be^{cn}.

[e]Persistence = (milk intake at 240 d of age - milk intake at peak) /d from peak to 240 d of age.

[f]Average milk intake was obtained by averaging the monthly estimates evaluated from each lactation curve.

Table 2. Relationship between Shape of Lactation Curve and Level of Milk Intake

	Pasture type							
	Fescue-legume				Fescue			
Predicted variables	Intercept[b]	b_1	R^2	RSD	Intercept	b_1	R^2	RSD
Milk intake at age 30 d/avg milk intake, %	1.57	-.066**	.54	.182	1.72	-.086**	.54	.179
Milk intake at age 60 d/avg milk intake, %	1.73	-.067**	.28	.216	1.66	-.054**	.40	.186
Milk intake at peak/avg milk intake, %	1.79	-.070**	.21	.237	1.69	-.052**	.41	.196
Milk intake at age 90 d/avg milk intake, %	1.57	-.045**	.29	.178	1.40	-.016	.38	.147
Milk intake at age 120 d/avg milk intake, %	1.30	-.016†	.46	.104	1.11	.015†	.46	.096
Milk intake at age 150 d/avg milk intake, %	1.01	.011*	.75	.058	.86	.035**	.58	.071
Milk intake at age 180 d/avg milk intake, %	.75	.033**	.62	.095	.66	.047**	.55	.089
Milk intake at age 210 d/avg milk intake, %	.53	.051**	.49	.145	.51	.053**	.49	.123
Milk intake at weaning/avg milk intake, %	.26	.076**	.34	.207	.39	.050**	.42	.166

[a]Regression equation: predicted variables = year, sex, birth date (Julian days), average milk intake (kg/d). b_1 is a partial regression coefficient of milk intake.

[b]Intercept has been corrected for year, sex, birth date.

*P <.05.

**P <.01.

†P <.01.

Table 3. Coefficients of Simple Correlation Between Weaning Traits and Milk Intakes at Monthly Intervals

Pasture type		Weaning data		Milk intake (kg/d) at various ages, days									Avg. milk intake kg/day
		Wither ht.	Fatness	30d	60d	Peak[a]	90d	120d	150d	180d	210d	240d	
Correlations of variables corrected for year, sex and birth date													
Fescue-legume	Weight (kg)	.61**	.51**	.69**	.61**	.60**	.62**	.65**	.62**	.55**	.47**	.40**	.69**
	Wither height (cm)		.32**	.44**	.35**	.34**	.34**	.36**	.36**	.33**	.30**	.28**	.42**
	Fatness (mm)			.46**	.39**	.37**	.38**	.37**	.33*	.28**	.22*	.18†	.39**
Fescue	Weight (kg)	.63**	.62**	.78**	.69**	.70**	.68**	.68**	.68**	.66**	.61**	.54**	.76**
	Wither height (cm)		.47**	.50**	.42**	.43**	.41**	.42**	.44**	.44**	.42**	.37**	.49**
	Fatness (mm)			.41**	.38**	.38**	.40**	.43**	.45**	.45**	.42**	.37**	.46**
Correlations of variables corrected for year, sex, birth date and avg. milk intake													
Fescue-legume	Weight (kg)	.49**	.35**	.45**	.31**	.29**	.21*	.08	-.26**	-.37**	-.34**	-.31**	.00
	Wither height (cm)		.22*	.24*	.12	.11	.04	-.05	-.24*	-.20*	-.13	-.10	.00
	Fatness (mm)			.29**	.20*	.18†	.13	.04	-.22*	-.28**	-.24*	-.22*	.00
Fescue	Weight (kg)	.46**	.47**	.47**	.16	.16	-.01	-.16	-.33**	-.35**	-.27**	-.22*	.00
	Wither height (cm)		.32**	.22*	.01	.03	-.08	-.15	-.20*	-.14	-.08	-.05	.00
	Fatness (mm)			.10	-.01	-.01	-.03	-.02	.03	.04	.02	-.02	.00

[a]Peak milk intake occurred from 35.1 to 109.2 d of age.
[b]All variables are residuals from the model: Y = year, sex, birth date (Julian day).
[c]All variables are residuals from the model: Y = year, sex, birth date (Julian day), average milk intake (kg/d).
*P > .05 for Ho: R = O.
**P > .01 for Ho: R = O.
†P > .10 for Ho: R = O.

Table 4. Relationship Between Level of Milk Intake at Peak of Lactation and Forage Intake During Later Lactation[a]

Predicted variables	Calf age at initiation (d)	Pasture type: Fescue-legume Intercept[b]	Fescue-legume b_1	Fescue-legume R^2	Fescue-legume RSD	Fescue Intercept	Fescue b_1	Fescue R^2	Fescue RSD
Forage DE intake during first trial	109	7.74(17.1)	.33(.73)	.57	3.93(8.67)	6.11(13.5)	.06(.13)	.58	2.18(4.81)
Forage DE intake during second trial	142	12.66(27.9)	.46(1.01)	.47	4.62(10.19)	9.06(20.0)	.06(.13)	.39	2.99(6.59)
Forage DE intake during third trial	192	13.97(30.8)	.67*(1.48)	.69	5.05(11.14)	14.11(31.1)	.07(.15)	.56	4.02(8.86)

[a]Regression equation: predicted variable = year, sex, birth date (Julian days), milk intake at peak lactation (kg/d). Coefficients in parentheses are in lb/d.

[b]Intercept corrected for year, sex and birth date. b_1 is the partial regression coefficient of milk intake at peak of lactation.

*$P < .05$ as determined by F test of partial sums of squares ($Ho: B_1 = 0$).

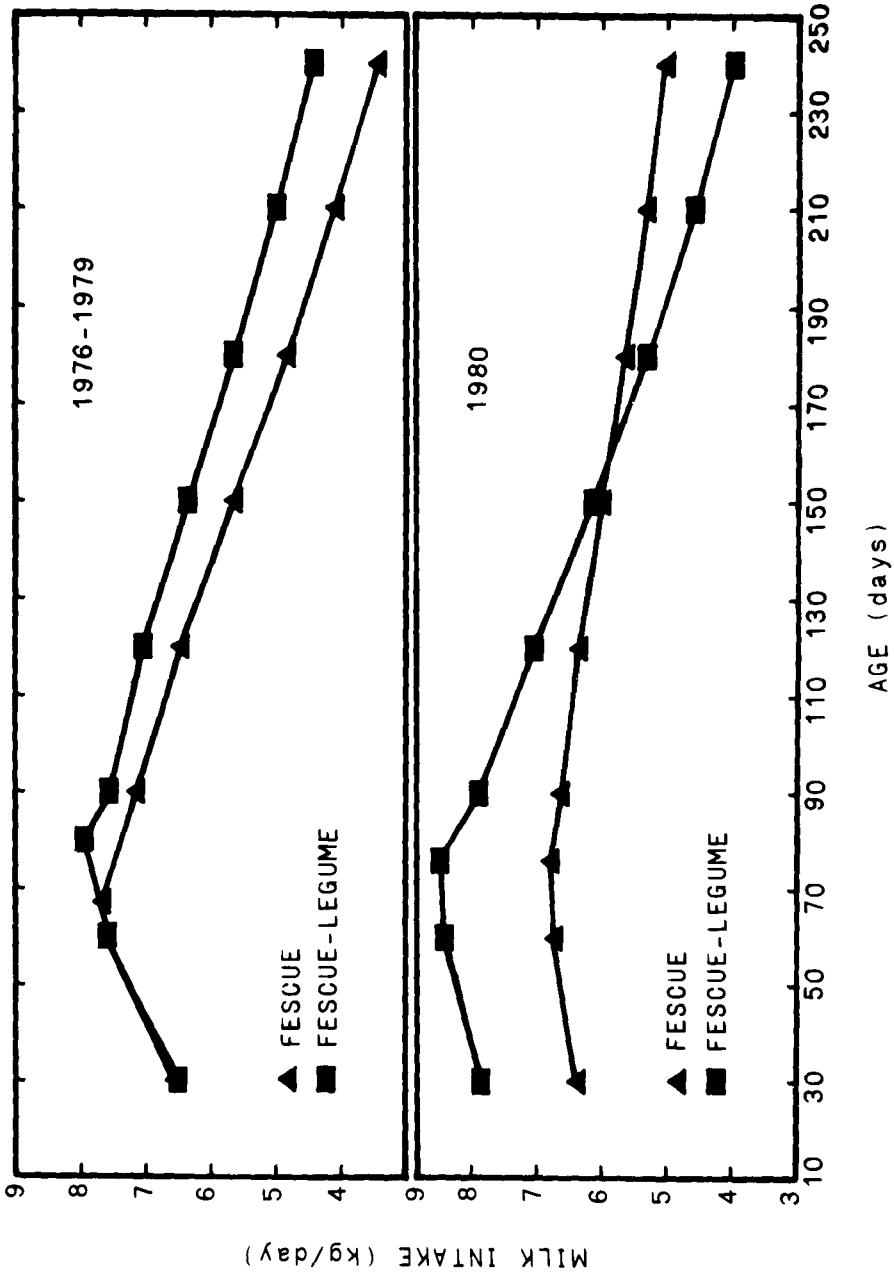


Figure 1. **Shape of lactation curve shape for calves grazing high or low quality pastures.**

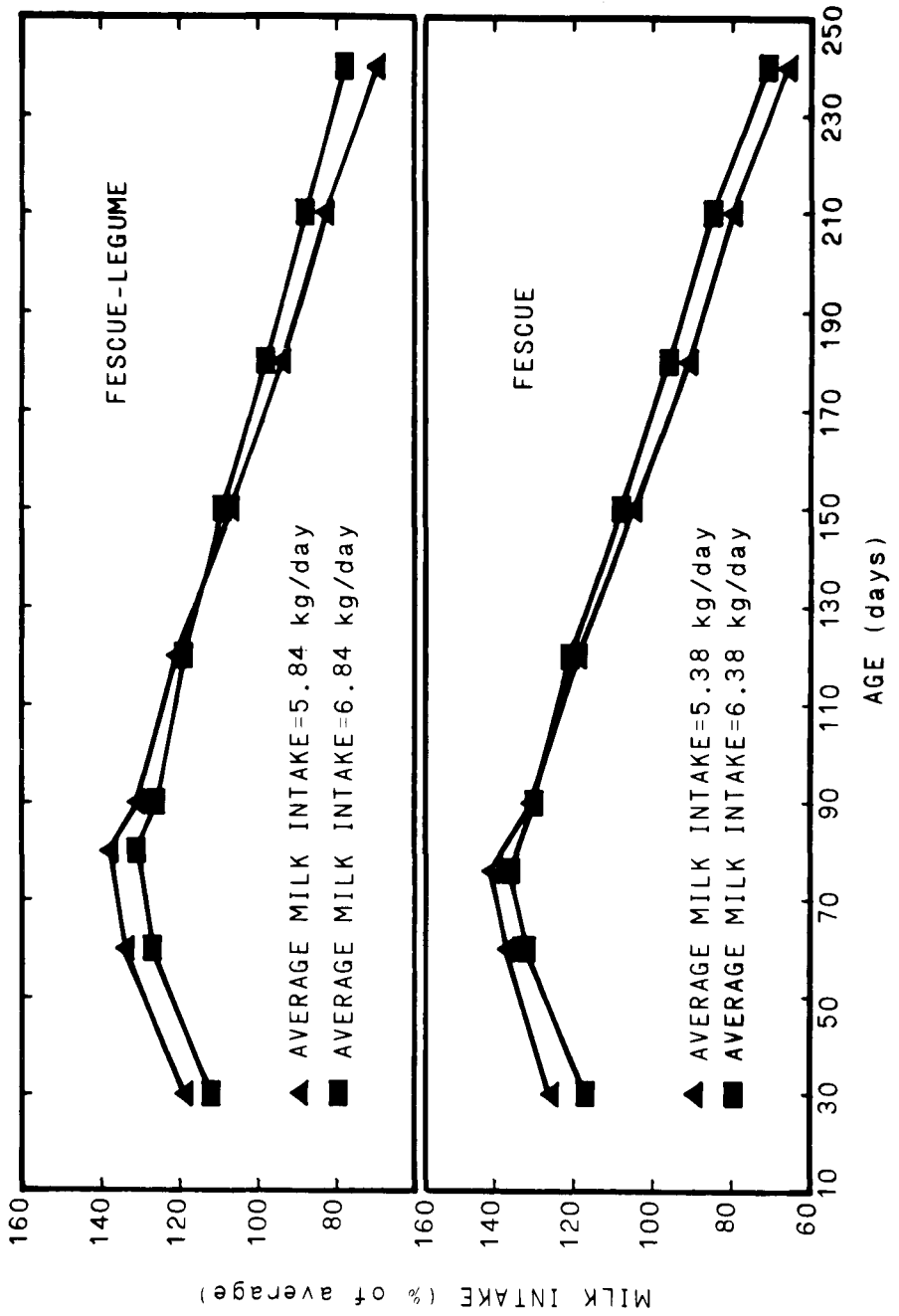


Figure 2. Relationship between lactation curve shape and level of milk intake.

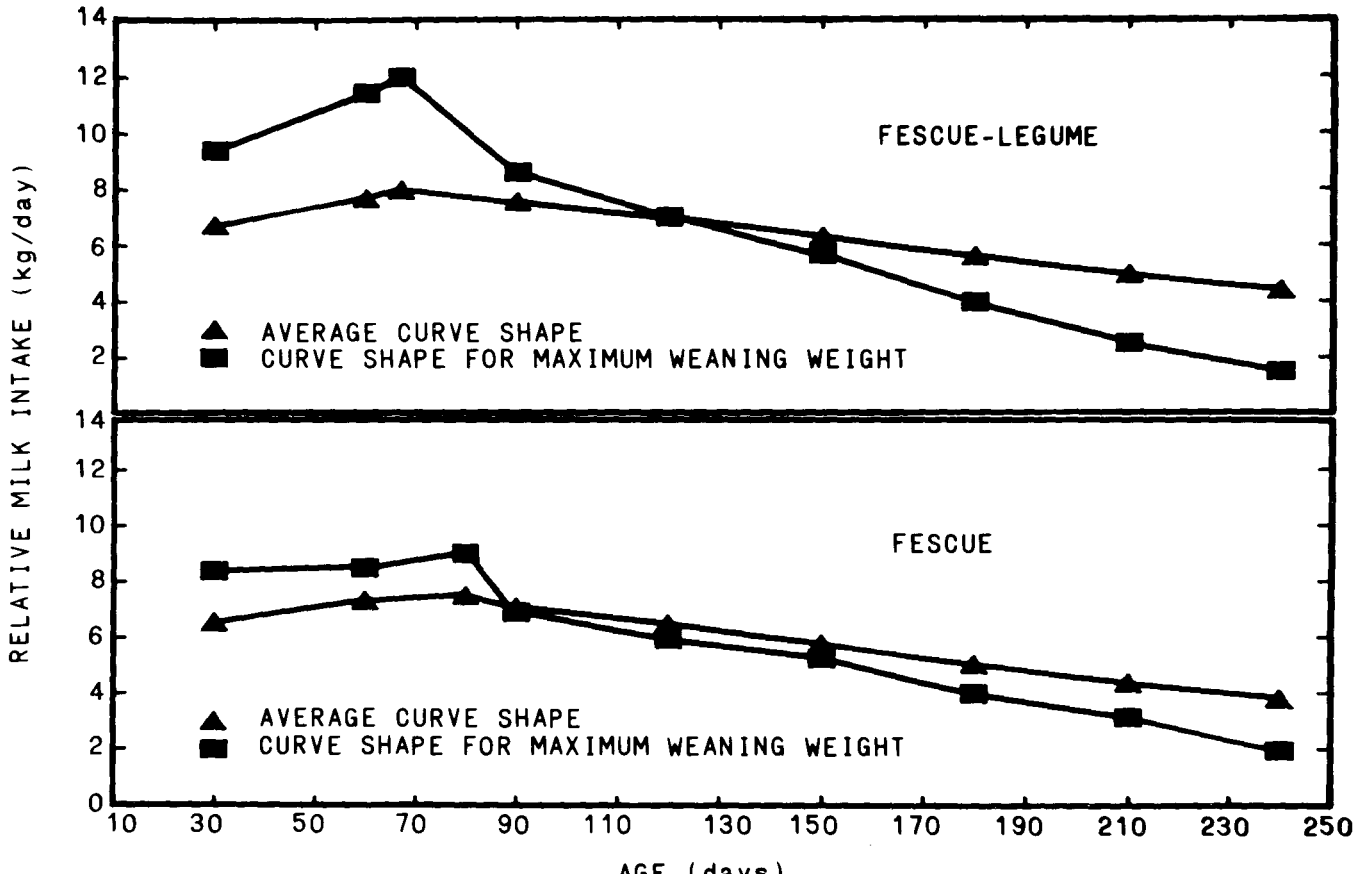


Figure 3. Relationship between lactation curve shape and weaning weight.

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