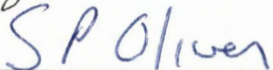


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EFFECTS OF SELECTION FOR MILK YIELD ON LACTATION
CURVE PARAMETERS IN JERSEYS

A Thesis
Presented for the
Master of Science
Degree
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Janeen Duncan Ward

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ABSTRACT

Daily milk weights were collected for daughters of bulls selected for high predicted difference for milk (selection line) and unselected controls between 1970 and 1984. Cows with records with less than 280 days in production were excluded. Production from day one through seven and beyond day 400 were excluded. Lactation curves for 383 selection and 153 control cows in first lactation cows were predicted from daily milk weights and regression coefficients of lactation curve parameters were used in subsequent analyses. Regression coefficients were analyzed with a model that included line, sire (line), month of calving, year of calving, month of calving * year of calving, and age at calving was a covariate. Line and age at calving did not affect parameter estimates, initial yield (a), prepeak slope (b), and postpeak slope (c). Month of calving, year of calving, and month of calving * year of calving significantly affected all lactation curve parameters. Initial milk yield approached significance for sire (line). Multivariate analysis was performed on lactation curve parameters, b and c, that determine shape. Line was not significantly different. Least square means for factors affecting lactation (total milk production, initial milk production, peak milk production, day of peak production, total days in lactation, and age at calving) were obtained using same model as univariate and multivariate analysis, excluding age at calving. Line significantly affected total milk production, peak milk production, and initial milk production. Selection cows tended to peak later,

but day of peak was not different significantly. Lactation curves for selection line cows were scaled upward due to higher initial yields. Line did not alter lactation curve parameters or shape.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	REVIEW OF LITERATURE	3
	Lactation Curve Parameters	
	Lactation Curve Models	
	Environmental Factors Affecting Lactation Curves	
	Genetic Factors Affecting Lactation Curves	
	Correlation Between Lactation Curve Parameters and Yield	
	Other Species	
	Summary	
III.	EFFECTS OF SELECTION FOR MILK YIELD ON LACTATION CURVE PARAMETERS IN JERSEYS	22
	Abstract	
	Introduction	
	Materials and Methods	
	Results and Discussion	
	Summary	
IV.	SUMMARY AND CONCLUSIONS	38
	REFERENCES	40
	APPENDIX	49
	VITA	52

LIST OF TABLES

TABLE	PAGE
1. Significance levels for univariate and multivariate analyses of lactation curve parameter estimates	29
2. Least squares means for parameter estimates using model [4]	31
3. Least squares means for factors affecting lactation using model [4] (excluding age fresh)	33
4. Factors affecting lactation and significance levels	35
A-1. Selection line sires	50
A-2. Control line sires	51

CHAPTER I

INTRODUCTION

Current genetic trends in Jersey cattle indicate that milk production increases at an annual rate of 36 kg (6). Since milk production is increasing then it is reasonable to assume that the lactation curve may have been altered. Major emphasis of recent lactation studies has been on cumulative milk yield, with little attention on lactation curve parameters.

Lactation curves have significant economic implications to the dairy industry. Knowledge of lactation curves increases understanding of production systems (1,47). Lactation curves are utilized to estimate how many animals will be required to generate adequate milk flow and to estimate how much feed will be needed (1,13,87).

Knowledge of lactation curve shape has been useful in accurately estimating lactation yield from milk production recorded on a few test days (69). Age correction and extension factors have enabled projection of incomplete lactation records to a standard age and length.

Extended records are beneficial to dairy producers, as they aid in identification of low producing cows early in their lactation. Projected records also allow daughters to be used in sire evaluation before they have completed a lactation, thus expediting sire proofs (13).

Since parameters of the lactation curve may have been altered due to selection for increased yield, these changes could lead to inaccurate estimation of total milk yield. Therefore, dairy producers could make errors in culling decisions and sire proofs may be biased.

The objective of this study was to determine if initial yield, prepeak slope, and postpeak slope of lactation curves of first lactation Jersey cows were changed due to selection for milk yield.

CHAPTER II

REVIEW OF LITERATURE

I. Lactation Curve Parameters

Interpretation of lactation curve parameters depends upon the method of calculation. The most commonly utilized lactation curve parameters are those estimated by Wood's equation. Therefore, lactation curve parameters considered were derived from Wood's equation as follows: initial yield (a), prepeak slope (b), and postpeak slope (c). Initial yield was generally considered as the scaling factor of the lactation curve (13,67,72,78,85) that changed curve height with no influence on shape (38). Killen and Keane (41) ascertained that prepeak and postpeak slopes describe curve shape. Prepeak slope (b) was the rising portion of the lactation curve to peak and postpeak slope was the decline of the lactation curve after peak (13,38,67,72,78).

Typical lactation curve pattern is characterized by a single rise during early lactation, with a positive estimate for prepeak and a negative estimate postpeak slope. Shanks et al. (72) defined atypical lactation curves as curves with negative estimates for initial yield, prepeak, or postpeak slope. He (72) stated, "Negative estimates of a implied that average production was less than zero." Two types of atypical shaped curves are recognized. Curves with negative estimates for prepeak and postpeak slopes are defined as concave (12,71,72). Concave curves decline from initiation and

approach zero, then turn upward (71). Second, downhill-shaped curves have negative estimates for prepeak slope and positive estimates for postpeak slope (71,75). These curves decline from initiation until termination of lactation (71).

Shimizu and Umrod (71) observed that 34% of lactation curves were atypical, with 2% concave and 32% downhill-shaped. They (71) ascertained that atypical lactation curves may be the product of problems with statistical procedures. Congleton and Everett (12) reported that 19.1% of lactation curves had negative estimates for prepeak slope when first milk weight was recorded 29 days postpartum or later. Schneeberger (69) noted when using Wood's equation 45% of all lactation curves were atypical but only 39% were atypical with the nonlinear regression method of Kellogg et al. (38).

Shimizu and Umrod (71) in a Japanese study of Holstein lactations suggested atypical shaped curves occurred more often in fourth and later lactations and in terminal lactations. However, Schneeberger (69) reported conflicting results that revealed that the number of atypical shaped lactation curves decreased as parity increased.

Miller (52) suggested atypical lactation curves are the result of environmental factors such as underfeeding, mastitis, improper milking, disease, and poor dry cow management. Shimizu and Umrod (71) indicated that the observed pattern of lactation curves can fluctuate due to effects of the environment. However, they (71) attributed atypical lactation curve shape to a "bug" in the statistical procedure. Shanks et al. (70) concurred with this idea.

Not all "normal" lactation curves follow the same shape. Madalena et al. (47) studied lactation curves of Holstein, Jersey, and different Holstein-Gir crosses and found lactation curves to be practically linear, which was consistent with other studies conducted in tropical regions. Madalena et al. (47) observed that cows calving during the rainy season peaked on day one of lactation and cows calving during the dry season experienced a small peak on day 13.

Peak and persistency are important characteristics in determining lactation curve shape (11). Peak yield is the point during lactation that highest milk production occurs. Persistency is the rate of decline in milk production after peak yield.

Peak occurred most often during the second month of lactation (7,15,52,58,61). Several studies have reported conflicting results. Gill et al. (27) observed that cows peaked during the third month of lactation, except second lactation cows that peaked during the second month. Rowlands et al. (61) noted first lactation cows peaked three weeks later than second and later lactation cows. Shanks et al. (70) cited similar findings.

Pradhan and Dave (58) reported week of peak was dependent on season of calving. However, Branton et al. (7) suggested season and year of calving had no effect on peak and maximum monthly milk yields.

Van Vleck and Henderson (82) stated, "Monthly milk or fat production, after peak, is a constant percent of the preceding month's production." Cobby and LeDu (11) determined that the average

decline in milk production following peak production was 1.2kg per week. Pradhan and Dave (58) found milk yield decreased 1.75% per week until the forty-first week of lactation, after this point the rate of decline was slower. Anderson (1) reported animals with extreme differences in peak production did not have extreme production differences at the end of lactation. Miller (52) noted first lactation cows were out producing second and later lactation cows by 4.5kg per day during the tenth month of lactation.

Persistency varies with age. First lactation cows were most persistent and had flatter curves (7,25,27,32,38,48,55,70,72,76). Persistency decreased as lactation number increased (13,23,27,52,58,59,61,62,69,72). Shanks et al. (70) observed cows in their first and third lactation were similar for persistency and week of peak. Gill et al. (27) published persistency decreased 8.8% from first to second lactation.

II. Lactation Curve Models

Different mathematical models have been proposed and applied to lactation curves. Early attempts at describing lactation curves only dealt with parts of the curve (8,9,10,21,22,23,62,80). Brody (8) and Gaines (22) suggested exponential functions which described the declining phase of secretion. These were the first algebraic models applied to lactation curves. In addition, Brody (10) proposed a model to describe the inclining phase of lactation. Others (30,48) suggested linear regression of milk yield on time. Nelder (54) proposed an inverse polynomial function which was the first model

that described an entire lactation curve; however, it has not been utilized (17).

Sikka (72) introduced a parabolic exponential function. Vujicic and Bacic (83) modified Gaines' formula in an attempt to design a model to vary directly and exponentially with time. Malhorta et al. (51) used a quadratic-cum-log function to describe lactation curves. Congleton and Everett (12) suggested an incomplete gamma curve to compare predictions of milk yield with actual milk production. Goodall and Sprevak (28) used Wood's equation to develop a stochastic model, that incorporated time series to predict milk yield. Over time various models have been suggested; however, they have not been widely accepted due computation difficulty, time and lack of fit.

Wood (85) proposed a gamma-type function based on logarithmic transformation of nonlinear data:

$$Y = an^b e^{-cn}$$

where Y is total milk yield; a, b, and c are constants that represent initial milk yield, slope to peak lactation, and slope from peak lactation, respectively; e is the base of natural logarithms; and n is day of lactation. Wood's gamma function has been the most widely accepted and utilized model to fit lactation curves (19,41) since it is considered to be a more manageable model (41). Deriving lactation curve parameter estimates from solving Wood's equation requires much less computer time (11,12,41).

Several researchers have modified Wood's equation. Kuck et al. (42) added sine and cosine terms, in an attempt to account for seasonal variation other than season of calving variation. This equation accounted for 92.8% of variation in log of milk sampling points at 10 day intervals (42). Dhanoa (16) used a reparameterization of Wood's equation by including a factor to account for time required to achieve maximum milk yield. Rowlands et al. (61) proposed three modifications of Wood's equation that included seasonal effectors. They (61) reported finding better estimates of maximum yield, which indicated solving Wood's equation with maximum likelihood methodology might be preferable to using linear regression since average residual variance was reduced in cows in second and later lactations. However, maximum likelihood was not as effective for first lactation cows since they typically have flatter curves.

Further work (11,38,68) supported use of nonlinear models to fit lactation curves. Scheafer et al. (68) questioned whether Wood's simple equation is adequate to fit lactation curves. Dhanoa and LeDu (17) reported Wood's model is most useful when peak is well defined. Cobby and LeDu (11) found Wood's model accounted for 94.2% of variation. Wood's equation overestimated milk yield up to 10 weeks, then underestimated milk yield from 10 to 20 weeks (11). These findings are in contrast with a report by Rowlands et al. (61). They (61) found modifications of Wood's equation to underestimate milk yield up to 12 weeks and overestimate milk yield between 12 and 25 weeks. Conflicting results might be due to position of peak and

seasonal effects (61). Batra (3) reported Wood's model can give a good fit, accounting for an average of 82.3% of variation in log weekly milk yield. Others (11,38) suggested using nonlinear estimation techniques to improve fit of Wood's equation. Kellogg et al. (38) stated linearizing Wood's model assumes errors enter the model in a multiplicative manner, which implies more variation around peak of curve than at extremes.

Others (47,51,94) compared several models with Wood's. Madalena et al. (47) reported goodness of fit with both linear and gamma type models was similar. They (47) indicated the gamma model was more valid under varied conditions. Yadav et al. (94) compared four models (exponential, parabolic exponential, gamma, and polynomial) fit of lactation curves. They (94) reported that the inverse polynomial model and the gamma model accounted for 99% and 95% of variation, respectively.

III. Environmental Factors Affecting Lactation Curves

Lactation curves are influenced by many environmental and genetic factors. Individually or combined, these factors can modify parameters (initial yield, prepeak slope, and postpeak slope), thus altering curve shape.

Herd environment significantly affects lactation curve parameters (27,63,65,79,94). Herd environment can be subdivided into nutrition (21,50,80), climate (27,47,65), management (22,49,80,95) and frequency and character of milking (22).

Batra (3) examined lactation curves at five research stations and found station was highly significant ($P<.01$) for all lactation curve parameters due to differences in climate, herdsman, housing, and feeding, although attempts were made to standardize management practices and grain feeding. Variation in lactation curve parameters was revealed (74) between herds with different production levels. Scheaffer and Burnside (65) indicated that geographical location could possibly produce differences in lactation curves.

Season modifies lactation curve parameters two ways. First, season may alter curve shape due to availability of specific feedstuffs during certain times (22,41). However, with modern confinement dairy systems and improved forage storage and preservation techniques, this source of variation has been reduced (90). Second, season of calving significantly influences curve shape (7,59,63,65,79,88).

Wood (87) provided the first estimates of seasonal variation in milk production. He (87) reported lactations experiencing spring hump seasonality (due to availability of specific feedstuffs) were 18.8% below average in January and 14.7% above average in June. Others (61,91) published similar results. Wood (93) reported milk production increased 12% in Great Britain from 1965 to 1975. He (93) observed higher producing cows experienced the same seasonal variation, but the effect was not as exaggerated. Killen and Keane (41), in an Irish study, reported cows produced 21.1% more in May and 26% less milk in December than average. They (41) attributed

this wide variation in milk production to grassland management practices.

In addition to their influence on curve shape (42,74,95), season and month also affect total lactation yield (72). Turner (79) suggested highest lactation records were made by cows calving between September and April in Missouri. He (79) noted that cows that calved in the fall and winter generally exceeded average production while cows that calved in the summer were usually below average. Mahadevan (49) found a 10% difference in total milk production between cows calving during winter and summer. Wood (88,89) stated that cows calving between October and December had 12% higher lactation records than cows that calved in July and August. Wood (92) later reported a 4% increase in milk, fat and protein production for cows calving during winter and a 4% decrease in all three for cows calving in the summer, for each of five breeds. Others (13,52) found similar results. However, Keown and Van Vleck (40), using complete lactation records compiled by the New York Dairy Records Processing Laboratory, observed Holstein cows calving from May through August had the highest average production across all lactations. They (13,40) found highest peak production occurred when cows calved between January through April and lowest peak production for cows calving between September and December. Yadav et al. (94), in an Indian study of Haryana cows and Haryana-Friesian crosses, determined season of calving had no significant effect on lactation curve parameters.

Month of calving significantly affected initial yield (31). Singh and Bhat (74), in an Indian study of Haryana cattle, reported

maximum initial yield was obtained from cows calving in August and lowest initial milk production came from cows calving in November. They (74) observed also initial production increased significantly from first lactation until fifth lactation. Congleton and Everett (13) ascertained maximum initial yield occurred in early summer with maximum slope to and from peak occurring during winter.

Persistency varied with month (86) and season of calving (7). Cows calving during summer were found to be more persistent (75), with first lactation cows being most persistent. Branton et al. (7) found, in a Louisiana study, cows calving between August and November were most persistent and cows calving during March through June were least persistent. Keown et al. (39) also reported cows calving in July and August were the most persistent due to their lower peak yields. Hamilton and Hillers (32), in a Washington State study, published that cows calving during summer and fall were 1.65 times as persistent as cows calving during other seasons. However, total production was approximately the same for all cows regardless of season of calving. Age and season of calving differences in milk production became greater as parity increased in all stages of lactation (65). Mahadevan (50) found a significant herd and month of calving interaction effect on persistency.

Year of calving significantly affects lactation curve parameters (42,63,65,79). Batra (3) found significant differences for prepeak and postpeak slope for first and second lactation cows due to year of calving. Branton et al. (7) published persistency was

affected by calving year. Sikka (72) observed a significant herd and year interaction effect on all parameters.

Age of calving (24,63,65,79) and parity (13) influence curve shape. Yadav et al. (94) suggested that age of first calving affected all lactation curve parameters. Batra (3) reported age of calving affected initial yield of first and second lactation cows and postpeak slope for cows in second lactation. Mahadevan (49) found lactation yield increased as age of calving increased, however, the effect of age of calving decreased as parity increased. Similar results were cited (52). Grossman et al. (31) and Kuck et al. (42) determined age at calving had no significant effect on lactation curve parameters.

As lactation number increases the lactation curve becomes steeper. In addition, there is generally an associated increase in total lactation yield (41). Madalena (47) and Zimmerman and Sommer (95) suggested that parity affected initial milk yield. First lactation cows had lower initial yields than other parities (94). Peak yield increased as cows matured (1,13,52). Sikka (72) ascertained fourth lactation cows had the highest peaks. Higher peak production generally leads to a more rapid decline in milk production resulting in a steeper lactation curve (50,52). Persistency was significantly influenced by lactation number (27,39,86,87). First lactation heifers had lower peak yields, were more persistent, and took longer to reach peak yield than second and later lactation cows (27,70,76).

Days open affects lactation curve shape (63,65,79). Cows

experienced uniform decreases in production at the same stage of pregnancy, however, older cows had a sharper decline in production due to higher peaks (41,87). Differences in production were detected by the fifth month of gestation (9,22,23,80). Auran (2) reported milk production was depressed between 1.8 to 2.0kg per month after the fourth month of pregnancy.

As days open increased, there was a reported (53,56) corresponding increase in total production. Funk et al. (20) published that as days open increased from 20 to 300 days, lactation yields for fat corrected milk (FCM), milk, and fat increased approximately 1250kg, 1350kg, and 45kg, respectively. Louca and Legates (44) found first lactation cows had an increase in total production of 1.16kg of milk for each additional day open, which was attributed to their higher persistency. In addition, they (44) observed second and third lactation cows experienced decreased production, 3.58 and 3.68kg, for each additional day open. Similar results (45,66) have been published. Gill and Allaire (26) indicated that days open accounted for 4.3% of variation in milk per day of herd life. Speicher and Meadows (77) noted that increased calving interval led to fewer lactations with greater production. Smith and Legates (76) revealed days open accounted for 7% of the variation in persistency in first lactation cows and 5% in second and later lactations. Berger et al. (5) suggested dairy producers tended to manage higher yielding cows differently, in that higher producing cows were rebred later in lactation and required more services per

conception. These cows were generating enough income that dairy producers could afford to delay rebreeding and allow additional time required to achieve pregnancy. Holmann et al. (35) determined that by increasing calving interval 12 to 13 months the positive value per day open, ranged from 21 to 40 cents.

Batra (3) showed days open significantly affected prepeak and postpeak slope parameters of first and second lactation cows. Congleton and Everett (13) cited a significant effect on postpeak slope in first lactation cows and on prepeak and postpeak slope in second lactation cows due to days open. However, others (31,42) reported days open were not significant. Grossman et al. (31) suggested that the differences in their data set were too small to detect.

IV. Genetic Factors Affecting Lactation Curves

Shanks et al. (70) stated, "Environmental influences have been assumed to dominate the shape of lactation curves; therefore, little research has been conducted on genetic aspects of lactation curves." Grossman et al. (31) and Kuck et al. (42) found that breed of sire influenced initial yield, indicating additive genetic variation. They (31,42) also reported significant breed of sire and breed of dam interaction for initial yield and postpeak slope which implies non-additive genetic variation. Batra (3) observed line of sire and line of dam significantly affected initial yield. He (3) indicated this parameter could be changed through selection. Madalena et al. (47) noted similar results when analyzing different breed types. Wood

(85,86) detected significant differences between progeny groups for all lactation curve parameters.

Lactation curve shape tends to be an individual characteristic of a specific cow. Differences in shape are greater between cows than curves of different lactations of the same cow (22,62,64). Grossman et al. (31) reported curve shape of relatives tended to be similar. They (31) also ascertained breed differences in lactation curve shape are due to different genetic make-ups of these breeds. Gaines (22) found no correlation for persistency between paternal half sisters. However, persistency between maternal half sisters was correlated. Correlations between maternal half sisters is probably due to a common environment, which is generally not present for paternal half sisters.

In a Wisconsin study of genetic lines of Holsteins, Kamphof et al. (37) published a significant effect of genetic line. They (37) found cows selected for high yields produced 760kg more milk, had higher and later peaks, and had slower declines from peak than cows with average genetic potential for yield.

Heritability estimates for persistency vary with lactation number and method of calculation. Estimates ranged from .1 to .24 (30,33,50,59). Schneeberger (59) derived heritabilities for persistency calculated three different ways and these estimates ranged from .19 to .29. Smith and Legates (76) published heritabilities for persistency for first lactation of .33 and for second and later lactations of .1. Sikka (72) indirectly converted

correlations to heritability estimates for persistency (.29) and peak (.30) from within-sire dam-daughter correlations. These estimates were probably biased upward due to dam-daughter environment. Shanks et al. (70) found low heritabilities for peak and persistency in first lactation, negative in second lactation, close to zero in third lactation, and moderate in fourth and later lactations. They (70) noted also heritability for peak decreased from first through third lactation. This decline in heritability may be due to selection. Shanks et al. (70) also reported heritability estimates for week of peak (.19), log of initial milk yield (.24), prepeak slope (.22), and postpeak slope (.23). Batra and Lin (4) found heritabilities for persistency (.02), week of peak (.02), peak yield (.23), log of initial milk yield (.10), prepeak slope (.06), and postpeak slope (.14). Since heritabilities of lactation curve parameters are of the same magnitude as yield traits, there is ample genetic variation to alter parameters through selection.

V. Correlation Between Lactation Curve Parameters and Yield

Sikka (72) observed the "general trend in persistency is opposite in direction to that of peak yield, their effects on total yield tend to neutralize each other." Mahadeven (50) suggested as persistency increased there was a corresponding increase in total production. Singh et al. (75) indicated an increase in peak yield increased persistency and total lactation yield. Rao and Sundaresan (59) found similar results. Hamilton and Hillers (32) reported lower

producing cows were 1.76 times as persistent as higher producing cows.

A significant negative correlation ($-.31$) was observed between peak and persistency (1). Sikka (72) revealed significant within cow correlation between peak and persistency ($-.17$). Peak yield appeared to be about three times as important as persistency in determining total yield (72). Pradhan and Dave (58) cited similar findings, reporting a significant negative correlation of $-.52$. Madsen (48) found correlations between peak and persistency (when measured as an absolute decrease in yield) between $-.46$ and $-.52$ (phenotypic) and yield relative to yield in early lactation, correlations between peak and persistency were $-.06$ to $-.13$ (phenotypic) and $.17$ to $.42$ (genotypic). Ferris et al. (18) determined a $-.37$ correlation between 305-day yield and peak.

Pradhan and Dave (58) reported a significant positive correlation between persistency and 305-day yield ($r=.678$). Similar results were observed (72,75,86). Smith and Legates (76) found the genetic correlation between total yield and persistency was $.55$. Schneeberger (69) showed genetic correlation between persistency and total lactation yield ranged from $.05$ to $.16$. However, Hamilton and Hillers (33) detected a negative correlation ($-.1$) between 305-day yield and persistency.

Significant positive correlations between peak yield and persistency ranging from $.7$ to $.8$ were published (1,72,76). Rao and Sundaresan (59) observed total yield, peak yield and persistency

were correlated positively to each other. They (59) noted also total yield and persistency was correlated negatively to prepeak and postpeak slope. Due to positive genetic correlations between yield and lactation parameters it seems reasonable to conclude that parameters may be changing with selection for increased yield. However, phenotypic correlations between yield and parameters are negative, indicating environmental influences have a greater impact on lactation curve parameters than genotype.

VI. Other Species

Lactation curves tend to be similar regardless of species. Tores-Hernandez and Hohenboken (78) used Wood's equation, developed for dairy cattle, to estimate shape parameters, prepeak and postpeak slope, for single and twin rearing ewes. They (78) observed parameter estimates for ewes to be of similar magnitude as those of dairy cattle. Differences in total and peak production were detected between ewes rearing single versus twin lambs (78); however, curves of the two groups were parallel. Others (14,46,57) reported similar findings. Peart et al. (57) also determined lactation pattern and total yield differed between crossbred and purebred ewes.

Kumar and Bhat (43) analyzed lactation curves of Indian buffaloes. They (43) found lactation curves were affected by farm, lactation order, and year of calving. Initial milk yield in buffaloes followed the same pattern as dairy cattle, being lowest in first lactation and increasing through fourth lactation (57).

Anderson (1) reported guinea pigs, like dairy cattle, that

experienced higher peak production had curves that declined more rapidly. He (1) found also that animals with wide variations in peak production were less extreme at the conclusion of lactation. Jara-Almonte and White (36) observed mice peak late in lactation.

VII. Summary

Literature has shown that lactation curves are influenced by many environmental and genetic factors. Environmental factors that have been shown to affect lactation shape are nutrition, climate, management, frequency and character of milking, and geographical location. Other non-genetic factors that have been determined to alter curve shape are month, season, and year of calving; age at calving; parity; and days open. Limited studies that deal with genetic aspects of lactation curves have been reported. Differences in initial milk yield, time of peak lactation, and amount of milk at peak lactation, between genetic lines, have been published.

Many different models have been proposed and applied to lactation curves. The most widely accepted and utilized model to fit lactation curves is Wood's gamma function. Wood's model has been repeatedly compared to other models in order to test its validity. Data sets used to derive lactation curves tend to be enormous. Wood's model has the advantage over other models in that it require much less computation. However, with advances in computer technology other models may prove to be superior in time.

Changes in lactation curves shape needs to be monitored since,

dairy farm profitability is directly affected by accurate estimation of lactation curves parameters. Lactation curves indirectly influence management decisions made dairy producers and consequently affect profitability.

CHAPTER III

EFFECTS OF SELECTION FOR MILK YIELD ON LACTATION CURVE PARAMETERS IN JERSEYS

I. Abstract

Daily milk weights were collected for daughters of bulls selected for high predicted difference for milk (selection line) and unselected controls between 1970 and 1984. Cows with records with less than 280 days in production were excluded. Production from day one through seven and beyond day 400 were excluded. Lactation curves for 383 selection and 153 control in first lactation cows were predicted from daily milk weights and resulting regression coefficients of lactation curve parameters were used in subsequent analyses. Regression coefficients were analyzed with a model that included line, sire (line), month of calving, year of calving, month of calving * year of calving, and age at calving was a covariate. Line and age at calving did not affect parameter estimates, initial milk yield (a), prepeak slope (b), and postpeak slope (c). Month of calving, year of calving, and month of calving * year of calving significantly affected all lactation curve parameters. Initial milk yield approached significance for sire (line). Multivariate analysis was performed on lactation curve parameters, b and c, that determine shape. Line was not significantly different. Least squares means for factors affecting lactation (total milk production, initial milk production, peak milk production, total days in lactation, day of

peak production, and age at calving) were obtained using the same model as univariate and multivariate analyses, excluding age at calving. Line significantly affected total milk production, peak milk production, and initial milk production. Selection cows peaked later, but day of peak lactation was not significantly different. Lactation curves for selection line cows were scaled upward due to higher initial yields. Line did not alter lactation curve parameters or shape.

II. Introduction

Dairy farm profitability is related directly to accuracy of lactation curve estimation. Indirectly, dairy producers utilize information derived from lactation curves to make daily management decisions. The validity of culling and sire selection decisions depends upon correctly extending incomplete lactations. Since extension and correction factors were developed before 1965 and milk production has increased 91kg per year (81); it is reasonable to assume that lactation curve parameters may have been altered over time.

The objective of this study was to determine if initial milk yield, slope to peak lactation, and slope from peak lactation of first lactation Jersey cows were changed due to selection for milk yield.

III. Materials and Methods

Experimental Population, Sire Selection, and Management

During 1967, the Jersey herd at the Dairy Experiment Station (DES) Lewisburg, Tennessee was divided into two breeding groups.

Initially, cows were assigned randomly within sire to groups on a 3:1 ratio. At the beginning of the project there were 160 foundation cows; 120 selection and 40 controls. Assignments were adjusted for milking ability, sire groups, age, size, and type. Both groups were subjected to the same environmental conditions and management practices.

Cows and their subsequent offspring in the selection herd were bred to the highest AI-proven sires available on the basis of their Predicted Difference for milk (PDM). In order to be used in the study selected sires were required to have 30 daughters in at least 20 herds and have 60% or greater repeatability. Sires were used for four consecutive years with an additional sire being added each year. Exceptions were three of the initial sires and other bulls with limited semen availability. Any sire could be reselected if the selection criteria were met. Sires used in the selection herd are shown in Table A-1 (see Appendix). Selection sires had an average PD of +133 for milk.

Cows and their subsequent offspring in the control herd were bred to 20 randomly selected sires in young sire sampling programs in 1967 and four young sires at DES with comparable pedigrees. Bulls used in the control herd are listed in Table A-2 (see Appendix).

Control line sires had an average PD of -756 for milk. Control cows were continuously bred to these bulls for the entire project in an effort to maintain a herd that would be unchanged genetically. The inbreeding coefficient of any mating in the selection or control herd did not exceed 6.24%

Involuntary culling, for health and reproductive disorders, occurred in both groups. The selection herd was culled on the basis of milk yield and culling was completely random in the control herd. All first lactation heifers completed 90 days of lactation before being removed from the herd.

Data Collection and Recording

Milk production was determined by volumetric weigh jars and recorded twice daily at a.m. and p.m. milkings. Daily milk weights and calving dates were recorded for each heifer. Calving dates were obtained from Dairy Herd Improvement Association (DHIA) records. Date of calving was considered as the first day of lactation. Heifers that milked less than 100 days were deleted. Cows with five or more consecutive days of missing milk weights were deleted.

Records with less than 280 days were deleted and records were truncated at 400 days. In an effort to standardize the beginning of the lactation, days 1-7 were deleted and all lactations began on day 8. Other researchers (13,70,72,74) delayed start of lactation from 6 to 15 days postcalving. Shanks et al. (70) started on lactation day 6. They noted that lactation day 6 corresponded to the first

possible test-day of DHIA. The data set included 383 selection and 153 control cows.

Statistical Analysis

Wood's (85) equation was used to fit lactation data:

$$Y=an^be^{-cn} \quad [1]$$

where Y is total milk yield; a,b, and c are coefficients that represent initial milk yield, slope to peak lactation, and slope from peak lactation, respectively; e is the base of natural logarithms (ln); and n is day of lactation. Linearization of data occurs when ln is taken (31,85), which allows data to be analyzed by the multiple linear regression procedure.

Linear regression procedure was used to fit each cow's lactation record to generate parameter estimates with the following model:

$$\ln(y)=\ln(a) + b \ln(n) + cn \quad [2]$$

where ln(y) and ln(n) are the natural logarithms of milk yield and day of lactation, respectively, and n is day of lactation. Equation [2] is in the familiar form (31) of a multiple linear regression model as:

$$Y=b_0 + b_1X_1 + b_2X_2 \quad [3]$$

Resulting regression coefficients were then analyzed by the General Linear Models procedure of SAS (29) using the following model:

$$b_{ijk mno} = u + L_i + S(L)_{j(i)} + M_k + Y_m + MY_{km} + A_n + e_{ijk mn} \quad [4]$$

where:

$b_{ijk mn}$ =constants a, b, and c,

u =population mean,

L_i =effect of the i^{th} genetic line

$S(L)_{j(i)}$ =effect of the j^{th} sire within i^{th} genetic line

M_k =effect of the k^{th} month of calving,

Y_m =effect of the m^{th} year of calving,

MY_{km} =effect of the interactions of the k^{th} month of calving with m^{th} year of calving,

A_n =effect of the n^{th} age at calving,

$e_{ijk mno}$ =residual

The GLM multivariate analysis of variance procedure utilizing SAS (29) was performed on parameter estimates b and c to detect differences in lactation curve shape. Parameter estimate a was deleted in this analysis since it was the scaling factor of the lactation curve and not a shape determinate (13,67,72,78,85).

Least-squares analysis of variance was performed on variables total milk production, initial milk production, peak milk production, day of peak milk production, total days in lactation, and age at calving. Least squares means for these factors were estimated using model [4] as were the parameter estimates.

IV. Results and Discussion

Significance levels for univariate analysis of lactation curve

parameter estimates are shown in Table 1. Line did not significantly affect parameter estimates. Initial yield approached significance for sire (line) ($P < .08$). This result agreed with the crossbreeding studies of (3), (31), and (42). Breed of sire influenced initial yield (31,42). Batra (3) found line of sire and line of dam affected initial milk yield significantly ($P < .05$). Wood (85,86) detected significant differences between progeny groups for all parameters.

Age of calving did not significantly influence lactation curve parameters (Table 1). Grossman et al. (31) and Kuck et al. (42) also concluded that age at calving had no significant affect on lactation curve parameters. Others (24,63,65,79) have published conflicting results that age at calving does influence curve shape. However, their (24,63,65,79) data included first and later lactations which could account for the contrasting results. Yadav et al. (94) observed age at first calving significantly affected all lactation curve parameters, in an Indian study.

Month of calving, year of calving, and interaction of the two were significant for all three parameters (Table 1). Significant effects due to month and season of calving have been reported (13,42,49,72,74,88,95). Month of calving (31) significantly affected initial yield. Year of calving was shown to significantly affect lactation curve shape (42,63,65,79). Batra (3) found significant differences ($P < .05$) for prepeak and postpeak slope for first and second lactation cows due to year of calving.

TABLE 1. Significance levels for univariate and multivariate analyses of lactation curve parameter estimates.

	Univariate			Multivariate
	Initial Yield (a)	Slope to Peak Lactation (b)	Slope from Peak Lactation (c)	
Line	.2910	.3723	.9018	.3665
Sire(Line)	.0807	.2350	.2751	.0001
Month fresh	.0001	.0001	.0001	.0001
Year fresh	.0214	.0007	.0001	.0018
Month fresh*Year fresh	.0176	.0009	.0206	.5437
Age fresh	.1556	.8836	.6236	.5437

When a multivariate analysis was performed on lactation curve parameter estimates, there was a significant ($P<.0001$) difference due to line. Least squares means for lactation curve parameters from this analysis are in Table 2. Since there were no significant differences between individual parameters due to line with univariate analysis, the question arose as to which parameters led to differences between lactation curves of selection and control cows. Another multivariate analysis was performed on parameters b and c, excluding parameter a, which is the scaler of the lactation curve, (13,67,72,78,85). Significance levels for this analysis are shown in Table 1. Line was not significantly different. This indicated that line differences in the first multivariate analysis were due to lactation curves of selection cows being scaled differently than those of control cows. Lactation curves predicted from parameter estimates for selection and control lines are shown in Figure 1.

Least squares means of several variables that influence lactation curves (Table 3) were obtained by model [4], excluding age at calving. These were total milk, initial milk, peak milk production, day of peak milk production, total days in production, and age at calving. Total milk production, age at calving, peak production, and initial milk production were different ($P<.0001$) and total days in production was different ($P<.005$) between selection and control lines. Selection cows peaked later than control cows; however, day of peak production was not significantly different. Significance levels for these factors are found in Table 4.

TABLE 2. Least squares means for parameter estimates using model [4].

Line*	Initial Yield	Slope to Peak Lactation	Slope from Peak Lactation
Selection	3.4446	0.0923	-0.0018
Control	3.3950	0.0803	-0.0018

*($P < .01$)

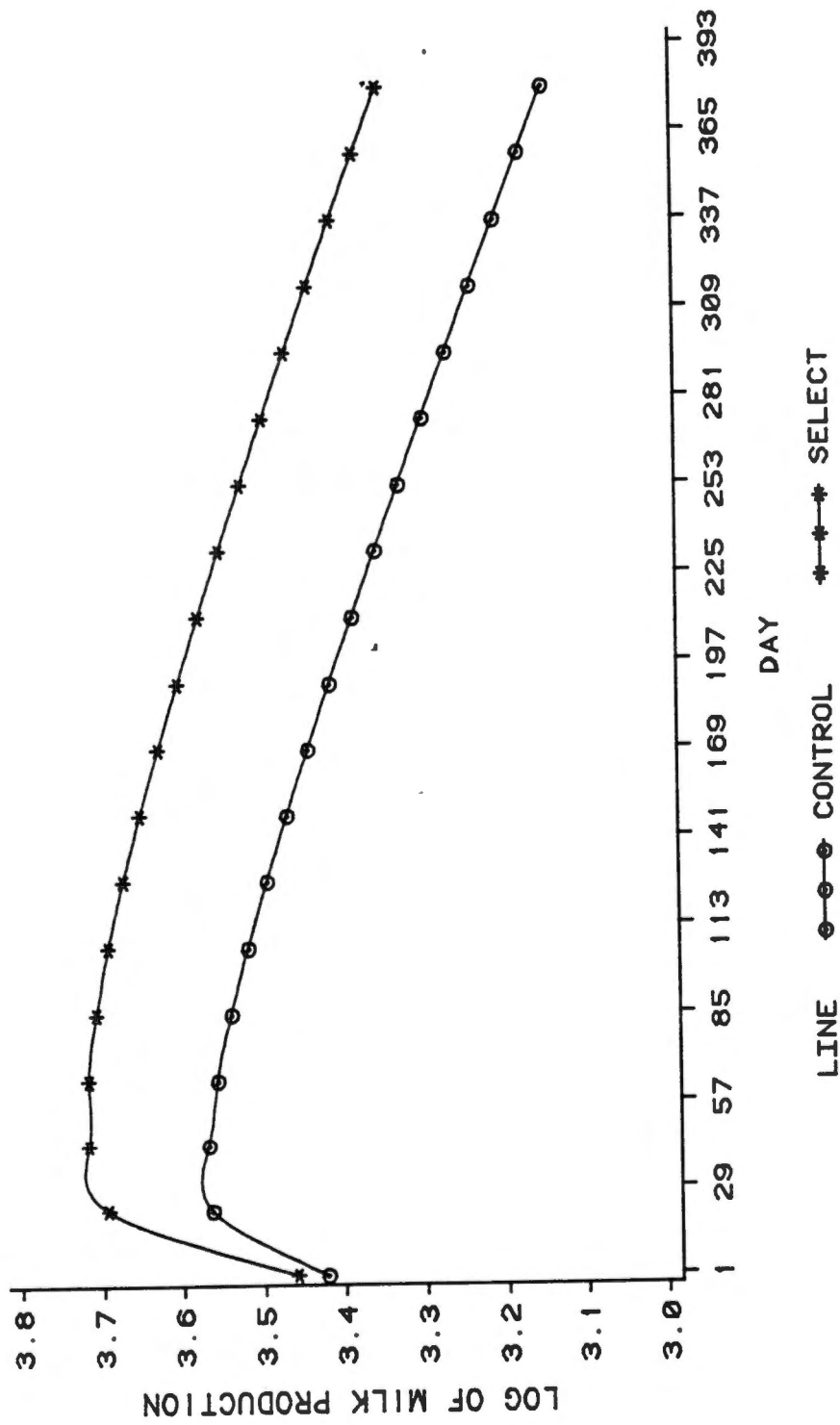


Figure 1. Predicted lactation curves.

TABLE 3. Least squares means for factors affecting lactation using model [4] (excluding age fresh).

Line	Selection	Control
Total milk production (kg)	5,465.98	4,837.31**
Initial milk production (kg)	14.48	13.59**
Peak milk production (kg)	23.30	21.11**
Day of peak (days)	59.91	57.55
Total days in lactation (days)	328.90	320.57*
Age at calving (months)	26.46	26.27**

* (P<.05)

** (P<.01)

Selection line cows produced more milk than control cows. The 629kg higher total milk production in the selection herd was due to the effect of line ($P<.0001$) (Table 4). Other studies (34,84) have reported direct response for milk yield due to selection. Hollon et al. (34) observed that Jersey selection cows averaged 659kg more than control cows during the first four generations. Wilk and McDaniel (84) found selection line cows produced 606kg, 846kg, and 924kg more milk than control cows in generation one, two, and three, respectively. Simerl et al. (73) and Richardson et al. (60) reported annual genetic change for milk yield of +49kg and +57kg, respectively. Total milk produced was also significantly influenced by sire (line) ($P<.0001$), month of calving ($P<.01$), year of calving ($P<.07$), and interaction between month and year of calving ($P<.02$) (Table 4).

Initial daily milk production of the selection herd was .89kg higher than initial yields of the control herd (Table 3). Line ($P<.02$), sire (line) ($P<.03$), and month of calving ($P<.03$) significantly affected initial milk production (Table 4). Others found sire (3,31,42) and month of calving (31,75) affected initial yield. Year of calving and the interaction between month and year of calving were not significantly different. Year of calving would not be expected to influence initial yield because cows differed genetically each year.

Peak production of selection cows were 2.19kg higher than that of control cows (Table 3). Peak milk production was affected ($P<.0001$) by line, sire (line), month of calving, and year of

TABLE 4. Factors affecting lactation and significance levels.

Factor	Total Milk Production	Age At Calving	Day of Peak Production	Peak Production	Total Days In Production	Initial Milk Production
Line	.0001	.6170	.6990	.0001	.1056	.0198
Sire (Line)	.0001	.0210	.0522	.0001	.8251	.0250
Month Fresh	.0097	.0001	.7290	.0001	.0238	.0237
Year Fresh	.0665	.0001	.3131	.0001	.0314	.1119
Month*Year Fresh	.0205	.1889	.8670	.2296	.2707	.3815

calving. There was no effect due to interaction between month and year of calving. Selection cows peaked 2.36 days later than control cows (Table 3), which was not significantly different. However, this factor was influenced by sire (line) ($P<.05$). Kamphof et al. (37) also reported selection line cows peaked higher and later than control line cows.

Significant differences in age of calving were found for sire (line) ($P<.02$), month of calving ($P<.0001$), and year of calving ($P<.0001$). These results were influenced by station management decisions. Line and interaction between month and year of calving did not significantly affect age at calving. Control line cows calved at a slightly younger age than selection line cows. This outcome was unexpected, since selection line heifers reached puberty at an earlier age.

Selection line cows had 8.33 more days in production than control line cows (Table 3). Differences were found for total days in production for month of calving ($P<.02$), year of calving ($P<.03$), and line was approaching significance ($P<.1$). Sire (line) and the interaction between month and year of calving were not significant.

V. Summary

Lactation curves parameters for 383 selection line and 153 control first lactation Jersey cows were analyzed to determine if selection for milk yield altered parameters of lactation curves.

Analysis of lactation curve parameters, initial yield(a), prepeak slope(b), and postpeak slope(c), revealed that breeding for

milk yield did not alter lactation curve shape. However, lactation curves for selection line cows were scaled upward due to their higher initial yields.

Selection for milk yield resulted in differences in factors that affect lactation. Selection line cows had significantly higher total milk production, initial yields, and peak production. Peak production tended to occur later in lactation for selection cows; however, this variable was not significant.

Lactation curve parameter estimates are primarily used to extend partial lactation records. Extended records are valuable tools for proving sires and identifying low producing cows. Dairy producers profits are directly affected by management decisions based on indirect usage of lactation curve parameters. Selection for increased milk yield did not alter lactation curve parameters. Therefore, current parameter estimates are most likely accurate.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The objective of this study was to determine if initial yield, prepeak slope, and postpeak slope of lactation curves of first lactation Jersey cows changed due to selection for milk yield.

Lactation curve parameter estimates for 383 selection and 153 control first lactation cows were analyzed. Line did not affect lactation curve parameters. Sire (line) approached significance for initial yield. Selection line cows started lactation at a higher level; therefore, their lactation curves were scaled upward from control lactation curves. Initial yield, a moderately heritable trait, should continue to increase because of selection for milk. Therefore, the trend of lactation curves being scaled upward should continue.

Line affected significantly total milk production, initial yield, peak production, and approached significance for total days in lactation. Line did not affect age at calving. Sire (line) affected significantly total milk, initial milk, peak production, day to peak, and age at calving.

Lactation curve shape needs to be monitored because of economic importance related to decisions dairy producers base on lactation curve estimation. Lactation curve parameters, to this point, have not been altered due to selection for milk yield; however, production patterns are changing. Cows are achieving higher peak milk production and later in lactation. Given these

production trends and additional time, lactation curves may be altered.

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APPENDIX

TABLE A-1. Selection line sires.

Sire	Latest (PD82) Predicted Difference					
	DOB ¹	Rpt.	Milk	%	BF	\$
Brigham Confident Infred	12-52	91	-228	-.05	-16	-42
Sybil Royal Predictor	3-56	95	-188	+.11	+3	-7
Sybil Carletta's Finalist	5-57	97	+20	-.12	+15	+27
Nobleman's Lotus Designer	11-58	99	-41	+.03	+1	-1
Observer Chocolate Soldier	12-56	96	+4	-.10	-11	-19
Milestones Generator	4-72	98	+535	-.06	+18	+62
Secret Baronent	9-64	99	+176	-.23	-19	-21
SS Quicksilver of Fallneva	9-64	99	-212	+.15	+7	-2
Vaucluse Sleeping Surville	8-60	99	-10	+.27	+31	+52
Milkboy Happy Hill Abe	1-66	99	-289	+.10	-3	-24
Supreme Virginian	10-68	98	-164	+.07	+15	+38
Glen Meadow Jeweled Mark	4-70	98	+258	-.11	-1	+15
Briarcliff Bold Torono	11-65	98	-160	-.03	-11	-29
Starn General	5-70	98	+524	-.30	-11	+15
Favorite Saint	2-72	98	+850	-.21	+14	+78
Briarcliff Soldier Boy	1-74	98	+624	-.24	+1	+42
Tenn Confident IEB Lad	5-70	92	+562	-.14	+10	+53

¹DOB=Date of birth, Rpt.=Repeatability, Milk=Lbs. milk,
 %=Percent butterfat, BF=Lbs. butterfat, \$=Dollars.

TABLE A-2. Control line sires.

Sire	Latest (PD82) Predicted Difference					
	DOB ¹	Rpt.	Milk	%	BF	\$
Sables Sybil Ira	11-64	64	-560	+.10	-27	-82
Milestones Bellringer	5-64	89	-1156	+.28	-26	-119
Secret Baronet	9-64	99	-212	+.15	+7	-2
Headspring Sparkle	11-64	66	-1130	+.18	-35	-132
Jester Infred Scotty	12-64	81	-474	+.06	-16	-58
UK Cherry Kelvin	4-65	59	-129	+.17	+13	+14
Confident Jeweler	2-65	79	-458	+.08	-13	-52
Stardust Itaska Designer A	4-65	91	-1003	-.11	-60	-167
Marlu Stylist Beacon	4-65	--	-1382	+.09	-57	-186
Headspring Sleeping Goliath	3-65	82	-812	+.09	-29	-102
Pixys Fancy Voyageur	1-65	80	-705	+.05	-28	-93
Jestermans Standard Basil	3-65	95	-700	+.25	-6	-55
Marlu Tempo	8-65	94	-965	.00	-46	-141
Patience Supreme	3-65	70	-1088	-.07	-59	-171
Beauty's Advancer	8-65	45	-1173	+.02	-54	-168
Borgs B. Etta Preceptor	6-65	57	-1364	+.05	-60	-190
Vaucluse Dazzling Rosemont	11-65	85	-1746	+.24	-60	-215
Cherry Secret Noble	8-65	81	-1010	+.12	-36	-126
Tymor Gipsy Snoball	9-66	75	-1434	+.21	-47	-172
Confident Infred Basil	10-65	66	-1214	+.06	-52	-167
Tenn Confident IEB Lad	5-70	92	+561	-.14	+10	+53
Tenn Milkboy B C Lad	NA ²	NA	NA	NA	NA	NA
Tenn Sleep Bart	NA	NA	NA	NA	NA	NA
Tenn Basil Ken	NA	NA	NA	NA	NA	NA

¹DOB=Date of birth, Rpt.=Repeatability, Milk=Lbs. milk, %=Percent butterfat, BF=Lbs. butterfat, \$=Dollars.

²Information not available.

VITA

Janeen Duncan Ward, the daughter of William and Ann Ward, was born on August 8, 1958 in Danville, Virginia. She was graduated from Porter High School in 1976. In the fall of the same year, she began attending The University of Tennessee, Knoxville. She was awarded a Bachelor of Science degree in Animal Science in 1982. She was a Bachelor of Science degree in Agricultural Education in 1983.

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