PRE- AND POSTPARTUM NUTRITIONAL EFFECTS ON MILK PRODUCTION,
MILK COMPOSITION, Calf WEANING WEIGHT AND POSTPARTUM REPRODUCTIVE
PERFORMANCE OF COMMERCIAL BEEF COWS

by

Jeffrey Mark Kearnan

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APPROVED:

W. E. Beal
M. L. Wahlberg

A. L. Eller, Jr.
Richard R. Frahm, Dept. Head

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PRE- AND POSTPARTUM NUTRITIONAL EFFECTS ON MILK PRODUCTION, MILK COMPOSITION, CALF WEANING WEIGHT AND POSTPARTUM REPRODUCTIVE PERFORMANCE OF COMMERCIAL BEEF COWS

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Abstract

The purpose of this study was to investigate the effect of prepartum and postpartum nutrition on milk production of commercial beef cows. Forty-three Angus or Angus X Holstein females, ranging in age from 2 to 6 yr, were randomly assigned by age and percentage Holstein within age to one of two prepartum grazing treatments (PRE). All females, regardless of PRE, were assigned at calving to receive the same post-calving nutritional energy. Females were assigned at calving by age, percentage Holstein within age, prepartum nutritional treatment and calving date to one of two milking groups. Milk weight (grams), milk composition (fat, protein, lactose, solids-not-fat, somatic cell count), dam body condition score (1 to 9), dam body weight, dam backfat thickness, ioineye area, calf weaning weight and postpartum interval to estrus were all evaluated. Milk removal occurred biweekly by vacuum milking machine after intravenous injection of 20 IU of oxytocin. Samples were weighed and taken for milk analysis and determination of milk components. At 76 ± 10 d post-calving, females were assigned by age, percentage Holstein within age, prepartum nutritional treatment, and calving date to receive one of two postpartum nutritional treatments (POST). Females continued to be milked by machine biweekly until calves were weaned 199 ± 10 d. Differences in grazing level prior to calving significantly effected calf birth weights, with dams on the prepartum
restricted grazing being lighter in weight at birth, 36.69±.68 and 38.95±.81 kg for PRE-L and PRE-H groups, respectively, however grazing differences did not effect calf weaning weight, calf gain or calf average daily gain. POST nutritional treatments significantly effected all calf performance traits with 37.10±.70, 38.54±.88; 196.89±4.9, 213.33±6.2; 159.79±4.8, 174.78±6.0; .809±.024, .888±.030; for birth weight, weaning weight, calf gain and calf average daily gain from cows on the POST-M or POST-H nutritional treatments, respectively. Pre-partum nutrition effected milk production (P<.001) with dams from the PRE-L grazing group producing less milk, 5622±75 vs 6888±80 g. Postpartum energy also effected milk production with dams on the POST-H energy level producing more milk than dams from the POST-M group. Percentages of fat, protein, lactose and solids-not-fat were not different between the prepartum or postpartum diets (P>.10). Somatic cell count was negatively correlated with dam milk production (P<.03). Postpartum interval to estrus was shorter for the PRE-L group than for the PRE-H, 43±4 vs 53±4 d.

Key Words: Beef Cattle, Milk Production, Weaning Weight, Postpartum Interval
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Table of Contents

PAGE

TITLE ................................................................................................. i

ABSTRACT ....................................................................................... ii

ACKNOWLEDGEMENTS .................................................................... iv

LIST OF TABLES ............................................................................. x

LIST OF FIGURES ............................................................................ xii

CHAPTER 1: REVIEW OF LITERATURE ................................................. 1

Introduction ...................................................................................... 1
Beef Cattle Management ................................................................. 1
Milk Production .............................................................................. 1

Measuring Milk Yield ...................................................................... 4
Machine Milking .............................................................................. 4
Hand Milking .................................................................................. 5
Teat Cannulation ............................................................................ 5
Calf Nursing ................................................................................... 5
Factors Affecting Milk Yield Measurement .................................... 6
Effect of Oxytocin .......................................................................... 6
Calf Separation Interval .................................................................. 7
Comparison of Methods for Measuring Milk Yield ....................... 9

Characterization of Milk Production in Beef Cows ......................... 11
Lactation Curves ............................................................................ 11
Milk Components .......................................................................... 13
Effect of Intramammary Infection .................................................. 19
Effect of Breed of Dam ................................................................. 21
Milk Yield ...................................................................................... 21
Effect of Sex of Calf ...................................................................... 22
Milk Yield ...................................................................................... 22
Effect of Age of Calf ..................................................................... 23
Effect of Calving Season ............................................................... 24

Factors Affecting Calf Performance ............................................... 25
Breed of Dam .................................................................................. 25
Milk Yield ...................................................................................... 26
Milk Composition .......................................................................... 28
Sex of Calf ..................................................................................... 29
Nutritional Effects on Milk Production and Weaning Weight .......... 30
Nutrition of the Dam ...................................................................... 30
Nutrition of the Calf ....................................................................... 32

Interaction Between Milk Production and Reproductive Efficiency .. 33
List of Tables

Table 1: Categorization of Cattle for Biological Type Relative to Milk Production.................................................................2

Table 2: Estimates of Components and Physical Properties of Raw Milk....15

Table 3: Estimates of Percent Butterfat (BF), Protein (P), Total Solids (TS), Solids-Not-Fat (SNF) and Lactose for various beef cattle breeds listed by author. ........................................................................16

Table 4: Estimates of Metabolizable Energy Required for Maintenance of Various Breeds or Breed Crosses...............................................................31

Table 5: Nutrient Concentrations of Feedstuffs on a Dry Matter (DM) Basis Fed to Dams at Calving and Maintained for 76±10 d Postcalving.................................................................43

Table 6: Nutrient Concentrations of Feedstuffs on a Dry Matter (DM) Basis Fed to Dams from 76 d Post-Calving until Weaning. ......................45

Table 7: Least Squares Means (±SEM) for Weights (kg) of Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H). .........................51

Table 8: Least Squares Means (±SEM) for Weights (kg) of Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Nutritional Levels (POST-M vs POST-H). ........................................53

Table 9: Least Squares Means (±SEM) for Weight Change (kg) of Dams on Differing Prepartum Nutritional Grazing Levels (PRE-L vs PRE-H)......55

Table 10: Least Squares Means (±SEM) for Weight Change (kg) of Dams on Differing Prepartum Nutritional Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H). ........................................57

Table 11: Least Squares Means (±SEM) of Ultrasonic Backfat and Loineye Measurements of Dams on Differing Prepartum Grazing Levels Evaluated at 76 d Pre-calving and Calving........................................58
Table 12: Least Squares Means (±SEM) of Ultrasonic Backfat and Loineye Measurements of Dams on Differing Prepartum Grazing Levels and Postpartum Energy Levels Evaluated at Calving and Weaning...........60

Table 13: Least Squares Means (±SEM) for Variables Representing Calf Growth and Performance of Calves from Dams on Differing Prepartum Nutritional Grazing Levels (PRE-L vs PRE-H) .................................................................62

Table 14: Least Squares Means (±SEM) for Variables Representing Calf Growth and Performance of Calves with Dams on Differing Postpartum Nutritional Levels (POST-M vs POST-H) .................................................................64

Table 15: Least Squares Means (±SEM) for Variables Representing Calf Growth and Performance of Calves with Dams on Differing Prepartum Nutritional Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) ........................................................................................................65

Table 16: Least Squares Means (±SEM) for Variables Representing Calf Growth and Performance of Calves with Dams on Differing Prepartum and Postpartum Nutritional Treatments and Grouped by Calf Sex..............68

Table 17: Least Squares Means (±SEM) for Variables Representing Calf Growth and Performance for Calves with Dams on Differing Prepartum and Postpartum Nutrition and Subgrouped by Dam Age and Percent Crossbreeding.............................................................................................69

Table 18: Least Squares Means (±SEM) for Milk Component Percentages from Initiation of Postpartum Nutrition at 76 d Post-calving to Weaning from Dams on Differing Prepartum Grazing Levels and Postpartum Energy Levels .......................................................................................88

Table 19: Residual Correlations Among Average Fat, Protein, Lactose and Fluid Components of Milk and Weaning Weight from Dams on Differing Prepartum Grazing Levels and Postpartum Energy Levels ...90

Table 20: Least Squares Means (±SEM) for Variables Representing Reproductive Performance from Dams on Prepartum Grazing Differences (PRE-L vs PRE-H) and Postpartum Energy Treatments (POST-M vs POST-H). .........................................................................................................................94
List of Figures

Figure 1: Experimental Design for Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) Fed to Forty-three Angus or Angus x Holstein Dams ........................................... 42

Figure 2: Average of Actual Weights of Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) from 76 d Pre-calving to 76 d Post-calving ................................................................. 50

Figure 3: Average of Actual Weights of Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) from 76 d Postcalving to Weaning at 209 d Postcalving ................................................................. 54

Figure 4: Calf Weaning Weights from Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) ................................................................. 66

Figure 5: Least Squares Means for Calf Weaning Weights from Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) and Subgrouped by Cow Age and Percentage Crossbreeding ................................................................. 70

Figure 6: Comparison of Statistical Models Utilized to Determine Average Milk Weight from Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) from Calving to Weaning at 209 d Postcalving ................................................................. 78

Figure 7: Average Actual Dam Milk Weights and Calf Weaning Weights from Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) ................................................................. 81

Figure 8: Average Actual Dam Milk Weights and Calf Weaning Weights from Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) and Subgrouped by Cow Age and Percentage Crossbreeding ................................................................. 82

Figure 9: Average Milk Production of All Dams Regardless of Prepartum Grazing Levels and Postpartum Energy Levels from Calving to Weaning at 209 d Postcalving ................................................................. 83

xii
Figure 10: Average Milk Production of Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) from Calving to Weaning at 209 d Postcalving. ......................................................... 81
CHAPTER 1

Literature Review

INTRODUCTION

Beef Cattle Management

The production of pounds of calf is the main economic goal of today's cow-calf producer. Milk production of the beef cow has a major impact on pounds of calf produced, thus influencing the production efficiency of the beef enterprise. However, when under a limited feed supply and/or a stressful environment, biological types having low to moderate size and/or low to moderate milk production tend to be better adapted and excel in biological efficiency over larger, heavier-milking types (intake vs. production; Ritchie, 1989; Table 1). For these reasons management decisions should be made with the entire beef enterprise in mind. In most environments and management systems, cattle should not be extreme in any one production trait, instead they should be moderate in most traits so as to withstand the changes that occur in climate, cattle prices and production costs (Notter, 1985; Ritchie, 1989). Milk production is one such aspect of beef cattle production and can be selected for or against, either purposefully or inadvertently.

Milk Production

Milk yield is dependent on the development of the secretory tissue (mammogenesis), development of the secretory capacity of the individual cells (lactogenesis) and development of the cow's ability to maintain an established milk yield (galactopoiesis; Sejrsen, 1978). These processes are under
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hormonal control and governed by hormones in the "lactogenic complex" (Hoffmann and Schams, 1975).

The influence of milk yield on calf performance to weaning, expressed as either calf average daily gain (ADG) or weaning weight has been evaluated. The single-most important factor influencing the calf's performance is the dam's milk production (Drewry et al., 1959; Neville, 1962; Todd et al., 1966; Rutledge et al. 1971; Boggs et al., 1980). The variation in weaning weight due to the effect of milk yield has been estimated to be between 60 and 66% (Drewry et al., 1959; Neville, 1962; Rutledge et al., 1971) and accounted for 71% of the variation in calf average daily gain (Gleddie and Berg, 1968). Jeffery and Berg (1971) estimated that each additional kg of milk produced per day by the dam increased calf preweaning weights 7 to 14 kg (19.2 kg milk/1 kg calf gain). Later, Boggs et al., (1980) determined that for each additional .45 kg of milk consumed per day, a calf was 4.5 kg heavier at time of weaning (20.5 kg milk/1 kg calf gain). Clutter and Nielson, (1987) noted a significant advantage in 205-d weights for calves suckling high-milking cows over those suckling low-milking cows. A large portion of this advantage at weaning was maintained through a postweaning feedlot period and was reflected in final weights at slaughter as well as in carcass weights.

Because of the important role that milk plays in beef production, this literature review will present information on several factors that influence the milk production of beef cows and how variation in milk production affects the pounds of calf weaned from the beef enterprise.
MEASURING MILK YIELD

Four methods have been used to measure milk output and to estimate daily milk production in beef cows. These methods are machine milking, hand milking, teat canulation and calf nursing (weigh-suckle-weigh). All of these methods require the separation of the calf from the cow for a predetermined interval.

Machine Milking

While used most widely in the dairy industry, machine milking is a highly-accurate and precise way of estimating milk yield in beef cows. A milking machine must remove milk from the cow thoroughly and rapidly, but not impose excessive stress or contamination to the teat and udder. The machine removes milk by applying vacuum to the exterior of the teat until it stretches sufficiently to open the streak canal. Periodic collapse of the teat cup liner by reducing the vacuum relieves tension on the teat sphincter and aids circulation of blood through the teat during milking.

Following a predetermined period of calf separation, each cow is administered oxytocin, either intravenously or by intramuscular injection. A vacuum milking machine is applied to each quarter of the udder for milk removal. The vacuum created by the machine causes the pressure outside the streak canal to be lower than that inside the teat cistern, thus allowing milk ejection. After it has been determined that all the milk possible has been removed, milk yield is recorded and composite samples can be taken for estimation of milk components (Gleddie and Berg, 1968; Batra et al., 1969;
Todd et al., 1969; Abadia and Brinks, 1972; Belcher and Frahm, 1979; Belcher et al., 1980; Martin, 1982; Humes and Taylor, 1983; Beal and Custer, 1989; Beal et al., 1990).

**Hand Milking**

Another method used for milk removal that is similar to machine milking is hand milking. This procedure is carried out precisely as machine milking except that the actual physical removal of the milk is done by hand (Hohenboken et al., 1973; Totusek et al., 1973; Lawson, 1981; Bastidas et al., 1990). In hand milking, hand pressure creates a greater pressure within the teat cistern than that outside the teat allowing the ejection of milk.

**Teat Cannulation**

Teat cannulation is another method used for estimation of milk yield. After injection of oxytocin, each teat orifice is washed with alcohol and a metal catheter is inserted into the teat canal. The milk can then be collected into a funnel held beneath the mammary gland (Berg and Peschiera, 1967; Holmes et al., 1968; Lamond et al., 1969; Jeffery and Berg, 1971; Falk et al., 1975; Bowden, 1981).

**Calf Nursing**

This method is by far the most widely used for obtaining milk yield estimates from beef cattle. After a period of separation from its dam, the calf is weighed, allowed to nurse the dam, and then immediately reweighed (weigh-suckle-weigh). The difference in the initial (pre-suckle) and the final (post-suckle) weight is an estimate of calf milk consumption and thus the milk production of the dam (Knapp and Black, 1941; Drewry et al., 1959; Dawson
et al., 1960; Neville, 1962; Dunn et al., 1965; Melton et al., 1967; Oxenreider and Wagner, 1971; Rutledge et al., 1971; Dickey et al., 1972a, 1972b; Totusek et al., 1973; Kress and Anderson, 1974; Neville et al., 1974; Williams et al., 1979; Boggs et al., 1980; Jenkins and Ferrell, 1984; Holloway et al., 1985; Jenkins et al., 1985; Odde et al., 1985; Daley et al., 1987; Beal et al., 1990).

In calf suckling, milk ejection is accomplished when the calf creates a greater pressure within the teat cistern while at the same time lowering the pressure outside the streak canal. Some studies have been conducted in which hand milking is conducted along with or in combination to machine milking or the calf nursing method (Christian et al., 1965; Wilson et al., 1969; Hohenboken et al., 1973; Totusek et al., 1973).

Factors Affecting Milk Yield Measurement

Effect of Oxytocin- Oxytocin is a key factor in eliciting milk ejection in mammals. Oxytocin, an octapeptide synthesized in the paraventricular nuclei of the hypothalamus, is stored in the posterior pituitary (neurohypophysis). Under natural conditions, oxytocin is released from the posterior pituitary into peripheral blood by stimuli associated with nursing (Sagi et al., 1980). Oxytocin then acts on the myoepithelial cells (smooth muscle cells) that surround the alveoli in the mammary gland. The contraction of the myoepithelial cells exerts pressure on the alveoli and displaces milk from the alveoli into the duct system of the mammary gland. This process is termed the milk ejection reflex.
Exogenous administration of oxytocin can also initiate milk ejection in mammals (Knodt and Petersen, 1944; Donker et al., 1954; Sprain et al., 1954; Koshi and Petersen, 1955; Turner, 1955). Sagi et al. (1980) studied the effects of various dosages of intravenously administered oxytocin on milk ejection response. Ten international units (IU) of oxytocin was the minimum amount needed to induce milk ejection in Holstein cows. Either 10 or 30 IU produced greater peak rates of milk flow and shorter milking times than the lower levels of injected oxytocin. Other studies comparing 10 and 20 IU of oxytocin concluded that 20 IU was adequate for complete milkout from cows with differing levels of milk production at various stages of lactation (Lamond et al., 1969; Hanjra et al., 1977). Most researchers have utilized intravenous administration of 20 IU oxytocin (Gleddie and Berg, 1968; Jeffery and Berg, 1971; Bowden, 1981) or 40 IU of oxytocin (Klett et al., 1965; Wistrand and Riggs, 1966; Todd et al., 1966, 1969; Melton et al., 1967; Rutledge et al., 1971; Cundiff et al., 1974; Hanjra et al., 1977; Belcher et al., 1980) for estimation of milk production.

Schwulst et al. (1966) evaluated milk production when utilizing oxytocin or no oxytocin. Oxytocin treatment did not have a significant effect on milk consumption by the calf or total milk produced by the dam. In addition there was no change in the composition of milk when cows were administered exogenous oxytocin. However, there was a trend towards higher milk production by dams administered exogenous oxytocin.

Calf Separation Interval - The amount of milk collected or consumed by the calf is affected by the length of time the cow and her calf are separated prior to milking (Williams et al., 1979; Belcher et al., 1980; Chenette and
Frahm, 1981). Hereford cattle were evaluated for the effects of 4-, 8- or 16-hr separation periods on milk yields (Williams et al., 1979). Treatment means adjusted to a 24-hr production differed significantly at 9.2, 7.6 and 5.9 kg for 4-, 8- and 16-hour separation, respectively. Williams concluded that the 8-hr separation gave the best estimate of milk production because of a more precise measurement, less discomfort to the cow and closer to natural interval of nursing by the calf.

The effect of separation intervals of 6-, 9-, or 12-hr on milk yield have also been evaluated for beef cattle (Belcher et al., 1980; Chenette and Frahm, 1981). Results from Belcher et al. (1980) showed that adjusted 24-hr milk yield was the highest for 6-hr separation for both the calf nursing and machine milking techniques (6.10 and 7.36 kg, respectively). The lowest yield estimates came from 12-hr separation time (5.48 kg for calf nursing and 6.83 kg for machine milking). Similar results were recorded by Chenette and Frahm (1981) who reported that cows in the 6-hr group had estimated daily milk yields that were 1.04 kg higher (P < .05) than those in the 12-hr group. As separation time increased from 6 to 9 to 12 hr, estimates for nearly all milk traits decreased. Milk protein percent was the only trait measured that increased as separation interval increased. It has been suggested that the 6-hr separation time be utilized as it is the least stressful on the cow (Lamond et al., 1969). However, other researchers have determined that milk production estimates are influenced less by the interval from separation to milk removal when that interval is 16 hours than when it is 4 hours (Williams et al., 1979; Beal et al., 1990). Beal et al., 1990 reported that the effect of the duration of time that the calf was separated from its dam prior to machine milking or
weigh-suckle-weigh (mean 19.9 hours) did not significantly affect milk production estimates as long as the calves separation interval was at least greater than 15 hr.

**Comparison of Methods for Measuring Milk Yield**

Each of the various milking methods has advantages and disadvantages. Machine milking is an extremely accurate method that allows for milk component analysis and places limited stress on the calf. However, machine milking also requires an intensive labor investment, more time and modern milking subjects the cow to greater stress than some of the other methods available. Machine milking is extremely accurate for predicting cow milk production, however, it may not reflect accurately the calf’s consumption of milk, particularly near peak lactation when the calf may be unable to consume and utilize all the milk produced.

Hand milking is used infrequently because of the extensive labor and time involved. Machine milking is a more accurate and desirable method than hand milking since management of the animals is similar and labor is less when utilizing the milking machine. Conversely, teat cannulation is extremely accurate and requires similar labor, however it is seldom used although it takes the least amount of time for actual milk collection. Insertion of the cannula into the teat canal may be considered to be the most stressful method of any of the techniques described.

Calf nursing method or weigh-suckle-weigh as it is often called, requires less labor and stress to the cow than other methods, but it does not allow for actual collection of the milk for component analysis. In addition, the weigh-
suckle-weigh technique has more room for error as defecation or urination between the time of the two weighings introduces a potential for error in this method. However, weigh-suckle-weigh may be the most accurate method for determining actual milk consumption of the calf, since the other methods discussed measure milk output of the cow rather than milk consumption by the calf.

Numerous studies have been completed to evaluate the accuracy of the methods for measuring milk yield. Belcher et al., (1980) reported a milk yield of 7.40 kg per day from machine milking which was 27% greater than the estimated milk yield of 5.80 kg per day achieved from the calf nursing method. On the other hand, Wistrand and Riggs (1966) found no significant differences between the calf nursing and machine milking methods. Beal et al., 1990 reported repeatability differences when comparing machine milking (.97) and weigh-suckle-weigh (.35), however when estimates were averaged he reported relatively no differences between machine milking (.75) and the weigh-suckle-weigh technique (.76) when correlated with pre-weaning calf gain. A study conducted by Neidhardt et al., (1979) obtained milk yield estimates by hand milking that were 29% lower than milk yield estimated by the calf nursing method. It has also been reported that calf nursing estimates for milk yield were 29% higher (5.85 vs. 4.54 kg) and less variable than estimates derived from hand milking (Totusek et al., 1973).

Milk production level between breeds is more variable than once realized. Peak milk production in Polled Hereford females occurred 50 d after calving at 6.8 kg per day while peak milk production in the Simmental females evaluated occurred 58 days postcalving at 9.0 kg per day (Schalles, et al.
1990). In contrast Marston et al. (1990) reported that the Angus and Simmental females peaked between 11.4 and 13.6 pounds at 70 days postcalving. Some of these differences may be attributed to variations in management and environmental conditions between studies.

**Characterization of Milk Production in Beef Cattle**

**Lactation Curves**

Milk production can be expressed as a lactation curve (dzm milk production X days) which varies among individuals, within a breed and from breed to breed. Lactation curves of beef cattle can be characterized by high levels of milk produced immediately following calving followed by decreased levels of milk with increasing days postpartum (Melton et al., 1967; Robison et al., 1978; Boggs et al., 1980; Singh and Shukla, 1987). Gleddie and Berg (1968) found an average of .02 kg/d decline in milk yield when expressed across the entire lactation curve. Lactation curves of beef cattle differ from those normally recorded for dairy cattle. Beef females tend to be more linear in their milk decline (high to low) while dairy cattle will usually have a "peak" during their lactation (medium to high back to medium).

Milk yield decline has been described as linear (Gleddie and Berg, 1968; Lamond et al., 1969). Gaskins and Anderson (1980) indicated lactation curves were more convex for cows which had higher milk production (three- and four-year olds) and were linear for those with lower milk production (two-year olds). Lamond et al. (1969) reported variation of curves from Hereford cows in which
most of the cows had a significant linear decline in production while others had no change at all. Daily milk yield of Brahman X Angus dams increased as lactation progressed, while production levels of other breed types remained approximately the same or declined throughout lactation (Daley et al., 1987). Peak milk production in Shorthorns occurred at the end of 8 wks as reported by Dawson et al. (1960), while Totusek et al. (1973) showed peak milk yields for hand-milked cows occurred at 3 wk and calf-nursed cows at 7 wks. Williams et al. (1979) and Butler et al. (1981) reported that milk yield was the greatest between 4 to 7 wk which is similar to the estimate of 30 to 40 d as reported by Abadia and Brinks (1972). Working with Brahman cows, Neidhardt et al. (1979) showed peak lactation was reached at 30 days.

The literature provides contrasting views on persistency of lactation. Cundiff et al. (1974) reported reciprocal cross-bred cows had greater persistency than the straightbred Angus, Hereford or Shorthorn females evaluated. Nielsen et al. (1983) showed that higher-producing dams had a more persistent lactation as compared to the lower-producing cows. In direct contrast, breed groups with high average milk levels were reported as being less persistent than those of lower levels (Notter et al., 1978). Todd et al. (1969) discovered young cows calving in the fall showed a marked decline in milk yields from February to June with cows older than 5 yr showing little decline. This could be attributed to the young cows' increased nutrient requirements for continued growth.
Milk Components

Various methods are available for the determination of milk components. The composition of milk is usually tested for protein, lactose, fat, total solids, solids-not-fat and somatic cell count. Butterfat or fat percent can be determined by Te-Sa method (Lamond et al., 1969), Babcock test (Todd et al., 1966; Batra et al., 1969; Rutledge et al., 1971), or Milk-O-Tester (Belcher et al., 1979). Protein percentage can be estimated by the Orange G dye (Batra et al., 1969), Buffalo black dye (Rutledge et al., 1971) or UDY method (Belcher et al., 1979). Total solids content has been analyzed by a lactometer (Todd et al., 1966; Lamond et al., 1969), the Monjonnier method (Totusek et al., 1973), or oven drying for a specific time (Belcher et al., 1979). The solids-not-fat can be analyzed by the Golding bead method (Batra et al., 1969) or by simple subtraction of butterfat from total solids percent (Todd et al., 1966).

When testing large numbers of milk samples for fat, protein and SNF content, Infrared Milk Analyzers are the only practical method. This method utilizes infrared light which is passed through various filters and combinations of filters, dependent on the component being analyzed. The signal is then received after being passed through the milk sample. In this way one machine is capable of analyzing all the major milk components (Barbano and Clark, 1989).

The major components of milk produced by mammals include water, fat, protein, lactose and minerals (Warwick, 1980). While the presence of certain milk components is generally similar among species, they will vary greatly in the proportion of the milk they represent (Warwick, 1980). Along with variation among species, the milk constituents will vary among breeds, herds
within breeds and among individuals within the same breed and herd (Laben, 1963). There are many factors influencing milk composition, the major factors being stage of lactation, season, nutrition, and environment (Wilcox et al., 1959; Laben, 1963; Klett et al., 1965; Rook and Campling, 1965; Gleddie and Berg, 1968). Dam age has also been shown to significantly effect milk components (Cole and Johansson, 1933; Wilcox et al., 1959; Laben, 1963).

Herrington et al., (1972) summarized the average composition of cows milk (Table 2). Total milk with the water removed is referred to as total solids (TS). Total solids with milk fat removed is termed solids-not-fat (SNF). Numerous researchers have given estimates of milk components and a summary of their findings are presented in Table 3.

The literature indicates that fat percentage is affected by many factors. Cole and Johansson (1933) established that fat percentage slightly decreased with increasing cow age. In addition, when approaching the end of lactation, it has been reported that butterfat tends to increase (Laben, 1963; Rook and Campling, 1965; Gleddie and Berg, 1968). Breed and age of dam were reported to have no effect on differences in percent butterfat of beef females (Melton et al., 1967; Cundiff et al., 1974). Contradicting evidence reported by Todd et al. (1966) and Belcher and Frahm, (1979) showed breed of cow was highly significant for fat percent or yield. Fat percent was significantly lower in two-year-old than in four-year-old cows in the study by Chenette and Frahm (1981). Munford et al. (1964) concluded that restricted grazing did not influence milk fat yield or percentage.

Solids-not-fat showed little variability in most reports (Klett et al., 1962; Todd et al., 1966; Totusek et al., 1973). Cundiff et al. (1974) determined that
TABLE 2: ESTIMATES OF COMPONENTS AND PHYSICAL PROPERTIES OF RAW MILK

<table>
<thead>
<tr>
<th>Component</th>
<th>Number of Obs.</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
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<tr>
<td><strong>Gross composition</strong></td>
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</tr>
<tr>
<td>Total solids, %</td>
<td>856</td>
<td>12.018</td>
<td>9.83</td>
<td>13.84</td>
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<tr>
<td>Fat, %</td>
<td>858</td>
<td>3.530</td>
<td>2.00</td>
<td>4.65</td>
</tr>
<tr>
<td>Protein, %</td>
<td>863</td>
<td>3.127</td>
<td>2.53</td>
<td>3.74</td>
</tr>
<tr>
<td>Lactose, %</td>
<td>493</td>
<td>4.82</td>
<td>4.42</td>
<td>5.81</td>
</tr>
<tr>
<td>Ash, %</td>
<td>378</td>
<td>0.725</td>
<td>0.68</td>
<td>0.76</td>
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<tr>
<td><strong>Physical Properties</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Specific Gravity</td>
<td>877</td>
<td>1.029</td>
<td>1.02</td>
<td>1.03</td>
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<td>Freezing point °C</td>
<td>376</td>
<td>-.543</td>
<td>-.52</td>
<td>-.57</td>
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<tr>
<td><strong>Protein components</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Casein, %</td>
<td>424</td>
<td>2.268</td>
<td>1.76</td>
<td>2.90</td>
</tr>
<tr>
<td>Whey protein, %</td>
<td>456</td>
<td>0.870</td>
<td>0.38</td>
<td>1.21</td>
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<td><strong>Mineral components</strong></td>
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<tr>
<td>Calcium, mg/100ml</td>
<td>451</td>
<td>111.0</td>
<td>61.0</td>
<td>134.0</td>
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<td>Magnesium</td>
<td>451</td>
<td>16.4</td>
<td>3.8</td>
<td>48.4</td>
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<td>Chlorides, %</td>
<td>871</td>
<td>0.11</td>
<td>0.095</td>
<td>0.146</td>
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<tr>
<td><strong>Acid components</strong></td>
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<td>6.98</td>
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<td>Titretable Acidity, %</td>
<td>361</td>
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<td>0.118</td>
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<tr>
<td>% lactic acid</td>
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<td>Breed or Cross</td>
<td>BF</td>
<td>P</td>
<td>TS</td>
<td>SNF</td>
</tr>
<tr>
<td>------------------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>-----</td>
</tr>
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<td>Bos taurus</td>
<td>3.7</td>
<td>3.4</td>
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<tr>
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<td>4.97</td>
<td>3.29</td>
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</tr>
<tr>
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<td>5.01</td>
<td>3.26</td>
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</tr>
<tr>
<td>Simmental x Angus</td>
<td>4.97</td>
<td>3.28</td>
<td>12.90</td>
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<tr>
<td>Simmental x Hereford</td>
<td>4.73</td>
<td>3.28</td>
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</tr>
<tr>
<td>Brown Swiss x Angus</td>
<td>4.62</td>
<td>3.19</td>
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</tr>
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<td>12.91</td>
<td></td>
</tr>
<tr>
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<td>3.37</td>
<td>13.57</td>
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<td>14.30</td>
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<tr>
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<td>4.06</td>
<td>3.56</td>
<td>13.40</td>
<td>4.95</td>
</tr>
<tr>
<td>At 6 weeks:</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Crossbreds</td>
<td>3.64</td>
<td></td>
<td>12.9</td>
<td>3.55</td>
</tr>
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<td>Straightbreds</td>
<td>3.76</td>
<td></td>
<td>12.17</td>
<td>8.38</td>
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<td></td>
<td>15.52</td>
<td>9.34</td>
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<td>9.0</td>
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<tr>
<td>Galloway</td>
<td>4.0</td>
<td>3.4</td>
<td>13.0</td>
<td>9.1</td>
</tr>
<tr>
<td>Angus</td>
<td>4.0</td>
<td>3.4</td>
<td>13.1</td>
<td>9.1</td>
</tr>
<tr>
<td>Charolais x Angus</td>
<td>3.7</td>
<td>3.5</td>
<td>12.9</td>
<td>9.2</td>
</tr>
<tr>
<td>Angus x Galloway</td>
<td>3.8</td>
<td>3.4</td>
<td>12.8</td>
<td>9.0</td>
</tr>
<tr>
<td>Hereford (2-yr-old)</td>
<td>3.6</td>
<td>3.8</td>
<td>12.7</td>
<td>9.1</td>
</tr>
<tr>
<td>Various Breeds</td>
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<td>3.28</td>
<td>8.67</td>
<td>9.50</td>
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<tr>
<td></td>
<td>5.77</td>
<td>3.93</td>
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<td></td>
</tr>
<tr>
<td>Angus</td>
<td>3.67</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Hereford</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angus</td>
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<td></td>
<td>11.31</td>
<td>8.64</td>
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<td>Charolais</td>
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<tr>
<td>Angus</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>-Control</td>
<td>4.34</td>
<td>2.87</td>
<td>12.67</td>
<td>8.59</td>
</tr>
<tr>
<td>-Oxytocin</td>
<td>4.21</td>
<td>3.00</td>
<td>12.89</td>
<td>8.65</td>
</tr>
<tr>
<td>after nursing</td>
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<td></td>
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<tr>
<td>-Oxytocin</td>
<td>3.94</td>
<td>3.03</td>
<td>12.42</td>
<td>8.49</td>
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16
<table>
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<tr>
<th>Breed Type</th>
<th>BF</th>
<th>P</th>
<th>TS</th>
<th>SNF</th>
<th>Lactose</th>
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<tr>
<td>Brahman</td>
<td>5.12</td>
<td>13.95</td>
<td>8.83</td>
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<tr>
<td>Hereford</td>
<td>3.22</td>
<td>11.83</td>
<td>8.61</td>
<td></td>
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<tr>
<td>Brahman x Hereford</td>
<td>3.83</td>
<td>12.44</td>
<td>8.61</td>
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<tr>
<td>Hereford x Brahman</td>
<td>3.27</td>
<td>11.63</td>
<td>8.36</td>
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<tr>
<td>Ang x Heref x Brah.</td>
<td>3.55</td>
<td>12.44</td>
<td>8.89</td>
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<tr>
<td>All Cows</td>
<td>3.90</td>
<td>12.46</td>
<td>8.66</td>
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<tr>
<td>Beef Cows</td>
<td>3.2</td>
<td>12.2</td>
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<tr>
<td>High Energy</td>
<td>3.47</td>
<td>3.54</td>
<td>8.79</td>
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<td></td>
</tr>
<tr>
<td>Low Energy</td>
<td>3.39</td>
<td>3.38</td>
<td>8.43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: BF = Butterfat, P = Protein, TS = Total Solids, SNF = Solids-Not-Fat, Lactose.*

Sources:
- Todd et al. (1966)
- Totusek et al. (1973)
- Wilson et al. (1989)
the percentage SNF was similar when comparing crossbred and straightbred cows at 6 wk, but was significantly higher (P < .05) in the straightbred cows at weaning. However, crossbred cows produced a yield of 9.7% more SNF at 6 wk and 33% more yield SNF at weaning when total milk production was multiplied by milk composition to calculate SNF yield. This is a direct reflection of the fact that crossbred cows tend to produce more milk across the entire lactation. Laben (1963) and Rook and Campling (1965) reported that SNF percentage rose sharply during late lactation. It has also been reported that SNF percentage decreased as cow age increased (Wilcox et al., 1959; Laben, 1963).

Total milk solids were found to be significantly affected by cow breed in a study by Belcher et al. (1979). Cundiff et al. (1974) determined that total solids tended to favor straightbred cows over crossbred cows. Gleddie and Berg (1968), reported that total solids content rose continuously through the fifth month of lactation. Breed of cow and age of dam both affected total solids yield (Melton et al., 1967). Variability of total solids was determined to be intermediate when compared to the other milk components studied in a trial by Todd et al. (1966).

Belcher et al., (1979) showed that cow breed significantly affected milk protein percentages. Protein percent has been reported to increase early in lactation and to sharply increase later in lactation (Rook and Campling, 1965). In direct contrast, Cole and Johansson (1933) found protein percentages tended to decrease with increasing lactation. Laben (1963) noted that underfeeding of total nutrients reduced protein percent as well as milk yields.
Effect of Intramammary Infection

Bovine mastitis, or intramammary infection, is a disease of the mammary gland that is spread from cow to cow and can significantly reduce milk production (Carrol, 1977; Kirkbride, 1977; Haggard et al., 1983; Watts et al., 1986). Most mastitis problems in dairy cows are a direct result of the rigors that daily machine milking places on the teat and streak canal, which in turn predisposes the cows to mastitis (Thompson, 1983). Beef females under range conditions do not undergo this trauma, however, occasionally it is necessary to cull beef cows because of clinical mastitis. Research also indicates that there appears to be some differences in epidemiologic characteristics of beef and dairy cow mastitis.

The pathogens responsible for the majority of intramammary infections in dairy cattle are *Streptococcus* and *Staphylococcus*. Examinations of beef cattle mammary infection in the United States have yielded primarily *Staphylococcus aureus* with minor incidence of *Klebsiella sp* and *Streptococcus sp*. In two reports, one from England (Hunter and Jeffrey, 1975) and one from Australia (Sobari et al., 1976), *Streptococcus agalactiae* was found in beef cattle udders. However, similar studies conducted in the United States have not revealed the presence of *Streptococcus agalactiae* in beef females (Sobari et al., 1976; National Mastitis Council, 1981). Thus the pathogen genus responsible for the majority of intramammary infections in beef females appears to be *Staphylococcus*.

The *Staphylococcus* family is any of various nonmotile gram-positive spherical bacteria that include parasites of the skin and mucous membranes.
Coagulase-positive staphylococci isolated from beef females are considered to be the most pathogenic of the micrococci and are not found to a great extent in dairy cattle. *Staphylococcus aureus* infections were associated with increased somatic cell levels and decreased 210 d weaning weights (P < .01). In dairy cattle, somatic cell count (SCC) increases with time of lactation and number of milkings. Research on the relationship between SCC and milk production in dairy cows has lead researchers to suggest that the greatest impact of intramammary infections on calf preweaning weight gains in beef herds is caused by reduced milk production of the dam. Linear regression analysis indicated a negative correlation (.48) between milk SCC levels from beef females and the weaning weights of their calves (Haggard, 1983).

Kirkbride, (1977) reported an incidence of 17.5%, about one-half the infection rate found in dairy females (39.5%), when evaluating beef cows for the presence of various intramammary pathogens. He concluded that calf weaning weights were reduced 12.5% as a result of these pathogens. A study by Haggard et al. (1983) on prevalence and effect of subclinical mastitis in beef cows, revealed 11.9% of cows infected, while calves from infected dams when compared to those of uninfected dams weighed 12.1 kg less at weaning in one study (203.9 vs. 218.2) and 14.3 kg less in another (162.5 vs. 174.6). These weight differences were determined at weaning and would probably have been more drastic if measured at 2 months of age when the majority of the dry matter, digestible protein, and digestible energy intake of the calf is derived strictly from milk. In another study, mastitis caused a reduction (P < .01) in percentage of lactose of beef cows but had no effect on milk yield (Daley et al., 1987).
Effect of Breed of Dam

Milk Yield. Breed of the dam has been shown to have a significant influence on variation in milk yields (Todd et al., 1966; Melton et al., 1967; Gleddie and Berg, 1968; Todd et al., 1969; Notter et al., 1978; Belcher and Frahm, 1979; Gaskins and Anderson, 1980; Jenkins et al., 1986). Gaskins and Anderson, (1980) reported means for daily milk production were 5.8, 7.7 and 7.7 kg/d for Angus-Hereford, Jersey-Angus and Simmental-Angus dams, respectively. Brown Swiss dams had a greater total milk yield than Angus dams which were intermediate and Hereford dams which were the lowest (Jenkins et al., 1986). Average estimated milk yields for a 175 d lactation period were 784, 664, and 581 kg for Charolais, Angus and Hereford dams, respectively (Melton et al., 1967). Notter et al., (1978) concluded that Jersey and Simmental cross females produced the most milk, with Limousin and Charolais cross dams and purebred Hereford and Angus cows giving the least.

Bowden (1981) reported on milk composition of different breed types. At 6 wk postpartum, Jersey-Angus cows had higher milk fat than Simmental-Angus or Charolais-Angus cows and milk from Hereford-Angus and Jersey-Angus contained more total solids than Simmental-Angus cows. Chenette and Frahm (1981) examined milk yield, protein percentage and total solids percentage and found that crossbred cow group was a significant source of variation. On the average Brown-Swiss dams, Jersey dams and Simmental-Angus dams produced 2.66 kg/day more milk than Hereford-Angus reciprocal cross females as 2-year olds and 1.23 kg/day more as 4-year old cows. Breed of cow was non-significant for yield or percentage of butterfat. Gaskins and Anderson (1980) showed Angus-Hereford cows (5.8 kg/day) gave significantly
less milk per day than either Jersey-Angus or Simmental-Angus dams (both 7.7 kg/day).

Breed of cow accounted for 82.5% of the variation in milk yield in a study conducted by Gleddie and Berg (1968), with mature Angus cows producing the most milk of the breed types evaluated. Melton et al. (1967) reported highly-significant breed differences in milk yield with average 175-d milk yields of 785, 664 and 581 kg for Charolais, Angus, and Hereford dams respectively. Significant variation among breed groups was reported on d 131 of lactation by Notter et al. (1978). This difference was primarily due to higher average production of females with Angus dams (5.0 kg/d) than those of Hereford dams (3.9 kg/d).

Milk production (12 hr) of crossbred cows was greater than straightbred cows by 7.5 percent at 6 wk and by 38% at weaning (Cundiff et al., 1974). No significant difference was found for butterfat or total solids percent. Drewry et al. (1959) also reported crossbred dams produced more milk. McGinty and Frerichs (1971) determined significant differences between breeds examined at 85, 135 and 180 d postcalving with Brown Swiss-Hereford exceeding the Hereford dam milk production at each period.

**Effect of Sex of Calf**

*Milk Yield.* Many researchers have investigated the influence of calf sex on dam milk yield. In the majority of studies, calf sex was a non-significant source of variation for dam milk yield (Christian et al., 1965; Todd et al., 1966; Melton et al., 1967; Gleddie and Berg, 1968; Wilson et al., 1969; Neville et al., 1974; Reynolds et al., 1978; Williams et al., 1979; Chenette and Frahm, 1981;
Chew et al., 1981; Lawson et al., 1981). However, some studies have shown an effect of calf sex on milk yield. Hohenboken et al. (1973) found sex of calf significantly influenced (P < .05) milk yield and composition of milk where dams nursing male calves produced more milk. This is in agreement with Pope et al. (1963) and Meitom et al. (1967) who reported increased milk production from dams with male calves. Daley et al., (1987) reported sex of calf influenced 24-hr milk yield at 60 and 105 days of lactation, with bull calves receiving more milk than heifers. In contrast, Rutledge et al. (1971) observed that dams nursing female calves produced approximately 56 kg more milk over a 205-day lactation than did those dams nursing male calves. Jeffery et al. (1971) noted that the effect of calf sex on milk yield of the dam was inconsistent, cows nursing male calves yielded more milk in one year but not in the next.

**Effect of Age of Calf**

Calf age and calf weight contribute to variation in estimated milk yields. Calf age can be expressed as dam day of lactation or stage of lactation. Todd et al. (1966) reported calf age had a highly significant influence on variation in milk yield estimates. Calf birth date significantly affected milk yield and 210-d weight of calves in two herds of Herefords studied (Neville et al, 1974). Females calving later in the calving season produced more milk and weaned heavier calves. Each day later in the 90-d calving season that birth occurred, milk production increased .01 kg and weaning weight increased .3 kg (P < .01) in one study (Neville et al., 1962) and increased .14 kg/d at 4 mo of age in another (Neville, 1974). Conversely, calves born earlier in the calving season grew significantly faster from birth to weaning and weighed more at weaning.
than calves born later in the calving season (Lesmeister et al., 1973). Drewry et al. (1959) stated heavier calves were able to stimulate milk production more intensively by imposing a higher nursing frequency. This assumption is supported by the positive correlation between birth weight of calf and milk yield of dam (Drewry et al., 1959; Neidhardt et al., 1979). Neidhardt et al. (1979) reported calf weight affected milk yield, probably because milk production and calf weight mutually influence each other.

Age of calf affected suckling behavior (Drewry et al., 1959; Hutchison et al., 1962; Reinhardt and Reinhardt, 1981). Heavier, older calves nursing lower-producing dams suckled more frequently early in the lactation period (1 mo) and spent more time suckling. However, later in lactation (6 mo), calves suckling heavier-producing dams tended to suckle more frequently and spend more time suckling their dams (Drewry et al., 1959). Ewbank (1969), observed a reduction in frequency of calf suckling as calf age increased. These results were inconsistent with those reported by other researchers (Walker, 1962; Somerville and Lowman, 1979; Odde et al., 1985) who observed no effect of age of calf on suckling behavior.

**Effect of Calving Season**

Season of calving has an affect on the composition and production of milk by the dam. Seasonal effects are also noted in percentage of components in milk samples attained during different months of the year (Laben, 1963). Wilcox et al., (1959) reported that SNF content was high in December and January, low in June and July and decreased with increased age of dam in a curvalinear manner. Using different phases of breed crossing, Batra et al. (1969) evaluated three generations of females and found that season of
calving explained a significant portion of the variation in both milk constituents and total milk produced. Crossbred females generally producing higher average milk yields and constituents, regardless of season.

**FACTORS AFFECTING CALF PERFORMANCE**

**Breed of Dam**

Preweaning calf gains and weights are significantly affected by dam breed (Todd et al., 1969; Cundiff et al., 1974; Reynolds et al., 1978; Neilson et al., 1983). Progeny of Jersey-cross cows had higher relative growth rates than progeny of other crossbred groups (Notter et al., 1978). McGinty and Frerichs (1971) reported differences (P < .01) in weaning weight with calves nursing Brown Swiss-Hereford cows weighing 261 kg and calves from Hereford cows averaging 236 kg.

Notter et al. (1978) reported that in three-year-old cows, calves from Simmental cross dams had higher (P < .01) relative growth rates than calves from the other crossbred groups. Progeny from two-year-old Simmental cows did not differ from those of Limousin or Hereford-Angus cross cows. Brown-Swiss dams had an advantage over Angus, Hereford and Charolais dams in a study conducted by Pahnish et al. (1969). Average advantages shown by the Brown-Swiss dams over the other three beef breeds for steer and heifer calves respectively, were .138 kg and .126 kg for pre-weaning daily gain and 33.6 and 32.5 kg for weaning weight. Crossbred calves performed better than straightbred calves in most instances as reported by Reynold et al. (1978).
Five of the six crossbred groups evaluated gained more rapidly than the four straightbred groups from birth (January) to mid-July. Crossbred dams had faster growing calves than did Hereford or Brahman dams (Todd et al., 1969). Of the crossbred dams evaluated, progeny daily gains were the highest for three-breed-cross cows (1/2 Angus-1/4 Brahman-1/4 Hereford) (.90 kg) followed in order by first-cross Brahman-Hereford cows (.79 kg), Hereford cows (.68 kg) and Brahman cows (.60 kg).

**Milk Yield**

Milk yield has been shown to have an important postnatal maternal effect on early growth traits in beef cattle (Rutledge et al., 1971; Koch, 1972; Willham, 1972) and is believed to be the greatest single factor influencing preweaning calf weight and gain. Production of milk in beef cattle has been reported to account for 60% of the variation in weaning weights of their calves (Drewry et al., 1959; Neville, 1962; Rutledge et al., 1971). This is due to the fact that the calf depends 100% on milk production for nutrition in the early stages of lactation. Neville, (1962) reported the value of milk and its relationship to calf gains was the greatest during the first 60-day period of the calf’s life.

Neidhardt et al., (1979) showed a considerable amount of residual milk was found only at the first nursing of the calf. This indicates that beef calves at least 1 month old should be able to ingest nearly all the milk the dam supplies. Milk yield of the range cow during the early stages of lactation, if in excess of calf capacity, should decline to the level of the calf’s appetite (Gleddie and Berg, 1968). Calf capacity was estimated at 10.3, 13.7 and 16.9 kg/d in the first, second and third months of lactation, respectively (Notter et
Calf capacity may limit milk production for the first 60 to 90 d in high-milk-producing dams (Notter et al., 1979).

Gleddie and Berg, (1968) also reported that average milk yield accounted for 71.3% of the variance in average daily gain of calves. Boggs et al., (1980) reported that each additional kg of milk produced per d added 7.2 kg of 205-day adjusted weaning weight and .34 kg/d of average daily gain to the calf. Similar results were reported by Butson and Berg, 1984, who noted that an increase of .454 kg of milk produced per day by the dam (93 kg total) generate from 3.6 to 10.5 kg more calf at weaning. Drewry et al., (1959) evaluated performance in Angus calves and estimated the amount of milk (kg) required for a kg of weight gain was 12.5, 10.8 and 6.3 in the first, third and sixth months of lactation, respectively.

Various dam nutritional treatments also have an affect on milk yield and subsequent calf gains (Neville, 1962). Calves reared by dams fed high precalving diets gained 90 kg in 109 days compared to 83 kg for calves reared by dams fed low precalving diets (Holloway et al., 1985). On average, 12.5 kg of milk on two lower nutritional planes was required and 23.5 kg under high nutrition treatment was needed for a 1 kg increase in calf weight. As nutritional treatments improved, additional milk was required to produce a pound of calf gain both early (4 mo) and late (8 mo) in lactation.

A comparison study conducted by Wyatt et al., (1977) evaluated Angus X Hereford calves on high and low milk levels and determined that calves receiving the high milk level required 4.1 kg more milk (P<.05) per kg of gain than calves on the low milk level. This represents a 63% decrease in efficiency of milk utilization by the calves on the high-milk-level diet. Similar
results were concluded with Charolais X Fresian calves where calves receiving a high milk level had a 72% decrease in efficiency compared to calves receiving low milk levels.

**Milk Composition**

The composition of milk has also been shown to have a significant effect on calf weight gains. Research conducted by Hohenboken et al., (1973) found that butterfat production was moderately correlated with calf gain ($r = .30$) and weaning weight ($r = .28$). Phenotypic correlations of calf ADG with yields of protein and total solids were $.71$ and $.79$, respectively, in a study conducted by Jeffery and Berg, (1971). Similar correlations were reported for weaning weight with protein yield ($r = .67$) and total solids yield ($r = .70$; Jeffery and Berg, 1971). Correlations with percentages of milk components were negative and non-significant. Another report indicated that correlations of total calf gain with yields of butterfat, solids-not-fat, and total solids of $.31$, $.43$ and $.41$, respectively (Melton et al., 1967).

Coefficients of correlation of calf weight with percent and total yield of butterfat were $.27$ and $.77$ (Totusek et al., 1973). The correlation of calf weight with percent total solids ($r = .23$) and yield of total solids $r = .80$) were similar to those obtained for calf weight with percent and total yield of butterfat.

Other research indicates that milk quantity rather than milk quality was more important in determining calf performance (Klett et al., 1965; Melton et al., 1967; Jeffery and Berg, 1981; Rutledge et al., 1971; Chenette and Frahm, 1981; Beal et al., 1990).
Sex of Calf

Calf birth weight, weaning weight and average daily gain have all been observed to be significantly different between male and female calves. Franke et al. (1978) observed that calf sex directly influenced calf weight gain during the entire suckling period. It has also been observed in numerous studies that males calves were heavier at birth than female calves (Koch and Clark 1955; Melton et al., 1967; Cundiff et al., 1974; Notter et al., 1978).

Weaning weight has been reported to be significantly different when comparing male and female calves. Koch and Clark (1955) reported male calves were 11.8 kg (7.1%) heavier at weaning than female calves. Cundiff et al. (1974) reported similar results with bull calves having a 13.7 kg (7.0%) advantage at weaning (200 d) over heifer calves. Marshall et al. (1976) evaluated efficiency of calf gain as measured by pounds of calf weaned per pound of cow exposed, determining that bull calves were 8% more efficient when compared to cows weaning female calves.

Sex of calf by age of dam effects will also influence calf weight. This implies that calf sex differences are greater for some age dams than for others. Notter et al. (1978) found this effect to be significant (P < .01) when comparing two-yr-old dams with three-yr-old dams, determining that calves of three-yr-old dams were superior to calves of two-yr-old females. Minyard and Dinkel (1965) found differences in weaning weight of the two sexes were slightly greater for 8- to 11-year-old cows, however the sex of calf by age of dam interaction lacked significance.
NUTRITIONAL EFFECTS ON MILK PRODUCTION AND WEANING WEIGHT

Nutrition of the Dam

In addition to the energy needed for milk production, the cow needs energy to maintain its body weight, to become pregnant, to regain fat if she is thin, and to continue to grow if she is less than 5 yr of age (Schalles, 1989). About 70 to 75% of the total energy requirements for beef production is used for maintenance functions (Ferrell and Jenkins, 1985). The cow herd uses an estimated 65 to 70% of the energy required for beef production (Gregory 1972; Klosterman and Parker, 1976). Thus, about 50% of the total energy required for beef production is used for cow maintenance. Higher-milking dams have been shown to require more energy for maintenance per unit of metabolic body weight than lower-milking dams (Table 4). Increased milk production was not favored in a simulated study by Bourdon and Brinks, (1987) when feed costs for the cow herd were high.

Milk yield and composition have been shown to be directly affected by nutritional status of the dam. Bowden (1981) studied the effects of a normal or high energy intake on milk production of crossbred dams. Daily milk production was greater (P<.05) at 22 wk into lactation (5.8 vs. 5.0 kg) and for the average of all three milkings evaluated (6.5 vs. 5.9 kg) for cows on the high level of feed than for those on the normal. Bowden also noted dams on the high plane of nutrition produced milk with higher protein content at 6 and 14 wks postpartum than those dams on the normal energy level. Energy level
### TABLE 4: ESTIMATES OF METABOLIZABLE ENERGY REQUIRED FOR MAINTENANCE OF VARIOUS BREEDS OR BREED CROSSES

<table>
<thead>
<tr>
<th>Cow Breed</th>
<th>Physiological State</th>
<th>Mature Size</th>
<th>Milk Production</th>
<th>Maintenance (kcal/kg(^{75}/d))</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-lactating</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angus-Hereford</td>
<td>Non-pregnant</td>
<td>Moderate</td>
<td>Moderate</td>
<td>130</td>
<td>92</td>
</tr>
<tr>
<td>Charolais-X</td>
<td>Non-pregnant</td>
<td>High</td>
<td>Low</td>
<td>129</td>
<td>91</td>
</tr>
<tr>
<td>Jersey-X</td>
<td>Non-pregnant</td>
<td>Low</td>
<td>High</td>
<td>145</td>
<td>103</td>
</tr>
<tr>
<td>Simmental-X</td>
<td>Non-pregnant</td>
<td>High</td>
<td>High</td>
<td>160</td>
<td>113</td>
</tr>
<tr>
<td>Angus</td>
<td>Non-pregnant</td>
<td>Moderate</td>
<td>Moderate</td>
<td>118</td>
<td>95</td>
</tr>
<tr>
<td>Hereford</td>
<td>Non-pregnant</td>
<td>Moderate</td>
<td>Low</td>
<td>120</td>
<td>97</td>
</tr>
<tr>
<td>Simmental</td>
<td>Non-pregnant</td>
<td>High</td>
<td>High</td>
<td>134</td>
<td>108</td>
</tr>
<tr>
<td><strong>Lactating</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angus</td>
<td>Non-pregnant</td>
<td>Moderate</td>
<td>Moderate</td>
<td>149</td>
<td>96</td>
</tr>
<tr>
<td>Hereford</td>
<td>Non-pregnant</td>
<td>Moderate</td>
<td>Low</td>
<td>141</td>
<td>91</td>
</tr>
<tr>
<td>Simmental</td>
<td>Non-pregnant</td>
<td>High</td>
<td>High</td>
<td>166</td>
<td>107</td>
</tr>
<tr>
<td>Charolais</td>
<td>Non-pregnant</td>
<td>High</td>
<td>Low</td>
<td>165</td>
<td>106</td>
</tr>
<tr>
<td>Angus-Hereford</td>
<td>Pregnant</td>
<td>Moderate</td>
<td>Moderate</td>
<td>151</td>
<td>96</td>
</tr>
<tr>
<td>Red-Poll-X</td>
<td>Pregnant</td>
<td>Moderate</td>
<td>High</td>
<td>157</td>
<td>100</td>
</tr>
<tr>
<td>Brown-Swiss-X</td>
<td>Pregnant</td>
<td>High</td>
<td>High</td>
<td>156</td>
<td>99</td>
</tr>
<tr>
<td>Gelbeigh-X</td>
<td>Pregnant</td>
<td>High</td>
<td>High</td>
<td>158</td>
<td>100</td>
</tr>
<tr>
<td>Maine Anjou-X</td>
<td>Pregnant</td>
<td>High</td>
<td>High</td>
<td>146</td>
<td>93</td>
</tr>
<tr>
<td>Chianina-X</td>
<td>Pregnant</td>
<td>High</td>
<td>Low</td>
<td>174</td>
<td>111</td>
</tr>
</tbody>
</table>
did not affect fat or total milk solids content at any of the milkings evaluated. Working with two levels of energy intake, Wilson et al. (1969) established a 1.48 kg difference (P<.01) in favor of the high energy group for 12-hr milk yield. He also noted that energy level did not significantly influence percent butterfat or protein, however the high-energy level did result in a greater percent solids-not-fat (P<.01). Four-hour milk weights were affected by two levels of nutrition in a study by Bastidas et al., (1990). He determined that milk production at 50 d postcalving was greater (1.2 kg/4h) in cows fed to maintain body condition score than in cows fed to lose body condition (1.1 kg/4h). Grazing quality affected milk yield, but not milk components, in a study conducted by Lamond et al. (1969). Similar results were reported by Holloway et al., (1985) when they evaluated fescue and fescue plus legume diets. They reported an increased milk production and calf growth by those dams on the high plane of nutrition (fescue + legume). Reduced level of feeding (80-85% NRC) decreased milk production and increased liveweight loss significantly (P<.05) when compared to high level of nutrition (115-120% NRC; Petit and Micol, 1981). Differences in prepartum energy intake (100% NRC, 85%, 75%) had no affect on milk yield of first-calf heifers (Falk et al., 1975). Cow weight loss during gestation, cow weight at calving and average daily gain during lactation did not account for a significant portion of the variation in either milk or constituent yields in a study conducted by Butson and Berg, (1984).

**Nutrition of the Calf**

Calf consumption of nutrients can be in the form of either forage, concentrates or milk and varies with degree dependent on stage of lactation of
the dam. Milk intake declined from 6.14 to 3.37 kg/h/d from early lactation to late in a study conducted by Boggs et al., 1980. Boggs determined that forage dry matter intake of calves born in March and April was inversely related to calf milk consumption and increased from .44 to 3.5 kg/calf/d from early lactation to late, representing .62, 1.46, 1.51, 1.75 and 2.2 percent of the calf's body weight each month from May through September, respectively. The forage intake of calves during the first two months of age was too small to measure, emphasizing the role which milk plays in total calf nutrition and early growth. However, Maddox (1965) suggested that by the time a calf is 3 mo old, more than one half of its energy comes from non-milk sources. This indicates that calves must make the transition from milk to forage during that time period.

Calves receiving more milk during the first two months after birth consumed more grass the following months to weaning and had heavier weaning weights (Peischei, 1980). Calves receiving less milk compensated by eating grass earlier, but were unable to grow enough to have the same intake as those calves which received more milk.

**Interaction Between Milk Production and Reproductive Efficiency**

Anestrus is the major cause of postpartum infertility and is affected by several minor factors: season, breed, parity, dystocia, presence of a bull and
uterine involution, as well as two major factors: suckling and nutrition (Short et al., 1990).

**Suckling Stimulus**

Most domestic livestock females experience a period after birthing during which postnatal support of existing offspring via lactation acts to inhibit further reproductive function (Edgerton, 1980). Clapp (1937) was the first to report the inhibitory effect of suckling on reproductive function in the bovine. Numerous investigators have since reported on the effects of suckling stimulus on reproductive function in cattle (Dunn et al., 1965; Saiduddin et al., 1968; Oxenreider and Wagner, 1971; Short et al., 1972; Bellows et al., 1974; Carruthers and Hafs, 1980; Lavoie et al., 1981; Acosta et al., 1983; Garcia/Winder et al., 1984; Faltys, 1985).

Oxenreider and Wagner, (1971) determined that ovarian activity in the postpartum cow is depressed by both nutritional stress due to milk production and sensory stimulation of the mammary gland due to calf nursing. They concluded that suckling inhibited ovarian activity more severely than milking, as shown by delayed follicular development and ovulation in dams suckling two calves verses dams machine milked twice daily. Cows suckling single calves had a longer interval from parturition to the first postpartum estrus than dams milked twice daily (Clapp, 1937; Wiltbank and Cook, 1958) or cows receiving no milking or suckling stimuli after 24 hr postpartum (Graves et al., 1968; Saiduddin et al., 1968; Smith and Vincent, 1972). Intervals to first estrus of non-suckled, non-lactating dams and suckled, lactating dams were 18 to 41 d and 53 to 93 d, respectively, in a study by Graves et al., (1968). In contrast,
the interval from parturition to first ovulation, as measured by serum P4 levels, was not related to the degree of suckling stimulus (suckling bouts/24-hrs) received from the calves of cows that varied in milk production and were nursing calves ad libitum (Day et al., 1987).

Increased suckling intensity increased the postpartum anestrous interval in range cows although percent body weight loss during lactation was maintained constant (19% vs. 18.6%; Wetteman et al., 1978). Wetteman et al., (1978) also reported that postpartum interval was shorter (P < .05) in cows suckling one calf (natural or foster) than in cows suckling two calves (67 and 63 d vs. 94 d, respectively). Estrus had occurred by 90 d postpartum in 71% of dams suckling their own calves, 89% of dams with a single foster calf and 43% (P < .05) of the dams suckling two calves (Wetteman et al., 1978).

Numerous investigators have attempted to reduce postpartum interval to estrus in anestrous cows suckling calves by manipulating the suckling stimulus. Weaning calves at 3 d of age resulted in an average postpartum interval of 19.6 d compared with 39.1 d in dams nursing calves to d 35 postpartum (Bellows et al., 1974). These data suggest that weaning initiated during the early postpartum period is an effective method to hasten the onset of estrus in postpartum cows. Weaning of calves at an average of 55 d after calving had a much greater effect on increasing the number of cows exhibiting estrus from calving to the end of the breeding season in 2- and 3-year-olds (29 and 27%, respectively) compared to mature cows (16.3%). Weaning at 55 d postpartum increased overall conception in the 42-d breeding period by 25.9% in 2-yr-old cows, 15.6% in 3-yr-old cows and 7.9% in cows 4-yrs-old and older (Laster et al., 1973). Reeves and Gaskins (1981) reported that Angus dams suckling
calves once daily for 30 min, beginning either 21 or 30 d postpartum, exhibited estrus 20 d earlier than cows suckled ad libitum by calves. In agreement with these data, several researchers have reported that short-term calf removal reduced the time from calving to first estrus in postpartum beef cows (Beck et al., 1979; Smith et al., 1979; Odde et al., 1982).

**Nutritional Affects on Reproduction**

Inadequate intake of nutrients or inadequate body reserves needed to meet production requirements after calving result in suppressed reproductive performance in cattle (Dunn and Kaltenbach, 1980; Randel, 1990). Higher-milking cows tend to require more nutrients to maintain adequate body condition for reproductive efficiency (Stevenson and Britt, 1979). This can be seen in that the interval from parturition to cyclicity in dairy cattle is directly related to the level of milk production (Marion and Gier, 1968; Stevenson and Britt, 1979) and is longer in cows with a higher genetic potential for milk yield (Whitmoore et al., 1974). Nutritional levels affecting reproduction can be broken down into two basic areas; prepartum and postpartum nutrition.

Varying prepartum energy levels (100% NRC=H, 85% NRC=M, 75% NRC=L) fed for 150 d prior to calving produced intervals from parturition to first observed estrus of 63, 67 and 78 d for the H, M and L groups, respectively (Falk et al., 1975). Bellows and Short (1978) reported that heifers receiving high feed levels (6.3 or 6.4 kg of TDN) 90 d prior to calving had shorter postpartum intervals and a greater number of heifers exhibited estrus
before the breeding season compared with heifers fed a low level of feed (3.2 or 3.4 kg TDN).

Postpartum energy intake also has an effect on milk production. Average energy balance during the first 20 days of lactation in Holstein cows was inversely related to days to normal ovulation \((r=-.60)\) and to milk production \((r=-.80)\) (Butler et al., 1981). Beef cows, fed low-energy diets, had longer intervals to first estrus (Wiltbank et al., 1962, 1964; Dunn et al., 1969), longer gestation periods (Kress et al., 1971) and lower fertility (Wiltbank et al., 1964; Folman et al., 1973) than cows fed diets higher in energy. High-energy diets fed during the postcalving period caused more first-calf heifers to ovulate (100% vs. 0%) by d 46 postpartum in a study by Etchternkamp, (1982). Increasing postcalving energy intake shortened the postpartum interval of 2- to 6-yr-old cows (Bartle et al., 1984). Bellows and Short, (1978) concluded that the effect of precalving feed level on subsequent postpartum reproduction (postpartum interval, PPI) is also dependent on postcalving feed level. They reported that high postcalving feed level tended to be advantageous when the precalving feed level was high (55.3 and 57.9 d, PPI), but was detrimental to postpartum intervals when the precalving feed level was low (45.6 and 69.8 d, PPI). Low levels of feed postcalving prolong the postpartum interval and high levels of feed postcalving cannot overcome the detrimental effects of low precalving feed levels.

The postpartum interval to first estrus was 45 d shorter in cows fed to maintain body condition (46.7 d) than in those fed to loose body condition (91.2 d; Bastidas et al., 1990). Eighty percent of females fed to maintain body condition following parturition were observed in estrus within 50 d following
parturition compared with 0% of the females that were loosing body condition ($P < .01$) (Bastidas et al., 1990). Bastidas et al., (1990) also reported pregnancy rate from a 45-d breeding season initiated 45 d postcalving, was 80% in cows fed to maintain body condition compared to 30% in cows fed to loose body condition. Results from Rutter and Randel, (1984) suggest that females maintaining body condition after parturition, regardless of calculated nutrient requirements, have an enhanced pituitary function and reproductive potential.

Beef cows producing more milk tended to lose more weight than lower-producing beef cows, however postpartum weight change prior to breeding did not affect postpartum interval as reported by Beal et al., (1990). Conversely, reproductive efficiency, as measured by calves weaned/cows exposed, tended to favor females with lower milk production in a study conducted by Montano-Bermudez and Nielson, 1989.

Females producing more milk must increase energy intake to maintain adequate body reserves. McMorris and Wilton, (1986) found that an increase in milk yield of 1 kg/d was associated with an increase of .28 kg DM/d in feed consumption during lactation. Intervals to first estrus were longer for cows with high milk production than for low producers (Menge et al., 1962; Saiduddin et al., 1968). Energy requirements for maintenance appear to be positively associated with genetic potential for milk production (Ferrell and Jenkins, 1984, 1985). Thus, the increased increment for nutrient requirements of higher-milking dams is not due to lactation alone. In contrast, researchers have indicated that when level of nutrition is inadequate, the cow attempts to maintain a level of milk production, according to her genetic potential, at the
expense of body reserves, and reproductive efficiency is seriously affected (McGinty and Frerichs, 1971; Holloway et al., 1975).

**Summary**

Increased production of milk by the dam allows the calf to express its full genetic potential for growth and leads to heavier calf weights at weaning. Pounds of calf is the number one product of the beef cattle enterprise, thus heavier calf weights at weaning generate a greater income for the beef cattle producer. However these increases in calf weaning weight may come at some cost to the beef herd.

As dam milk production increases, so to does the nutrition required for that female to maintain body condition and weight. This does not create a problem as long as the females are in adequate body condition to begin with, or if females are not allowed to continue in a negative state of energy for a long period.

Extended periods of negative energy balance, in which dams begin to loose body reserves, can negatively affect subsequent reproductive performance of the cow herd. Thus, increasing milk production and subsequent calf weaning weights may have a detrimental affect on the cow herd, if future reproductive performance of the herd is seriously affected.

Beef cattle managers interested in increasing calf weaning weights through dam milk production must consider many aspects of the beef enterprise. Nutrition, future reproductive performance and total herd longevity are the main areas that can be negatively affected if increases in milk production cannot be supported with adequate dietary energy and protein.
However, if herd females tend to be in good condition at calving and feed availability is adequate then increasing calf weaning weights through selection to increase milk production should not result in decreased reproductive efficiency.

The objective of this experiment was to evaluate the effect of varying levels of prepartum and postpartum nutrition on milk production, subsequent calf weaning weights and reproductive performance of commercial beef cows.

The purpose of this type of experiment is to determine if limited feed supply prepartum lowers initial milk production (when calf utilization is low) and to see if high levels of nutrition postpartum could increase milk production later in lactation (when calf utilization is maximized), even in females nutritionally restricted prepartum. If this is possible, then producers can lower feed costs during the prepartum period yet still realize increased calf weights at weaning due to increased milk production later postpartum.
CHAPTER 2

DAM PERFORMANCE AND CALF GROWTH

Materials and Methods

Experimental Design

Forty-three Angus or Angus X Holstein females, ranging in age from 2 to 6 yr, were randomly assigned by age and percentage Holstein within age group to one of two prepartum nutritional treatments (PRE; Figure 1). Prepartum nutritional treatments consisted of either a prepartum ad libitum grazing group (PRE-H) or a prepartum restricted grazing group (PRE-L). PRE-H females (N=21) were allowed to graze 40% fescue, 40% orchardgrass, 10% bluegrass, 10% clover pastures ad libitum prior to calving. Grazing restriction (PRE-L) consisted of confinement of 22 head to 3.25 ha of the pasture described above for 76±10 d prior to calving (N=22; PRE-L). Differences in stocking rates were imposed in an attempt to decrease body condition scores (1 to 9 scale; Herd and Sprott, 1985) of females on the PRE-L treatment by two levels during the prepartum treatment period. Females on the PRE-H treatment were expected to maintain body condition during the prepartum treatment period.

All females, regardless of PRE, were assigned at calving to receive the same postcalving nutritional treatment for 76±10 d after calving (Table 5). This ration consisted of 18.2 kg barley silage, 1.4 kg corn and 3.2 kg hay per head group fed on a daily basis. The ration was estimated to contain
Figure 1: Experimental Design for Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) Fed to Forty-three Angus or Angus x Holstein Dams.
TABLE 5: NUTRIENT CONCENTRATIONS OF FEEDSTUFFS ON A DRY MATTER (DM) BASIS FED TO DAMS AT CALVING AND MAINTAINED FOR 76 ± 10 d POST-CALVING

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>Intake (kg)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>As Fed</td>
<td>DM</td>
<td>TDN(kg)</td>
<td>CP(kg)</td>
</tr>
<tr>
<td>Barley Silage</td>
<td>18.2</td>
<td>6.643</td>
<td>4.250</td>
<td>.757</td>
</tr>
<tr>
<td>Corn</td>
<td>1.4</td>
<td>1.260</td>
<td>1.008</td>
<td>.126</td>
</tr>
<tr>
<td>Hay</td>
<td>3.2</td>
<td>2.595</td>
<td>1.531</td>
<td>.324</td>
</tr>
<tr>
<td>DM Total (kg)</td>
<td></td>
<td>10.50</td>
<td>6.789</td>
<td>1.207</td>
</tr>
<tr>
<td>DM Total (%)</td>
<td></td>
<td>64.7%</td>
<td>11.5%</td>
<td></td>
</tr>
</tbody>
</table>
64.7% TDN (Table 5). The diet supplied 24.5 Mcal of metabolizable energy per cow and contained 11.5% crude protein and was balanced for 95% of the NRC requirements for 550-kg beef cows with superior milking ability (NRC, 1984).

At an average of 76 d postcalving, females were assigned by age, percentage Holstein within age group, prepartum nutritional treatment, and calving date to receive one of two postpartum nutritional treatments (POST; Figure 1). Postpartum nutritional treatments consisted of either a postpartum high-energy, high-protein ration (POST-H; Table 6) or continuation of feeding of the postpartum ration described above (POST-M; Table 5). The high-energy, high-protein diet consisted of a ration formulated at 69.7% TDN containing 18.2 kg barley silage, 5.4 kg corn and 1.4 kg hay group fed to each animal on a daily basis. The POST-H diet provided 31.8 Mcal of metabolizable energy per cow and contained 11.4% crude protein and was balanced at 120% of NRC requirements for 550-kg beef cows with superior milking ability (NRC, 1984).

Measuring Calf Performance

Calf growth measurements included birth weight, weaning weight, calf average daily gain from birth to weaning and preweaning calf gain. Birth weight of the calves was recorded within 24 h after calving and all bull calves were immediately castrated utilizing the elastrator method. Except when calf separation occurred prior to milking, calves were kept continuously with their dams until weaning at 198 ± 10 d of age. Calves were weighed on three consecutive d prior to weaning and the average weight was recorded as weaning weight. Calf gain was determined by subtracting the birth weight of the calf from its weaning weight. Calf
TABLE 6: NUTRIENT CONCENTRATIONS OF FEEDSTUFFS ON A DRY MATTER (DM) BASIS FED TO DAMS FROM 76d POST-CLAVING UNTIL WEANING

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>Intake (kg)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>As Fed</td>
<td>DM</td>
<td>TDN(kg)</td>
<td>CP(kg)</td>
</tr>
<tr>
<td>Barley Silage</td>
<td>18.2</td>
<td>6.643</td>
<td>4.250</td>
<td>.757</td>
</tr>
<tr>
<td>Corn</td>
<td>5.4</td>
<td>4.860</td>
<td>3.888</td>
<td>.544</td>
</tr>
<tr>
<td>Hay</td>
<td>1.4</td>
<td>1.135</td>
<td>1.531</td>
<td>.324</td>
</tr>
<tr>
<td>DM Total (kg)</td>
<td>25.00</td>
<td>12.64</td>
<td>8.808</td>
<td>1.442</td>
</tr>
<tr>
<td>DM Total (%)</td>
<td></td>
<td></td>
<td>69.7%</td>
<td>11.4%</td>
</tr>
</tbody>
</table>

45
average daily gain was determined by dividing calf gain by calf age at weaning.

Measuring Dam Performance

_Dam Weight_- Dam body weight was monitored throughout the course of the study. Initial weights were recorded on July 19th and 20th, 1989 and averaged. Thereafter, cow weights were recorded at least monthly until calving. Dam weight was recorded within 24 h after calving. Dams were weighed biweekly after calving until approximately 75 d postpartum. Dams were then weighed weekly for the duration of the study.

_Dam Height_- Dam hip heights were taken on July 19th and 20th, 1989 and averaged. Measurements were taken utilizing a standard hip height measuring stick equipped with a leveling device. Hip heights and dam weights were used to calculate a weight(kg)/height(cm) (wt/ht) ratio for each dam at each weight period.

_Dam Body Condition Score (BCS)_- Body condition score (1 to 9, 1 = emaciated to 9 = obese; Herd and Sprott, 1985) was estimated each time dam weight was recorded throughout the course of the study. Condition score was determined by the same evaluator throughout the study to reduce technician variation.

_Dam Loineye Area_- Loineye area (longissimus dorsi muscle) was evaluated throughout the course of the study. An Aloka 210, B-Mode Realtime Linear Array Ultrasound Unit (Corometrics Medical Systems Inc.) equipped with a 3.5 MHz transducer (UST-5021) was utilized to monitor
changes in loineye area measured between the 12th and 13th ribs. Images were redirected through a 9" video monitor (TR-930B, Panasonic) to assist the technician in loineye imaging. Duplicate measurements were taken monthly until calving. At calving duplicate measurements were taken biweekly for 5 wk. Measurements were then continued monthly for the remainder of the study. Loineye images were recorded at each date via a portable VHS video recorder (AG-2400, Panasonic). Loineye recordings were later viewed on a 14-inch video monitor (Conrac, ITP Inc.) and the circumference of the loineye was traced from the screen onto acetate sheets (215mm x 267mm MX22 Blackline, USI). Loineye areas were then measured utilizing a computer digitizer (Summasketch Plus, Summagraphics Corp.).

**Dam Backfat.** Backfat measurements were taken at the same time as each loineye measurement throughout the course of the study. An Equisonics LS-300A, B-Mode, Linear-Array Ultrasound Unit (Tokyo Keiki Co., LTD.) equipped with a 5 MHz veterinary transducer (LSU-3505-V) was utilized to image backfat between the 12th and 13th rib approximately three-quarters of the distance from the medial to the lateral edge of the longissimus muscle. Backfat estimates were determined directly from the images utilizing the internal caliper function of the ultrasound unit.

**Statistical Analysis.**

Data for calf performance were analyzed using the General Linear Model (GLM) procedure of Statistical Analysis Systems (SAS, 1985). Weaning weight, calf gain, calf average daily gain and birth weight were
dependent variables in the model. Prepartum nutritional grazing levels of the
dam (PRE-L and PRE-H) were independent variables in the model for calf
birth weight. Prepartum nutritional grazing levels of the dam, postpartum
energy levels (POST-M and POST-H), and the interaction between prepartum
grazing and postpartum energy level, were independent variables in the
model for weaning weight, calf gain and calf average daily gain. In addition,
a classification of cow age X percentage Holstein was included as an
independent variable in all analyses (cow age = 2, 3, 4, 5 or 6 with
percentage Holstein = 0, 12.5 or 25). Due to the genetics of the dams and
age groupings used, the variable allowed for the classification of seven dam
groups (2,0; 2,12.5; 3,0; 3,12.5; 4 to 6,0; 4 to 6,12.5; 6,25; for cow age
and percentage Holstein, respectively). Calf age at weaning was also
included as a covariate in the models for analysis of weaning weight, calf
gain and calf average daily gain.

Data for dam performance were analyzed using the General Linear
Model (GLM) procedure of Statistical Analysis Systems (SAS, 1985). Dam
performance was partitioned into three separate analyses with body weight,
body condition score and dam ultrasound measurements considered
separately. Prepartum grazing levels (PRE-L and PRE-H) were included as
independent variables in the model for analysis of body weight,
weight/height ratio, and body condition score to the following times: 76-d
precalving, just prior to calving, 24-h postcalving and 76-d postcalving.
Both prepartum grazing levels and postpartum energy levels (POST-M and
POST-H), and the interaction between prepartum grazing levels and
postpartum energy level, were included in the model for analysis of body
weight, weight/height ratio and body condition score at the time of
weaning. Calving date was included as a covariate in the models for analysis of 76-d postcalving weight and weights at weaning.

Loineye area and backfat measurements were considered as the dependent variables in a separate analysis. Measurements recorded at the start of the study (76-d precalving), prior to calving and at the time of calf weaning were analyzed. Prepartum grazing levels and postpartum energy levels and the interaction between prepartum grazing levels and postpartum energy levels were included as independent variables in the analysis of ultrasound measures recorded at weaning. Only prepartum grazing levels were included as independent variables in the analysis of ultrasound measures recorded prior to calving and at calving. Calving date was included as a covariate in the analysis of ultrasound measures at weaning.

The mean seperation test for all means was the protected F-test utilizing the GLM/LSMEANS procedure (SAS, 1985)

Results and Discussion

Dam Performance

Differences in nutrient level prior to calving significantly affected dam body weights (Figure 2), weight change and weight/height ratio. Weights taken at the beginning of the study averaged 554±25 kg and were not different between the two grazing groups (P>.4; Table 7). However, body weight of cows in the PRE-L group were lower at the last weight recorded prior to calving (P<.001) and at calving (P<.001). Weight change from the initiation of the study to 24 h postcalving was -99±6 kg for the PRE-L cows
Figure 2: Average of Actual Weights of Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) from 76 d Pre-calving to 76 d Post-calving.
TABLE 7. LEAST SQUARES MEANS (±SEM) FOR WEIGHTS OF DAMS ON DIFFERING PREPARTUM GRAZING LEVELS (PRE-L VS PRE-H)

<table>
<thead>
<tr>
<th>Diets</th>
<th>N</th>
<th>76 d Pre-Calving</th>
<th>Pre-Calving(^a)</th>
<th>Calving</th>
<th>76 d Post Calving</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-L</td>
<td>22</td>
<td>549 ± 11.6</td>
<td>526 ± 11.1(^b)</td>
<td>448 ± 11.8(^b)</td>
<td>502 ± 12.3(^d)</td>
</tr>
<tr>
<td>PRE-H</td>
<td>21</td>
<td>565 ± 12.8</td>
<td>590 ± 12.3(^c)</td>
<td>521 ± 13.1(^c)</td>
<td>551 ± 13.7(^e)</td>
</tr>
</tbody>
</table>

\(^{a}\) Pre-calving denotes the last dam weight of all dams taken before any dams calved.

\(^{b, c, d, e}\) Means in same column with differing superscripts are different (P < .001).

Means in same column with differing superscripts are different (P < .005).
and $-42 \pm 7$ kg for cows in the **PRE-H** group ($P < .001$). Due to the significant dam weight loss, wt/ht ratios were also lower ($P < .001$) in **PRE-L** ($2.85 \pm 0.06$) than **PRE-H** dams ($3.26 \pm 0.07$) at 24 h postcalving.

Dam weight loss equal to calf birth weight was expected as the calving weights were taken 24 h after calving. With birth weight averages of $39.0 \pm 0.8$ kg, it is apparent that cows in the **PRE-H** grazing group maintained their body weight during this portion of the study and appeared to loose weight only due to the birth of the calf. Conversely, cows on the **PRE-L** group lost an average of 60 kg of body weight each during the last 75 d prior to calving, even after consideration of calf birth weights.

Numerous other investigators have established that dam weight can be manipulated through prepartum nutrition (Lamond et al., 1969; Wilson et al., 1969; Falk et al., 1975; Bowden, 1981; Butson and Berg, 1984; Holloway et al., 1985; Bastidas, 1990). In some instances, prepartum nutrition significantly affected subsequent milk production of the dam (Lamond et al., 1969; Wilson et al., 1969; Bowden, 1981; Holloway et al., 1985; Bastidas, 1990).

By 75-d postcalving when the dams were assigned to the **POST** nutritional treatments, differences in body weight and wt/ht ratio between cows in the **PRE-L** ($502 \pm 12$ kg and $3.18 \pm 0.06$) and **PRE-H** ($550 \pm 17$ kg and $3.43 \pm 0.07$) groups were still apparent ($P < .01$; Table 8; Figure 3). Weight change of dams from calving to 76-d postcalving was significantly different between groups ($P < .04$; Table 9). While receiving the common postcalving diet, the dams from the **PRE-L** group gained more weight presumably to compensate for weight loss prior to calving.

Body weight change from 76d postcalving to weaning was less ($P < .05$) for females on the **POST-M** energy level (2 kg) than for those females
TABLE 8. LEAST SQUARES MEANS (±SEM) FOR WEIGHTS OF DAMS ON DIFFERING PREPARTUM GRAZING LEVELS (PRE-L VS PRE-H) AND POSTPARTUM NUTRITIONAL LEVELS (POST-M VS POST-H).

<table>
<thead>
<tr>
<th>Diets</th>
<th>N</th>
<th>76 d Post Calving</th>
<th>Weaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-L POST-M</td>
<td>11</td>
<td>497 ± 17.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>509 ± 20.6</td>
</tr>
<tr>
<td>PRE-L POST-H</td>
<td>11</td>
<td>506 ± 19.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>531 ± 22.4</td>
</tr>
<tr>
<td>PRE-H POST-M</td>
<td>11</td>
<td>555 ± 18.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>547 ± 21.6</td>
</tr>
<tr>
<td>PRE-H POST-H</td>
<td>10</td>
<td>550 ± 19.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>560 ± 23.3</td>
</tr>
</tbody>
</table>

<sup>ab</sup> Means in same column with differing superscripts are different (P < .08).
Figure 3: Average of Actual Weights of Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) from 76 d Postcalving to Weaning at 209 d Postcalving.
### TABLE 9: LEAST SQUARES MEANS (±SEM) FOR WEIGHT CHANGE (KG) OF DAMS ON DIFFERING PREPARTUM NUTRITIONAL GRAZING LEVELS (PRE-L VS PRE-H)

<table>
<thead>
<tr>
<th>Diets</th>
<th>N</th>
<th>76 d Pre-Calving to PreCalving&lt;sup&gt;a&lt;/sup&gt;</th>
<th>76 d Pre-Calving to Calving</th>
<th>Pre-Calving to 76 d PostCalving</th>
<th>Calving to 76 d PostCalving</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-L</td>
<td>22</td>
<td>-23 ± 2.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-64 ± 5.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-24 ± 5.4&lt;sup&gt;d&lt;/sup&gt;</td>
<td>16 ± 7.1&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>PRE-H</td>
<td>21</td>
<td>25 ± 2.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-4 ± 6.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-39 ± 6.0&lt;sup&gt;e&lt;/sup&gt;</td>
<td>-10 ± 7.9&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Pre-calving indicates the weight of each dam before any dams calved.

<sup>b,c</sup> Means in same column with differing superscripts are different (P<.001).

<sup>d,e</sup> Means in same column with differing superscripts are different (P<.07).

<sup>f,g</sup> Means in same column with differing superscripts are different (P<.03).
on the POST-H energy levels (18 kg). Furthermore, like the trend set from calving to 76 d postcalving, cows that had been on the restricted grazing prior to calving (PRE-L) gained more weight (19 kg) during the POST feeding period than cows which had grazed ad libitum (PRE-H; 1 kg) prior to calving (Table 10). Body weights at weaning were not different (P > .4) for dams on the POST-M vs POST-H energy levels or for dams which had been in the PRE-L vs PRE-H grazing groups.

Differences in nutrient level prior to calving significantly affected dam body condition score (P < .001). Condition scores recorded at the beginning of the study were not significantly different between the two grazing groups (P > .25), with mean scores of 6.0 and 5.8 for the PRE-L and PRE-H grazing groups, respectively. However, differences in condition score (P < .001) were noted between the two groups at the last weighing before the first dam calved (5.0 vs 6.0) and after calving (4.6 vs 5.6 for PRE-L and PRE-H, respectively). There was still a significant difference, 5.1 vs 5.8, in condition score at 76 d postcalving when the dams were assigned to POST nutritional treatments. Body condition scores of the PRE-L and PRE-H group at weaning were 5.12 and 5.47, respectively. Like the difference in weight, however, the difference in body condition was not different (P > .3). Body condition score appears to be an accurate method for monitoring dam "condition" and was positively correlated with body weights (r = .70; P < .001). There was no interaction between the effects of precalving grazing levels and postpartum energy levels on body condition score in this study.

Backfat and loineye measurements were not different (P > .15) between the two grazing groups at the start of the study (Table 11). However, differences were noted between the groups (PRE-L vs PRE-H) for
TABLE 10: LEAST SQUARES MEANS (± SEM) FOR WEIGHT CHANGE (KG) OF DAMS ON DIFFERING PREPARTUM NUTRITIONAL GRAZING LEVELS (PRE-L VS PRE-H) AND POSTPARTUM ENERGY LEVELS (POST-M VS POST-H)

<table>
<thead>
<tr>
<th>Diets</th>
<th>N</th>
<th>Calving to 76 d PostCalving</th>
<th>76 d PostCalving to Weaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-L POST-M</td>
<td>11</td>
<td>4 ± 10.3&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>12 ± 6.7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>PRE-L POST-H</td>
<td>11</td>
<td>28 ± 10.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>26 ± 7.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>PRE-H POST-M</td>
<td>11</td>
<td>-3 ± 10.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-8 ± 6.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>PRE-H POST-H</td>
<td>10</td>
<td>-17 ± 11.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10 ± 7.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>ab</sup> Means in same column with differing superscripts are different (P<.04).
TABLE 11. LEAST SQUARES MEANS (± SEM) OF ULTRASONIC BACKFAT AND LOINEYE MEASUREMENTS OF DAMS ON DIFFERING PREPARTUM GRAZING LEVELS EVALUATED AT 76 d PRE-CALVING AND CALVING

<table>
<thead>
<tr>
<th>Diet</th>
<th>N</th>
<th>Backfat Thickness (mm)</th>
<th>Loineye Area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>76 d Pre-calving</td>
<td>Calving</td>
</tr>
<tr>
<td>PRE-L</td>
<td>22</td>
<td>5.3 ± .4</td>
<td>2.1 ± .5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>PRE-H</td>
<td>21</td>
<td>6.2 ± .5</td>
<td>3.8 ± .5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>ab</sup> Means in the same column with differing superscripts differ (P<.03).
<sup>cd</sup> Means in the same column with differing superscripts differ (P<.02).
both backfat (P < .03) and loineye measurements (P < .02) at calving (Table 11). Backfat thickness averaged 2.1 ± .5 and 3.8 ± .5 mm (P < .03), and loineye area averaged 65.4 ± 2.3 and 74.1 ± 2.4 cm² (P < .02) for the PRE-L and PRE-H groups, respectively. Backfat thickness and loineye area (24 h postcalving) were both positively correlated with cow body condition score, .81 and .79, respectively. Significant differences were also noted between PRE (P < .10) and POST (P < .06) nutritional treatments for backfat measurements at the end of the study (209 d postpartum). However, differences in loineye area were not significant at that time (P > .80; Table 12).

In summary, females assigned to the PRE-L grazing level lost significantly more weight prior to calving than those dams assigned to the PRE-H group. From calving until 76 d postcalving, when all cows were placed on the same nutritional level (Table 5), the body weights between the PRE-L and PRE-H groups remained different. Females were then fed on the differing energy levels from 76 d postcalving until weaning. Females on the POST-H energy levels gained more weight from 76 d postcalving to weaning than did those females on the POST-M levels. The difference in body weights of the POST-M and POST-H dams at weaning, however, was not different (P > .10). Conversely, because the animals which had been assigned to the PRE-L group prior to calving gained more weight on both the POST-M or POST-H diet than animals assigned to the PRE-H group, weight differences between the PRE-L and PRE-H group had disappeared (P > .4) by the time calves were weaned.
TABLE 12. LEAST SQUARES MEANS (± SEM) FOR ULTRASOUND BACKFAT AND LOINEYE MEASUREMENTS OF DAMS ON DIFFERING PREPARTUM GRAZING LEVELS AND POSTPARTUM ENERGY LEVELS EVALUATED AT CALVING AND WEANING.

<table>
<thead>
<tr>
<th>Diet</th>
<th>N</th>
<th>Backfat Thickness (mm)</th>
<th>Loineye Area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Calving</td>
<td>Weaning</td>
</tr>
<tr>
<td>PRE-L</td>
<td>22</td>
<td>2.13 ± .5⁵</td>
<td>3.16 ± 1⁶</td>
</tr>
<tr>
<td>PRE-H</td>
<td>21</td>
<td>3.84 ± .5⁴</td>
<td>5.74 ± 1⁷</td>
</tr>
<tr>
<td>POST-M</td>
<td>22</td>
<td>2.03 ± .5⁴</td>
<td>2.83 ± 1⁸</td>
</tr>
<tr>
<td>POST-H</td>
<td>21</td>
<td>3.77 ± .6⁵</td>
<td>6.08 ± 1⁹</td>
</tr>
</tbody>
</table>

⁵⁶⁷⁸ Ab,c Means in the same column within period (PRE, POST) with differing superscripts differ (P < .03).
⁵⁷⁸⁹ cd Means in the same column within period (PRE, POST) with differing superscripts differ (P < .10).
⁵⁶ Means in the same column within period (PRE, POST) with differing superscripts differ (P < .02).
⁶⁹ Mean in the same column within period (PRE, POST) with differing superscripts differ (P < .06).
Calf Growth and Performance

The reduction in nutrient level prior to calving decreased (P<.05) birth weights of calves from dams on the prepartum restricted grazing. Calf weights at birth were 37±.7 and 39±.8 kg for PRE-L and PRE-H groups, respectively (Table 13). The reduction in birth weight observed in this study is similar to that reported by Bellows and Short, (1978) who examined the effects of feeding a low- (3.2 or 3.4 kg TDN) or high-energy (6.3 or 6.4 kg TDN) diet for 90 d prepartum on subsequent birth weights of beef calves. They determined that precalving gestation feed levels increased birth weights of calves from dams fed the high-energy diet by approximately 2 kg. Other research by Falk et al., (1975) failed to reveal an effect of prepartum energy restriction on birth weights, with high- (100% NRC), medium- (85% NRC) and low-energy (75% NRC) prepartum diets of cows having no effect on calf birth weights (29.2, 30.3 and 29.1 kg, respectively). Bowden, (1981) also observed no difference in weights, 33.4 and 33.8 kg, of calves from dams fed either 100% or 110% of NRC requirements prepartum, respectively. The differences in calf birthweight in this study and those noted by Bellows and Short, (1978) may have been due to the degree of energy deficiency that the dams on the low prepartum diets experienced, thus limiting energy for calf growth in an attempt to meet their own maintenance requirements. It may also have been due to the dams on the ad libitum prepartum grazing treatment transferring the extra energy intake to their calves for extra prenatal growth.

Differences in nutrient level of the dams prior to calving produced no significant effects on weaning weights of their calves (P>.3), on calf gain (P>.5) or on calf average daily gain (P>.5; Table 13). Restricted grazing
<table>
<thead>
<tr>
<th>Diet</th>
<th>N</th>
<th>Birth Weight (kg)</th>
<th>Weaning Weight (kg)</th>
<th>Calf Gain (kg)</th>
<th>Calf ADG (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-L</td>
<td>22</td>
<td>36.7 ± .68&lt;sup&gt;a&lt;/sup&gt;</td>
<td>201.8 ± 4.9</td>
<td>165.1 ± 4.7</td>
<td>.84 ± .02</td>
</tr>
<tr>
<td>PRE-H</td>
<td>21</td>
<td>38.9 ± .81&lt;sup&gt;b&lt;/sup&gt;</td>
<td>208.4 ± 5.9</td>
<td>169.4 ± 5.7</td>
<td>.86 ± .03</td>
</tr>
</tbody>
</table>

<sup>ab</sup> Means with differing superscripts are different (P<.05).
prepartum may not have been severe enough or imposed long enough to produce significant differences in the calves at weaning. However, PRE diet effects on weaning weight, calf gain and calf average daily gain all tended to favor the unlimited grazing group over the restricted group (Table 13). These results are in agreement with Dunn et al., (1965) who fed either low- (7.7 Mcal of DE) or high-energy (17.4 Mcal of DE) diets for 140 d prepartum and recorded 109 d calf weight gains of 83 and 90 kg, respectively for calves from dams fed the low- or high-energy diets. Similar results were reported by Falk et al., (1975) who recorded 205-d calf weaning weights of 179, 168 and 165 kg respectively, for calves from cows receiving high- (100% NRC), medium- (85% NRC) and low-energy (75% NRC) diets for 150 d prior to calving.

In contrast to the effects of the prepartum nutritional treatments, postpartum nutritional treatments of the dams imposed beginning an average of 76 d postcalving significantly affected all calf performance traits measured (Table 14). Wilson et al., (1969) demonstrated that postpartum nutritional levels of 115% NRC (high) and 85% NRC (low) significantly (P<.01) affected calf weight gains with the high and low diets producing calf gains of 118.4 and 88.3 kg, respectively. Since the POST diet was imposed when calves should have been able to utilize nearly all the milk produced by the dams, greater differences in calf weight between the nutritional levels was noted due to differences in the postpartum energy levels rather than due to the nutrient differences imposed on the cows during prepartum grazing (Table 15; Figure 4).

The interaction of PRE and POST diets did not explain a significant source of the variation in the model for weaning weight, calf gain, calf ADG or birth weight (P>.5; Table 15). Hence, the provision of additional energy
TABLE 14. LEAST SQUARES MEANS (± SEM) FOR VARIABLES REPRESENTING GROWTH AND PERFORMANCE OF CALVES WITH DAMS ON DIFFERING POSTPARTUM NUTRITIONAL LEVELS (POST-M VS POST-H).

<table>
<thead>
<tr>
<th>Diet</th>
<th>N</th>
<th>Weaning Weight (kg)</th>
<th>Calf Gain (kg)</th>
<th>Calf ADG (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>POST-M</td>
<td>22</td>
<td>197 ± 4.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>160 ± 4.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>.81 ± .02&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>POST-H</td>
<td>21</td>
<td>213 ± 6.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>175 ± 6.0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>.88 ± .03&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>ab</sup> Means in same column with differing superscripts are different (P < .05).
<sup>cd</sup> Means in same column with differing superscripts are different (P < .06).
TABLE 15. LEAST SQUARES MEANS (±SEM) FOR VARIABLES REPRESENTING GROWTH AND PERFORMANCE OF CALVES WITH DAMS ON DIFFERING PREPARTUM NUTRITIONAL GRAZING LEVELS (PRE-L VS PRE-H) AND POSTPARTUM ENERGY LEVELS (POST-M VS POST-H)

<table>
<thead>
<tr>
<th>Diets</th>
<th>N</th>
<th>Birth Weight(kg)</th>
<th>Weaning Weight(kg)</th>
<th>Calf Gain(kg)</th>
<th>Calf ADG(kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-L</td>
<td>11</td>
<td>35.7 ± 1.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>195 ± 7.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>160 ± 6.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>.81 ± .04&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>POST-M</td>
<td>11</td>
<td>37.7 ± 1.08&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>208 ± 7.7&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>171 ± 7.4&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>.87 ± .04&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>PRE-H</td>
<td>11</td>
<td>38.5 ± 1.05&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>198 ± 7.4&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>160 ± 7.2&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>.81 ± .04&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>POST-H</td>
<td>10</td>
<td>39.0 ± 1.15&lt;sup&gt;b&lt;/sup&gt;</td>
<td>218 ± 8.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>179 ± 7.8&lt;sup&gt;d&lt;/sup&gt;</td>
<td>.91 ± .04&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>ab</sup> Means in same column with differing superscripts are different (P<.06).
<sup>cd</sup> Means in same column with differing superscripts are different (P<.10).
Figure 4: Calf Weaning Weights from Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-L vs POST-H).
during lactation increased weaning weights of calves, regardless of whether cows were adequately fed or feed was restricted prior to calving.

Sex of the calf was a significant source of variation in birth weight of the calves (P < .01). Male calves were heavier at birth than female calves, 39.3 ± .6 and 36.3 ± .9, respectively (Table 16). These results are in agreement with those of other researchers (Koch and Clark, 1955; Melton et al., 1967; Cundiff et al., 1974; Notter et al. 1978). Calf sex did not significantly affect weaning weight (P > .1), calf gain (P > .2) or calf ADG (P > .3), however, all performance traits favored steer calves over heifers (Table 16). Weaning weight of male and female calves have previously been shown to be significantly different (Koch and Clark, 1955; Cundiff et al., 1974; Marshall et al., 1976).

Cow age and degree of crossbreeding (%Holstein) were combined in the statistical model. Weights of the calves from 2-yr-old dams were lower at birth (P < .001; Table 17). This was expected because the 2-yr-old females all had been artificially inseminated with semen from a "calving ease" bull that was expected to sire lighter calves at birth. The fact that the calving ease bull was used to sire calves of all the 2-year-old females also accounts for the calves' lower performance through weaning. Dam age and crossbreeding percentage significantly affected weaning weights of the calves, with older dams possessing greater crossbreeding producing heavier calves than groups of younger cows with less Holstein crossbreeding (Table 17; Figure 5). Two-year-old dams, tended to have calves that were lighter at weaning and performed poorly when compared to the other groups. Females with 25% Holstein tended to out-perform all the other groups in the calf performance traits.
**TABLE 16: LEAST SQUARES MEANS (± SEM) FOR VARIABLES REPRESENTING GROWTH AND PERFORMANCE OF CALVES FROM DAMS ON DIFFERING PREPARTUM AND POSTPARTUM NUTRITIONAL TREATMENTS AND GROUPED BY SEX OF CALF**

<table>
<thead>
<tr>
<th>Calf Sex</th>
<th>N</th>
<th>Birth Weight (kg)</th>
<th>Weaning Weight (kg)</th>
<th>Calf Gain (kg)</th>
<th>Calf ADG (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>20</td>
<td>36.3 ± .83(^a)</td>
<td>200 ± 6.3</td>
<td>163 ± 6.1</td>
<td>.83 ± .03</td>
</tr>
<tr>
<td>Male</td>
<td>23</td>
<td>39.3 ± .66(^b)</td>
<td>211 ± 4.7</td>
<td>171 ± 4.5</td>
<td>.87 ± .66</td>
</tr>
</tbody>
</table>

\(^{a,b}\) Means in same column with differing superscripts are different (P < .01).
TABLE 17. LEAST SQUARES MEANS (± SEM) FOR VARIABLES REPRESENTING GROWTH AND PERFORMANCE OF CALVES FROM DAMS ON DIFFERING PREPARTUM AND POSTPARTUM NUTRITION AND GROUPED BY DAM AGE AND PERCENT CROSSBREEDINGa

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Birth Weight(kg)b</th>
<th>Weaning Weight(kg)c</th>
<th>Calf Gain(kg)d</th>
<th>Calf ADG(kg)e</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>29.7 ± 1.2</td>
<td>183 ± 8.8</td>
<td>153 ± 8.4</td>
<td>.77 ± 0.4</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>29.7 ± 1.2</td>
<td>186 ± 8.5</td>
<td>157 ± 8.2</td>
<td>.79 ± 0.4</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>39.3 ± 1.1</td>
<td>198 ± 7.7</td>
<td>159 ± 7.4</td>
<td>.80 ± 0.4</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>38.9 ± 1.9</td>
<td>192 ± 13.5</td>
<td>152 ± 13.0</td>
<td>.77 ± 0.7</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>39.9 ± 1.1</td>
<td>206 ± 7.7</td>
<td>166 ± 7.4</td>
<td>.84 ± 0.4</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>43.5 ± 2.5</td>
<td>233 ± 17.7</td>
<td>189 ± 17.0</td>
<td>.97 ± 0.9</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>43.6 ± 1.3</td>
<td>238 ± 9.1</td>
<td>194 ± 8.8</td>
<td>.98 ± 0.4</td>
</tr>
</tbody>
</table>

aSub-groups (cow age and % Holstein) 1) 2, 0%; 2) 2, 12.5%; 3) 3, 0%; 4) 3, 12.5%; 5) 4-6, 0%; 6) 4-6, 12.5%; 7) 6, 25%.
bDifferences in Least Squares Means > 9.2 are significant (P<.001); differences > 4.7 are significant (P<.05).
cDifferences in Least Squares Means > 42.0 are significant (P<.05).
dDifferences in Least Squares Means > 27.7 are significant (P<.02).
eDifferences in Least Squares Means > .13 are significant (P<.03).
Figure 5: Least Squares Means for Calf Weaning Weights from Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) and Subgrouped by Cow Age and Percentage Crossbreeding.
Implications

Performance was different for dams on the **PRE** grazing diets, with body weights, ht/wt ratio's, body condition scores and loineye area and backfat measurements at calving all being different between the **PRE-L** and **PRE-H** grazing groups. However, these nutritional differences that affected performance did not cause differences in the weaning weights of calves. Body weight gain from 76 d postcalving to weaning was less for females on the **POST-M** energy level than for those females on the **POST-H** energy levels. Body weights at weaning were not different for dams on the **POST-M** vs **POST-H** energy levels or for dams which had been in the **PRE-L** vs **PRE-H** grazing groups.

The postpartum moderate energy diet in this experiment may not have been low enough (95% NRC) to cause a severe change in weight and performance. However, unlike the prepartum grazing levels, the postpartum energy levels did significantly affect the performance of the calves, regardless of the prepartum nutritional level. Dams from the **POST-M** group had calves that gained less prior to weaning than those calves from dams on the **POST-H** group. Hence, while the **POST** nutrition did not significantly affect body weight and composition, it did affect calf performance, the economic endpoint of the beef cow-calf enterprise.
CHAPTER 3

MILK PRODUCTION AND REPRODUCTIVE PERFORMANCE

Materials and Methods

Experimental Design

Forty-three Angus or Angus X Holstein females, ranging in age from 2 to 6 yr, were randomly assigned by age and percentage Holstein within age group to one of two prepartum nutritional treatments (PRE) as described in Chapter 2 (Figure 1). Grazing was restricted for cows in the PRE-L group, while cows in the PRE-H group were allowed to graze ad libitum. At the time of calving, females were assigned by age, percentage Holstein within age group, prepartum nutritional treatment and calving date to one of two milking groups.

Milk removal occurred biweekly, beginning approximately 14 d postcalving, and continued until weaning. A vacuum milking machine was used for milk removal after iv injection of 20 IU of oxytocin as described by Beal et al., (1990). Milk collected was immediately weighed and samples were taken for analysis of milk composition.

At the time of calving all females were placed on a common postcalving diet. This ration consisted of 18.2 kg barley silage, 1.4 kg corn and 3.2 kg hay per head which was group fed on a daily basis. The ration was estimated to contain 64.7% TDN (Table 5). The diet supplied each cow 24.5 Mcal of metabolizable energy and contained 11.5% crude protein

72
and was balanced for 95% of the NRC requirements for 550-kg beef cows with superior milking ability (NRC, 1984).

At 76±10 d postcalving, females were assigned by age, percentage Holstein within age group, prepartum nutritional treatment, and calving date to receive one of two postpartum nutritional treatments (POST; Figure 1). Postpartum nutritional treatments consisted of either a postpartum high energy, high-protein ration formulated at 69.7% TDN and containing 11.4% crude protein (POST-H; Table 6) group fed to each animal daily, or continuation of feeding of the postpartum ration described above (POST-M; Table 5).

**Measuring Dam Milk Production**

*Calf Separation Interval* - Calves were separated from their dams at approximately 1730 h on the d prior to milking, with milking beginning at 0700 h the next d. Hence, calves were separated from their dams for an average of 17.5±1.3 h prior to initiation of milking. Housing during the separation period consisted of standard cattle corrals with at least two fences and 10 m between calves and dams. Dams and calves could view each other during the separation period, however, no physical contact could be initiated.

*Milk Removal* - Milk removal was facilitated by the iv injection of 20 IU of oxytocin immediately (<2 min) prior to the application of a vacuum milking machine. Restraint of the female during milking consisted of a "self catching" headgate attached to a solid-sided chute (77cm width). Once the head of an animal was secure, the hinged side door was opened and the milking machine was applied. In an attempt to minimize stress, no
"squeeze" was used to restrain the animals. Prior to milking the udder was washed with water and each teat was hand "stripped" until milk flow was initiated. A vacuum milking machine was then applied to each of the four quarters of the udder. Pulse frequency of the vacuum milking machine was 50:50. The milking machine was left on the animal until all milk flow had ceased for at least 1 min. The milking machine was then removed and females were allowed to return to their calves. Time of machine removal was recorded for each individual in order to determine the interval from calf separation until completion of milking. Each dam's milk sample was weighed on a triple-beam balance immediately after collection.

*Milk Component Analysis*—After weighing each composite milk sample, a subsample (approximately 20 ml) was taken for evaluation of milk components. Plastic bags containing potassium dichromide tablets were supplied by the Dairy Herd Improvement Association (DHIA) for the collection of samples. Analysis of milk components was conducted by the Virginia DHIA laboratory utilizing an Infrared Milk Analyzer (Multispec Infrared Dairy Product Analyzer, Berwin Instr. Group). Methods and procedures for analysis of milk components have been described by Akers and Thompson, (1987) and Barbano and Clark, (1989). Components analyzed included the percentage of fat, protein, lactose and solids-not-fat in each sample. Yields of fat, protein, lactose and solids-not-fat were calculated by multiplying the percentage of the component by the weight of the milk from the dam. Fluid portion of the milk was calculated by subtracting the yields of fat, protein and lactose from the milk weight of the dam. The number of somatic cells (leucocytes x 10^5/ml) was also
determined. These components were determined for each milk sample collected throughout the study.

**Measuring Dam Reproductive Performance**

Dams on this study calved during a 47-d period in the fall of 1989, September 15\(^{th}\) to November 1\(^{st}\). The breeding season began on December 14\(^{th}\), 1989 (76±10 d postpartum) and females were bred by artificial insemination 12 h after detection of estrus. The breeding season concluded on February 14\(^{th}\) 1990. Reproductive parameters evaluated included postpartum interval to ovulation, d to first service, d to conception and reproductive status (pregnant or non-pregnant) at the end of the breeding season.

Blood samples were collected from dams via venipuncture, beginning approximately 14 d postcalving and continued weekly until the beginning of the breeding season. After blood collection, blood was allowed to stand at room temperature for at least 3 h prior to centrifugation to separate serum. Serum was decanted and stored at -20°C until it could be assayed for progesterone (P\(_4\)). Radioimmunoassay (RIA) of P\(_4\) was performed by solid-phase RIA kits (Coat-A-Count, Diagnostic Products Corp.) as described by Pathiraja et al., 1986. All P\(_4\) samples were analyzed in the same assay. Intra-assay coefficient of variation was 3.47%.

Beginning at the start of the breeding season (76±10 d postpartum), females were checked for behavioral signs of estrus twice daily (0700 and 1530 h) for approximately 45 min. Those females determined to be in standing estrus were then artificially inseminated approximately 12 h later using the standard am/pm rule. Artificial insemination technicians (N=3) were randomly assigned to perform breedings. Semen from three sires was
randomly assigned to individual females throughout the breeding season. Pregnancy was diagnosed by transrectal ultrasonography (Tokyo Keiki, LS 300A) at 45 to 65 d post-insemination, as described by Kastelic et al., (1988).

Either Serum P₄ or dates of estrous detection were used to estimate the timing of first ovulation. In animals that initiated estrous cycles prior to the beginning of the breeding season, females were considered to have initiated estrous cycles if P₄ levels of > 1 ng/ml were detected for two consecutive wk. Cyclic cows were considered to have ovulated on the d before the first of the two consecutive samples in which P₄ was > 1 ng/ml. If cows initiated estrous cycles after the beginning of the breeding season, ovulation was assumed to have occurred 24 h after estrous detection. The estimated d of ovulation was then used to calculate the postpartum interval to ovulation (PPI). The interval (d) to first service was determined from the breeding records. Days to conception was determined from ultrasound evaluation of pregnancy status and the date of last service received by the female. Females open at the end of the breeding season were not included in the calculation of mean d to conception.

**Statistical Analysis**

Data for milk production were analyzed using the General Linear Model (GLM) procedure of Statistical Analysis System (SAS, 1985). Three statistical models were initially used to characterize milk production throughout lactation. Model 1 incorporated the use of unadjusted milk production averages over time per cow for comparison of differences in milk production during various stages of lactation relative to imposition of the diets. Model 2 utilized d of lactation to fit the area under the lactation curve.
for each individual dam. The mathematical equation used was $\text{Milk} = \beta_0 + \beta_1(d)$ with $\beta_0 =$ graphical Y intercept from actual milk values, $\beta_1 =$ slope of the lactation curve and $d$ was equal to the $d$ of lactation of the dam. Model 3 evaluated area under the lactation curve for each individual dam in a similar manner as Model 2, utilizing the equation $(\log \text{ (milk/d)}) = \beta_0 + \beta_1 d)$. All three models indicated the same trends in milk production, with slightly higher mean milk values for each successive model (Figure 6). The three models were evaluated and compared by estimating milk production across the entire lactation curve and then calculating the range and mean $R^2$ values for each individual dam’s lactation curve fitted from each model. The $R^2$ values for Model 1 ranged from .52 to .65 with mean $R^2$ of .6. Model 2 was evaluated in the same manner with $R^2$ range of <.01 to .83 and a mean of .45 ± .24. The last Model, Model 3, ranged from .74 to .97 with a mean $R^2$ of .9 ± .04. This model was determined to supply the best "fit" for the lactation curves of the dams evaluated and all further analysis conducted utilized the milk production estimates determined from this model.

Pre-calving grazing levels (PRE-L and PRE-H) were included in the model for analysis of milk production estimates from 14 d postcalving to 76 d postcalving. Prepartum grazing differences, postpartum energy levels (POST-M and POST-H), and the interaction (PRE X POST) were included in the model for analysis of milk production estimates after 76 d in milk. Day of lactation and milk somatic cell count were included in the models as covariates. Calf separation interval was initially included in the model, however, it was not a significant source of the variation in milk production and was removed.
Figure 6: Comparison of Statistical Models Utilized to Determine Average Milk Weight from Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) from Calving to Weaning at 209 d Postcalving.
Milk components were analyzed using the General Linear Model (GLM) procedure of Statistical Analysis Systems (SAS, 1985). Percentages and yields of fat, protein, lactose and solids-not-fat were included in the model as dependent variables. Somatic cell count was also included in the model as a dependent variable. Differences in grazing levels imposed prior to calving (PRE-L and PRE-H) were included in the model for analysis of milk components from calving to 76 d into milk. Differences in postcalving energy levels (POST-M and POST-H) and the interaction between the effects of precalving and postcalving nutritional treatments were included as dependent variables in the model for analysis of components 76 d postcalving. Day of lactation was included in all models as a covariate.

The General Linear Model procedure (SAS, 1985) was used to analyze dam reproductive performance. Reproductive parameters analyzed included postpartum interval to first ovulation, d to first service and d to conception, all of which were dependent variables in the model. Precalving grazing levels (PRE-L and PRE-H), postpartum energy levels (POST-M and POST-H), and the interaction between the effects of prepartum and postpartum nutritional treatments were included in the model as independent variables. Reproductive status (pregnant vs non-pregnant) at the end of the breeding season was analyzed using the CATMOD procedure of SAS, with PRE and POST nutritional treatments and their interaction as main effects. Calving date was included in all models as a covariate.
**Results and Discussion**

**Milk Production and Calf Performance**

Milk production was determined by machine milking each dam at various d postcalving. The average amount of milk collected throughout the experiment was $5671 \pm 214$ g. Mean interval from calf separation to milking for all dams was $17.5 \pm 1.3$ h. Calf weaning weight was highly correlated with the average milk production of the dam ($P < .001; r = .70$; Figure 7; Figure 8).

Regardless of prepartum grazing level or postpartum energy levels, milk production declined linearly as d of lactation increased (Figure 9). When expressed across the entire lactation, milk produced by dams on this study declined .014 kg/d. This is in agreement with research conducted by Gleddie and Berg, (1968) who found an average of .02 kg/d decline in milk production throughout lactation. The value of .014 is somewhat less than that observed by Gleddie and Berg, (1968), indicating females from this study were more persistent in their lactation. This may have been due to the large number of crossbred females with Holstein breeding on this study. Lactation curves of beef cows have been described by others as linear (Gleddie and Berg, 1968) and either linear or curvilinear (Lamond et al., 1969). Of the 62 cows evaluated by Lamond et al., (1969), 46 (77%) had a significant linear decline in milk production, two showed no relative change, and 14 (23%) had a significant linear and curvilinear descent in their lactation curves. These individual differences in lactation curve shape were attributed to changes in response due to environment and to cow "individuality".
Figure 7: Average Actual Dam Milk Weights and Calf Weaning Weights from Dams on Differing Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H)
Figure 8: Average Actual Dam Milk Weights and Calf Weaning Weights from Dams on Differing Prepartum grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) and Subgrouped by Cow Age and Percentage Crossbreeding.
Figure 9: Average Milk Production of All Dams Regardless of Prepartment Grazing Levels and Postpartum Energy Levels from Calving to Weaning at 209 d Postcalving.
Milk production was greater from calving to 76 d postcalving for dams on the PRE-H grazing treatment (Figure 10). Average milk production during that period was 5812±64 and 6378±68 g for dams on the PRE-L and PRE-H treatments, respectively (P<.001). These data indicate that prepartum grazing differences significantly altered milk production from calving to 76 d postcalving. In contrast, Falk et al., (1975), utilizing the teat cannulation method of milk removal, reported similar milk production early in lactation for dams fed 100, 85 or 75% NRC requirements prepartum. Milk production differences in that study were determined after 8-hr calf separation.

Despite the 9.3% difference in milk production recorded during early lactation, weaning weights of calves from dams on the restricted grazing level prepartum were not different from those of calves reared by dams which grazed ad libitum prior to calving (Table 12). Machine milking measures the milk producing ability of cows rather than the amount of milk which the calf consumes. During the first two months after birth calves are unable to consume the maximum amount of milk the dam is able to produce (Boggs et al., 1980). Therefore, failure to observe a difference in weaning weights despite a large difference in milk producing potential caused by the prepartum treatments may have been due to the fact that the maximum difference in milk production levels occurred at a time when the calf was incapable of consuming the cows total potential milk yield.

The interaction between the effects of prepartum grazing levels and postpartum energy levels on milk production was significant for milk production from 76 d postcalving to weaning (P<.10). This interaction indicates that the differences in postpartum energy level affected milk production differently for cows in the two prepartum grazing groups. Cows
Figure 10: Average Milk Production of Dams on Differing Dowshell Prepartum Grazing Levels (PRE-L vs PRE-H) and Postpartum Energy Levels (POST-M vs POST-H) from Calving to Weaning at 209 d Postcalving.
from both prepartum grazing levels had higher milk production from 76 d postpartum to weaning when the daily energy level was increased from 24.5 (POST-M) to 31.8 Mcal (POST-H) of metabolizable energy. However, the extra energy supplied by the POST-H diet caused a greater increase in milk production of cows that were on the ad libitum grazing level prior to calving (PRE-H). This indicates that cows on the prepartum restricted grazing level (PRE-L), which were lighter and had lower body condition scores when the postpartum dietary energy was increased, probably partitioned more of the energy from the POST-H diet to rebuilding body stores than did cows from the PRE-H group.

Weaning weights of calves reared by dams receiving the POST-H diet were greater than weights of calves raised by dams receiving the POST-M diet (Table 13). The difference in weaning weights (POST-M vs POST-H) was slightly greater for calves of cows on the ad libitum grazing level prior to calving (20 kg) than for calves of the cows in which prepartum grazing was restricted (13 kg). The interaction between prepartum grazing level and postpartum energy level, however, was not significant.

Average milk production over the entire lactation was significantly influenced by both prepartum (P<.001) and postpartum (P<.001) nutrition. The interaction of PRE x POST for milk production across the entire lactation curve approached significance (P = .15). The interaction of PRE and POST nutrition on milk production from 76 d to weaning was significant (P<.10).

Calves appeared to be more sensitive to decreased milk levels late in lactation, when milk intake was greater. However, the reduction in weaning weight caused by lower milk production late in lactation, may have been partially compensated for by forage consumption of the calves. Except when separated from dams before milking, roughages were available to
calves at all times. Greater consumption of hay by calves reared by dams which produced less milk could have masked some differences in weaning weight.

These prepartum and postpartum nutritional effects on milk production are in agreement with similar studies (Dunn et al., 1965; Wilson et al., 1969). Wilson et al., (1969) studied the effects of differing nutrition on milk yield with rations fed postpartum at 115% and 85% of NRC (1963) requirements. They found highly significant differences (P<.01) for milk yield, with dams on the low postpartum ration producing on average 1.48 kg less milk for 12-h milk yield estimations. The average 12-h yield was 4.7 kg which was a slightly lower amount than the average milk collected in this study after 17-h separation, however, the amount collected by Wilson et al. for 12-h was higher than those estimates attained by other researchers (Knapp and Black, 1941; Gifford, 1953; Drewry et al, 1959; Dawson et al., 1960; Neville (1962); Klett (1963); Christian et al., 1965; Melton et al., 1967;). This may be due to the fact that machine milking was utilized in both the study by Wilson et al., (1969) and in this study. Furthermore, dams utilized in both studies were crossbred cows of Angus X Holstein breeding.

**Milk Components**

Percentages of milk fat, protein, lactose or solids-not-fat were not influenced (P>.20) by **PRE** or **POST** nutrition levels (Table 18). In addition there was no interaction of **PRE** and **POST** nutrition with milk component percentages.

Grazing differences prepartum (**PRE**) did significantly affect yields of milk fat (P<.10), solids-not-fat (P<.05) and lactose (P<.10), however,
TABLE 18. LEAST SQUARES MEANS (± SEM) FOR MILK COMPONENT PERCENTAGES FROM INITIATION OF POSTPARTUM NUTRITION AT 76 d POST-CALVING TO WEANING FROM DAMS ON DIFFERING PREPARTUM GRAZING LEVELS AND POSTPARTUM ENERGY LEVELS$^a$

<table>
<thead>
<tr>
<th>Diet</th>
<th>N</th>
<th>Milk Fat(%)</th>
<th>Protein(%)</th>
<th>Lactose(%)</th>
<th>Solids Not Fat(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-L</td>
<td>22</td>
<td>3.8 ± .16</td>
<td>3.2 ± .05</td>
<td>4.6 ± .05</td>
<td>8.4 ± .07</td>
</tr>
<tr>
<td>PRE-H</td>
<td>21</td>
<td>3.5 ± .17</td>
<td>3.2 ± .05</td>
<td>4.6 ± .05</td>
<td>8.4 ± .08</td>
</tr>
<tr>
<td>POST-M</td>
<td>22</td>
<td>3.8 ± .16</td>
<td>3.2 ± .05</td>
<td>4.6 ± .05</td>
<td>8.5 ± .07</td>
</tr>
<tr>
<td>POST-H</td>
<td>21</td>
<td>3.5 ± .19</td>
<td>3.2 ± .06</td>
<td>4.5 ± .06</td>
<td>8.4 ± .08</td>
</tr>
</tbody>
</table>

$^a$ Due to variations in calving date, the dates of sampling are different among cows.
protein yield only approached significance \( (P = .27) \). Nutritional variation postpartum (POST) significantly affected solids-not-fat yield \( (P < .10) \) and approached significance for yields of lactose \( (P = .16) \), however, yields of fat and protein were not significant \( (P > .40) \).

Milk protein, lactose and fat yield were highly correlated with one another and with the fluid content of milk (Table 19). Calf weight was significantly correlated \( (r = .63) \) with all milk components. When the fluid component (milk yield minus fat, protein and lactose) was used as a covariate in the statistical model to determine if any other component explained significant variation in calf gain independent of the fluid level, partial correlations between fat \( (r = .12) \) protein \( (r = .04) \) or lactose \( (r = -.16) \) and calf gain were not significant. Hence, the explanable variation in calf weaning weight attributable to milk yield was not improved upon by including measures of milk composition.

Results reported by Lamond et al., (1969) indicated that fat percentages were above average in the first 3 mo of lactation and were well below average in the last 3 mo. Hence, the fat percentages tended to decline with d of lactation, however the decline was significant in only one-third of the cows evaluated. They concluded that the wide variation both in shape of the lactation curves (as described above) and the fat percentages, reflected individuality between the cows in their response to environment. Fat yields in this study were also negatively correlated \( (r = -.12) \) with d of lactation.

Somatic cell count (SCC) was not different among groups of animals on the different prepartum grazing or postpartum energy levels, however SCC did have a significant effect on milk production, regardless of PRE and POST nutritional treatments \( (P < .03) \). Increases in somatic cell count were
TABLE 19: RESIDUAL CORRELATIONS AMONG AVERAGE FAT, PROTEIN, LACTOSE AND FLUID COMPONENTS OF MILK AND WEANING WEIGHT OF CALVES FROM DAMS ON DIFFERING PREPARTUM GRAZING LEVELS AND POSTPARTUM ENERGY LEVELS.a.

<table>
<thead>
<tr>
<th>Item</th>
<th>Fluid</th>
<th>Protein</th>
<th>Lactose</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaning Weight</td>
<td>.51</td>
<td>.49</td>
<td>.47</td>
<td>.40</td>
</tr>
<tr>
<td>Fluid</td>
<td></td>
<td>.95</td>
<td>.97</td>
<td>.69</td>
</tr>
<tr>
<td>Protein</td>
<td></td>
<td></td>
<td>.90</td>
<td>.59</td>
</tr>
<tr>
<td>Lactose</td>
<td></td>
<td></td>
<td></td>
<td>.64</td>
</tr>
</tbody>
</table>

a Milk composition for fat, protein, and lactose (component percentage x milk weight) was averaged for all milkings evaluated from calving to weaning.
negatively correlated with milk production \((r = -0.13)\) throughout the course of the study. These results are similar to those reported in dairy cattle (Carrol, 1977; Thompson, 1983) and those of studies that have evaluated SCC in beef cattle (Hunter and Jeffery, 1975; Kirkbride, 1977; Haggard et al., 1983; Watts et al., 1986). Somatic cell count was also negatively correlated \((r = -0.04)\) with calf weaning weights in this study. Negative correlations have been reported by Haggard et al., (1983), in which the negative correlation \((-0.48)\) between milk SCC from beef females and the weaning weights of their calves was greater than that recorded in this experiment. Calves from the infected \((SCC > 10^6/ml)\) females \((11.9\%)\) weighed 12 kg less at weaning in one study and 14 kg less in another (Haggard et al., 1983).

Somatic cell count is a significant source of decreased milk production and culling in dairy cattle, but is not generally reported as a significant source of culling in the beef industry. Research conducted by Kirkbride, (1977) indicated an elevated SCC \((\text{presence of micrococci})\) detected in 17.5\% of beef cattle evaluated. This figure is about half that normally detected in dairy females \((40\%)\).

Decreased milk production of beef females, resultant of increases in SCC, were significant in this study but probably would not have been noted by a producer in a normal beef cattle range situation. Close contact because of biweekly machine milking, revealed no visible phenotypic differences between those females in this study with "normal" SCC levels and those with counts that were elevated. Machine milking of dairy cattle, conducted under milking parlor conditions, has been shown to increase SCC levels in dairy cattle (Thompson, 1983). Therefore, it is also possible that the procedure of biweekly "barn" machine milking used in this study may
have introduced some mammary infection into these beef cows that under range conditions would not have occurred.

Reproductive Performance

Postpartum interval to first ovulation differed (P < .12) for PRE-L and PRE-H groups (53 ± 4 vs 43 ± 4 d, respectively). Differences in prepartum nutrition have previously been shown to affect the postpartum interval in beef cows (Falk et al., 1975) and heifers (Bellows and Short, 1978). Variations in prepartum nutritional levels of 100% to 85% or 75% NRC produced subsequent postpartum intervals to first observed estrus in beef cows of 63, 67 and 78 d, respectively, (Falk et al., 1975). Postpartum interval was also affected by milk production, with days postpartum being negatively correlated (r = -.64) with milk production (P < .001).

Days to first service (92 ± 2.7) and d to conception (93 ± 2.9) were not significantly different (P > .40) among the cows on the PRE-L and PRE-H grazing treatments. These results may be due to the fact that the breeding season was initiated 72 ± 10 d postcalving and many females from the PRE-L grazing group had enough time to regain cyclic status, despite the longer interval from calving to first ovulation. At the beginning of the breeding season 81% of all cows had begun exhibiting estrous cycles. However only 64% (14/22) of cows from the PRE-L treatment were cycling when compared to 100% (21/21) of PRE-H females. The percentages of cows cycling at the beginning of breeding for cows assigned to the PRE-L/POST-M, PRE-L/POST-H, PRE-H/POST-M and PRE-H/POST-H groups was 73, 55, 100 and 100%, respectively. If the breeding season had started at 45 d postcalving, instead of 72 d postcalving, even more females from the PRE-L
group would have been anestras and the interval to first service may have been significantly greater for PRE-L than for PRE-H dams (Table 20).

The interval from calving to first service was different between the POST nutritional groups ($P < .04$). POST-M and POST-H females had intervals of $97 \pm 2.6$ and $88 \pm 2.6$ d from calving to first service, respectively ($P < .04$). The rise in energy associated with the change to the POST-H diet caused some of the females in the PRE-L/POST-H group to initiate cyclicity and be bred earlier during the breeding season. However, postpartum energy level effects on d to conception only approached significance in the model, with POST-H and POST-M dams having $89 \pm 2.8$ and $96 \pm 3$ d to conception, respectively ($P < .11$). The interaction between PRE and POST nutritional effects was not significant ($P > .5$) for the interval to first service or the interval to conception.

The proportion of females pregnant at the end of the 45-d breeding season was higher for the PRE-H group (81%) than the PRE-L group (68%; Table 20), however, the difference was not statistically significant ($P > .5$). The POST diets and the interaction of PRE and POST nutrition on pregnancy rate were not significant ($P > .5$). Precalving energy level affected the pregnancy rate during the first 100 d after calving in a study by Dunn et al., (1969). They determined that 41% of the 120 cows on the low-energy level (8.7 Mcal DE) precalving were pregnant at 80 d postcalving compared to 47% of the 120 cows on the high precalving energy level (17.3 Mcal DE). Pregnancy rates at 100 d postcalving were still significantly different at 60% and 68% for the low and high precalving nutrition, respectively (Dunn et al., 1969).
TABLE 20: LEAST SQUARES MEANS (±SEM) FOR VARIABLES REPRESENTING REPRODUCTIVE PERFORMANCE OF DAMS ON DIFFERENT PREPARTUM GRAZING LEVELS (PRE-L VS PRE-H) AND POSTPARTUM ENERGY TREATMENTS (POST-M VS POST-H)

<table>
<thead>
<tr>
<th>Diet</th>
<th>N</th>
<th>Postpartum Interval to Estrus(d)</th>
<th>Postpartum Interval to First Service(d)</th>
<th>Postpartum Interval to Conception(d)(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-L</td>
<td>22</td>
<td>53.0 ± 4.3(^b)</td>
<td>90.9 ± 2.7</td>
<td>93.0 ± 3.0 (15)</td>
</tr>
<tr>
<td>PRE-H</td>
<td>21</td>
<td>43.4 ± 4.4(^c)</td>
<td>94.0 ± 2.5</td>
<td>92.3 ± 2.8 (17)</td>
</tr>
<tr>
<td>POST-M</td>
<td>22</td>
<td>43.2 ± 4.3(^d)</td>
<td>96.6 ± 2.6(^f)</td>
<td>96.2 ± 3.1(^h) (15)</td>
</tr>
<tr>
<td>POST-H</td>
<td>21</td>
<td>53.2 ± 4.4(^e)</td>
<td>88.2 ± 2.6(^g)</td>
<td>89.1 ± 2.8(^i) (17)</td>
</tr>
</tbody>
</table>

\(^a\)Values in ( ) are number of animals pregnant within groups at end of breeding season

\(^b^c\)Means in same column within diet (PRE,POST) with differing superscripts differ (P < .14).

\(^d^e\)Means in same column within diet (PRE,POST) with differing superscripts differ (P < .13).

\(^f^g\)Means in same column within diet (PRE,POST) with differing superscripts differ (P < .04).

\(^h^i\)Means in same column within diet (PRE,POST) with differing superscripts differ (P < .11).
CHAPTER 4

Summary and Conclusions

This experiment was conducted to evaluate the effect of prepartum and postpartum nutritional differences on milk production, reproductive performance and subsequent calf performance.

Grazing variations imposed prepartum caused a significant difference in dam body weights, body condition score (BCS) and ultrasound measurements of body composition. Dams limit grazed prepartum lost significantly more weight, had lower BCS and displayed less backfat and loineye area when compared to dams on the ad libitum grazing treatment (PRE-L vs PRE-H). Grazing differences prepartum also significantly lowered calf birth weights in the PRE-L treatment and increased these females' postpartum interval to first ovulation.

Grazing limitations seriously affected these dams, however, they did recover during the postpartum period and by weaning differences in body weight, BCS or ultrasound measures of composition were not significantly different. Utilizing the same available feedstuffs, limit grazed dams were able to "catch up" to the other females' stage of conditioning. However this need to gain condition combined with the added metabolic stress of lactation caused these females to suffer in their reproductive efficiency. The number of females pregnant by the end of the 45-d breeding season was less for the limit grazed group (68%) than for the ad libitum treatment (81%).

95
Although less milk was collected from cows between calving and 76 d postcalving (5,812 vs 6,378 g) that had grazing restricted prior to calving, their calves’ weights at weaning were not lower than those of calves from cows grazing ad libitum prior to calving. Milk production differences seen during the early postpartum period in this study were either not severe enough to affect calf weaning weights or were at a period during the calf’s development when milk utilization was limited by the age and size of the calf and not by the milk producing potential of the dam. If calf consumption cannot match milk production of the dam then differences in calf performance will not be noted, even though milk production differences were noted by machine milking. If grazing limitation had continued into the postpartum period then differences in milk production would have become apparent in the calves’ performance and phenotypic appearance as the need for increased levels of milk continued but were not met.

Nutritional treatments imposed on females from 76 d postpartum to weaning caused a significant difference in both milk production and calf weaning weights with dams receiving the high-energy level (POST-H) increasing subsequent milk production and calf weaning weight when compared to those dams receiving the moderate nutritional treatment (POST-M). As calves grow older, consumption of milk increases and limitations in milk production cause decreased calf performance. The diets imposed beginning 76 d postpartum significantly affected all calf performance traits, regardless of prepartum nutritional treatment. There was, however, a significant interaction of PRE and POST nutrition on milk production from 76 d to weaning. Dams limit grazed prepartum used more energy to replenish their own body stores, rather than to increased milk production, when compared to the ad libitum grazed females.
Variations in nutrition prepartum thus affected the way in which females utilized nutrients postpartum.

The postpartum moderate-energy treatment (95% NRC) was not severe enough however to cause a significant difference in dam body weights or condition scores by the end of the study (weaning). These moderate restrictions were not severe enough to cause significant weight change, however, a difference in the interval from calving to first service was significant with females on the POST-H energy level being serviced sooner (88 d PP) when compared to the dams on the moderate-energy level (POST-M; 97 d PP). The POST-H energy level may have been high enough to cause a "flushing" of these dams and perhaps initiate cyclicity in some non-cycling females in addition to the POST-M diet actually limiting females. However there was not a significant difference in d to conception (89 vs 96 d) between the POST-M and POST-H dams, respectively.
Literature Cited


VITA

Name.......................................................... Jeffrey Mark Kearnan

Parents ....................................................... Joseph Kearnan (deceased)
                                       Barbara Kearnan

Stepfather .................................................. Donald Paul Morrell

Date of Birth ............................................. December 12, 1965

Birthplace .................................................. Worcester, Massachusetts

Schools Attended:

   Lemoore Union High School.......................... 1979 to 1983
   Lemoore, California

   West Hills College .................................. 1983 to 1985
   Coalinga, California

   California Polytechnic Institute
   and State University ......................... 1985 to 1988
   San Luis Obispo, California

   Virginia Polytechnic Institute
   and State University ......................... 1988 to 1990
   Blacksburg, Virginia

Degrees Received:

   Associate of Science ............................... 1985

   Baccalaureate of Science ......................... 1988

   Master of Science ................................ 1991

Future Goals:

   Become the best possible teacher and supporter of agriculture that
   I can, marry a girl I love and who loves me, raise a large family,
   live happily ever after.