MILK PRODUCTION AND REPRODUCTIVE PERFORMANCE OF MATURE BEEF COWS SIRED BY HIGH AND LOW MILK EPD ANGUS AND HEREFORD BULLS

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NOMENCLATURE

ADG	Average Daily Gain
d	day(s)
EPD	Expected Progeny Difference
g	gram(s)
h	hour(s)
lb	pound(s)
kg	kilogram(s)
TDN	Total Digestible Nutrient
WSW	Weigh-suckle-weigh method
yr	year(s)

CHAPTER I

INTRODUCTION

Calf performance is greatly affected by the milk production of the dam. Therefore, milk production of beef cows is considered one of the most important factors affecting the weaning weight of calves and the profitability of the cow-calf enterprise. Naturally, many cow-calf producers make selection for increased weaning weight as a priority. The calves need the genes for growth and a desirable environment to express those genes. A large part of this environment is provided by the cow in terms of her milk production that is made available to the calf. Cows with high genetic merit for maternal ability are expected to wean heavy calves. Expected progeny differences (EPD) have been developed and adapted by many breed associations to predict the genetic merit of cattle for different traits. The milk EPD predicts genetic merit for maternal ability. The differences between the milk EPD of two bulls should be a prediction of the difference in calf weaning weight between calves from daughters of the two bulls, due to milk production of the daughters. This EPD is measured in units of calf weaning weight, not units of milk.

It is important to understand the relationship between milking ability and reproductive performance of cows for beef cow-calf production. Reproductive performance of beef cows is the dominant determinant of economic efficiency in cow-calf enterprises. Profitability of a cow-calf operation depends on the percentage of cows in the herd that consistently calve every 12 months. Calving interval, calving percentage, calving date and age at first calving are indicators of reproductive efficiency in beef cattle and many traits associated with reproduction are lowly heritable and this makes the genetic improvement of reproduction difficult (Bourdan and Brinks, 1983; Macgregor, 1995; Meacham and Notter, 1987; Meyer et al., 1990; Morris and Cullen, 1988; Lopez de Torre and Brinks, 1990). Body energy reserves play an important role on the reproductive performance of cows at certain points of production (Selk et al., 1988, Spitzer et al., 1995). Insufficient body energy reserves can negatively impact the reproductive performance of cows. A negative effect on reproductive performance may be expected due to increased maternal ability in beef cows. Increased milk production causes an increase in protein and energy demand. Previous work by Buchanan et al. (1993, 1995, 1996a) has shown that the milk EPD is an effective tool for increasing weaning weight of calves but at the expense of cow body condition. Preliminary results by Buchanan et al. (1996b) described a very slight decline in reproductive performance, measured by calving date, calving interval and calving percentage in cows sired by bulls with high milk EPD. Therefore, management of cows to a specific body energy reserve is a key to preserve favorable reproductive efficiency. The objective of this study was to evaluate the effect of sire milk EPD level on differences in milk production and calf performance and to determine its relationship to reproductive performance of mature beef cows.

CHAPTER II

LITERATURE REVIEW

General Characteristic of Angus and Hereford

The Angus and Hereford are among the most popular beef breeds in the USA. They are maintained widely as straightbred and crossbred. The Angus and the Hereford have some similar characteristics that make them reasonable choices in many commercial beef industry.

The Angus was established and named in Scotland (Rouse, 1973). The first introduction of the Angus into the U.S took place in 1873 by Scotsman George Grant at Victoria, Kansas (Rouse, 1973; Porter, 1992). The Hereford was originated from Herefordshire in western England and imported into the U.S by Statesman Henry Clay in 1816 (Rouse, 1973; Porter, 1992). The polled and horned Hereford is the same breed. The polled Hereford was originated in 1893 by grading with Angus and Red Poll, but also by natural mutation at the turn of the century (Porter, 1992). Warren Gammon of Iowa provided much of the effort to establish polled Hereford herds around 1900 (Porter, 1992).

The color of the Angus breed is completely black, but there is also red Angus. Red is recessive but increasingly popular in some countries and usually registered separately. The Angus probably remains one of the most economical breed to rear, able to thrive on rough grazing and fatten on low rations (Porter, 1992). Brown and Dinkel

(1982) looked at the efficiency to slaughter of calves from Angus, Charolais and reciprocal cross cows. They found that Angus cows and their calves were more efficient in total TDN per unit slaughter weight.

The Angus is exported to more than 60 countries (Porter, 1992). Daily weight gains in England average 1.23 kg and performance-tested bulls achieve average 400-d weights of 460 kg (Porter, 1992). There are no parturition problems associated with the Angus and they also give a shorter gestation period by about a week (Porter, 1992). Notter et al. (1978a) studied birth weight, gestation length, dystocia and mortality in 653 2-yr-old and 622 subsequent 3-yr-old calvings out of Hereford-Angus reciprocal crosses plus crosses of Charolais, Simmental, Limousin, Jersey and South Devon sires on Hereford and Angus cows. In 2-yr-olds, calves by Angus, Hereford and Devon sires were lightest at birth and had the least dystocia and mortality. In 3-yr-olds, calves by Angus and Hereford sires had the lowest birth weight (34.7 kg), the shortest gestations (283-d) and the least dystocia (12 %).

The Angus breed produces the beef that is lightly marbled, succulent and tender (Porter, 1992). Koch et al. (1976) compared composition and quality characteristics of 1,121 steer carcasses after mating Angus and Hereford cows to Angus, Hereford, Jersey, South Devon, Limousin, Charolais and Simmental sires. Their results showed that Angus had higher average quality grade and higher marbling scores. In another study, Baker et al. (1984) compared the carcasses from bulls of Angus, Brahman, Hereford, Holstein, Jersey, and their crosses. They reported that Angus and Herefords ranked high for conformation score, marbling score and final grade.

The Hereford is characterized and differentiated from other breeds with the white face and red-colored body. The Herefords are economic producer, docile, easy to manage, early maturing, reliable, consistent, highly adaptable and particularly good for fattening on grassland or range. In a study by Gregory et al. (1978) the Hereford breed was exceeded by the Angus breed in terms of breed maternal effect for preweaning average daily gain (ADG) and 200-d weight. Their typical sizes in England are 150/136 cm and 895-1,300/630-825 kg (Porter, 1992), but it has grown noticeably taller, and longer in the body in recent years in many countries in order to meet modern needs. Their milk production is fairly low, mothering ability is adequate and cows will rebreed well. They have high conception and calving rates. Bailey and Moore (1980) reported that straightbred Hereford or Angus x Hereford matings had 10 % greater ($P < 0.05$) pregnancy rate than Hereford cows bred to Brahman sires. Also percentage live calves were higher ($P < 0.05$) for straightbred Hereford and Red Poll x Hereford matings than for Hereford x Red Poll crosses.

Milk EPD

The expected progeny difference (EPD) has become common among beef cattle breeders. An EPD is just the way it sounds. It is a prediction of difference between the average performance of future progeny of an animal and the performance of progeny of a theoretical reference animal, an animal with an EPD of zero. In order to make this comparison fair, we assume similar environments and mates of the same genetic value. From the definition above we see that an EPD can only be used to predict differences between animals and not absolute performance. An EPD is expressed in trait units. For growth traits, the units are pounds or kilograms (kg). Producers use EPD to compare animals and rank them as potential parents.

The reliability of EPD can be determined by regressing an individual's performance on their own EPD, or the EPD of parents or maternal grandparents, and comparing the regression coefficient to its expected value (Mallinckrodt et al., 1993).

The milk EPD is unique and it results from the separation of weaning weight into growth and milk segments. It predicts differences in weaning weights of calves out of cows by a particular sire, due to differences in mothering ability. The milk EPD is measured in units of calf weaning weight, not units of milk produced.

Marshall and Long (1993) studied the relationship of beef sire milk EPD to maternal performance of crossbred daughters. They found that a 1-kg change in sire milk EPD corresponded to a change in daughter's 214-d milk production of 13.4 kg. They also reported that a 1-kg change in sire total maternal weaning weight EPD corresponded to a change of 1.8 kg for daughter's calf weaning weight. The authors concluded that the differences among sires in milk and total maternal EPD values, on average, were positively related to actual crossbred daughter milk production and daughter's offspring weaning weight. They finally commented that breeders using sire milk and total maternal EPD values as selection tools should expect such selection to be effective, on average, but should also be cautious that a substantial proportion of individuals or small groups will not rank as predicted. The data involving Hereford and Simmental by Mallinckrodt et al. (1990) indicated that milk and total maternal EPD were reasonably good predictors of genetic differences in milk production and weaning weight.

Marston et al. (1990) reported that 1-kg increase in milk EPD showed an increase of 69 ± 19.8 and 70.7 ± 16.9 kg of total milk production in Angus and Simmental, respectively. Their study also indicated that 1-kg increase in milk EPD of cows resulted in an additional 3.8 ± 1.0 and 2.9 ± 1.1 kg of weaning weight for Angus and Simmental calves, respectively. They concluded that total milk production can be used to predict weaning weight but more important than this, milk EPD can be used to predict both weaning weight and total milk production.

A study by Marston et al. (1992) investigated the relationship of milk EPD of a dam to actual milk yield and offspring weaning weights of Angus and Simmental cattle. They found simple correlations between 205-d total milk yields and adjusted 205-d calf weaning weights of 0.30 ($P < 0.001$) and 0.47 ($P < 0.001$) for Angus and Simmental, respectively. In addition, their results showed that milk EPD was positively correlated to adjusted weaning weight ($r = 0.38$, $P < 0.001$; $r = 0.39$, $P < 0.001$) and total milk yield ($r = 0.32$, $P < 0.001$; $r = 0.44$, $P < 0.001$) for Angus and Simmental cows, respectively. The authors reported that a 1-kg change in dam's milk EPD resulted in a 4.85 ± 1.14 kg change in weaning weight ($P < 0.001$) in Angus and a 3.74 ± 1.73 kg change in weaning weight ($P < 0.05$) in Simmental.

Another study involving Angus and Simmental by Marston et al. (1989) indicated that a 1-kg increase in cow milk EPD resulted in an additional 56.6 kg and 70.2 kg of total milk production in Angus and Simmental, respectively.

In a Hereford study by Diaz et al. (1992), a positive and linear relationship was found between the milk EPD of sires and the actual milk production of daughters. This study reported correlations of 0.26 ($P < 0.01$) between sire's milk EPD and daughter's milk yield. They concluded that milk EPD of sires predicted differences in actual milk yield of their daughters.

Marshall and Freking (1988) studied several breeds and found that daughters of high-milk EPD sires ranked higher than daughters of low-milk EPD sires for weaning weight and milk production. However, the differences were not significant. Even though Hereford maternal weaning weight EPD of grandsires was a good predictor of the weaning weight of calves, Angus and Tarentaise maternal weaning weight EPD of grandsires did not predict the differences in weaning weight of calves as accurately. Similarly, Minick et al. (2001) found that daughters of high-milk EPD sires yielded more milk and weaned heavier calves than those of low-milk EPD sires, but this was at the expense of body condition. Their results suggested that sire milk EPD were sufficiently linked with milk production and calf performance to be useful tools in genetic improvement of preweaning performance.

Milk Production of Beef Cattle

In cow-calf operations weaning weights of the calves has a great influence on net income. Milk production is generally considered to be major component of maternal effects on calf weaning weight and has been studied extensively in beef cattle (Gifford, 1949; Gifford, 1953; Neville, Jr., 1962; Furr and Nelson, 1964; Gleddie and Berg, 1968; Rutledge at al., 1971; Jeffery et al., 1971b; Totusek et al., 1973; Robison et al., 1978; Belcher and Frahm, 1979; Butson et al., 1980; Chenette and Frahm, 1981; Mondragon et al., 1983; Jenkins and Ferrell, 1984; Bourden and Brinks, 1987; Clutter and Nielsen, 1987; Marston et al., 1992; Marshal and Long, 1993; Mallinckrodt et al., 1993; Minick et al., 2001).

Beal et al. (1990) concluded that milk production of the dam is the greatest single factor affecting preweaning gain in calves of similar breeding. Neville, Jr. (1962) reported that 66 % of the variation in calf weaning weight was due to milk consumption. It has also been reported by Taylor (1994) that 60-70 % of the variation in weaning weight of calves is explained by differences in milk production of the dam; the remaining 30-40 % comes from grass and other forage that the calf directly consumes.

Rutlegde et al. (1971) reported that on a within-herd-year-sex-basis approximately 60 % of the variance in 205-d weight was due to the direct effect of the dam's milk production. They also reached a conclusion that milk quantity rather than milk quality was more important in its effect on 205-d weight.

Koch (1972) investigated the role of maternal effects in animal breeding and reported that variation due to maternal effects account for 40-46 % of the gain from birth to weaning.

Jeffery et al. (1971b) reported that milk yield had the greatest effect on preweaning performance, explaining 56-59 % of total variation in average daily gain (ADG) to weaning and 42-57 % of total variation in weaning weight.

It has been reported that cows with higher levels of milk production weaned heavier calves (Totusek et al., 1971; Butson et al., 1980; Clutter and Nielson, 1987). Butson et al. (1980) studied the factors affecting weaning weights of range beef and dairy-beef calves. They reported that in general, calves from dams with dairy breeding tended to show higher weaning weights than those from either straightbred or crossbred beef breeding.

In a study with three groups of beef cows, similar in growth and mature size, but different in genetic potential for milk level, indicated that estimated 205-d milk yield of the high milk group exceeded that of the medium and low milk groups by 186 and 561 kg, respectively (Clutter and Nielsen, 1987). It was also reported in same study that calves suckling high milk-group cows had 16.9 kg greater 205-d weaning weight than those suckling low milk-group cows.

Estimates of correlation between the milk production of cows and the weaning weight of their calves vary greatly depending on various environmental conditions, lactation stages, and different estimation procedures used. Some of the correlations reported between the milk production of cows and the weaning weight of their calves were 0.395 (Mallinckrodt et al., 1993), 0.63 (Robison et al., 1978) and 0.64 ($P < 0.0001$)(Diaz et al., 1992) for Herefords; 0.30 ($P < 0.001$)(Marston et al., 1992), 0.39 (Marston et al., 1990), 0.62 (Marston et al., 1989) for Angus; 0.355 (Mallinckrodt et al., 1993), 0.47 ($P < 0.001$)(Marston et al., 1992), 0.52 (Marston et al., 1990) and 0.62 (Marston et al., 1989) for Simmentals. Minick et al. (2001) found a correlation of 0.43 between the milk production of crossbred cows (sired by high- and low-milk EPD Angus and Hereford bulls) and weaning weight of their calves.

The regression of total milk production on weaning weight has varied greatly. A study combining the results of Angus and Simmental cows found that an additional 26.8 kg of total milk production was required for each 1-kg increase in weaning weight (Marston et al., 1989). Another study by Marston et al. (1990) found that 62 and 40 kg of total milk production in Angus and Simmental cows, respectively resulted in a 1-kg increase of weaning weight. A further study by Marston et al., (1992) reported that 1-kg change in total milk yield of the dam resulted in 0.014 ± 0.006 and 0.032 ± 0.009 kg of adjusted weaning weight for Angus and Simmental calves, respectively. Boggs et al. (1980) reported that each kg of milk produced per day added 7.20 kg of 205-d adjusted weaning weight and 0.34 kg/day of ADG. A 1-kg increase in daily milk production resulted in an increase of 7.7 kg (Butson et al., 1980) and 11.3 to 14.6 kg (Jeffery et al., 1971b) in weaning weight of calf. Marshall and Long (1993) reported a theoretical expectation for regression of daughter cumulative milk yield on sire milk EPD as 20.4 kg/kg for crossbred cows. Minick et al. (2001) reported 1.22 and 0.93 kg increase in weaning weight for every 1-kg increase in sire milk EPD for Angus and Hereford-sired cows, respectively. The authors also reported a regression of 1.09 with both breeds together.

Factors Affecting Milk Production in Beef Cattle

It has been reported that there are breed differences in the amount of milk produced by the cow (Gleddie and Berg, 1968; Jeffery at al., 1971b; Comerford et al., 1978; Notter et al., 1978b; Jenkins and Ferrell, 1992). Gleddie and Berg (1968) reported that an important effect of breed of dam accounted for 82.5 % of the variance in average milk yield in their data. Jenkins and Ferrell (1992) reported that milk yield at the time of peak lactation (kilograms per day) was similar ($P = 0.4$) for Braunvieh (11.9 ± 0.3), Gelbvieh (11.5 ± 0.3), Pinzgauer (11.1 ± 0.3), and Simmental (10.9 ± 0.3). These four breeds produced more milk ($P < 0.05$) than Angus (9.4 ± 0.3), Hereford (8.5 ± 0.3), Limousin (9.5 ± 0.3), and Charolais (9.8 ± 0.3) at the time of peak lactation. This study also reported total milk production ranging from 1,200 to 1,800 kg for the breeds mentioned above. Braunvieh's total milk production (1,803 ± 60 kg) over a 210-d lactation period exceeded ($P < 0.05$) that of all breeds except Gelbvieh ($P = 0.4$). The milk production of the Hereford (1,191 ± 57 kg) was similar only to the milk production of the Limousin (1,349 ± 54 kg). Melton et al. (1967) studied the milk production of Angus, Charolais, and Hereford cows. They reported that total milk production of Charolais (784.8 kg) was higher ($P < 0.05$) than Hereford (581.0 kg). Nelson et al. (1985) also reported differences in milk production among breeds that the Hereford was lowest (4.8 kg) and Simmental was highest (8.0 kg) for daily milk production. Klett et al. (1965) reported average daily milk yields of 2.92 kg for Herefords and 3.90 kg for Angus.

Crossbred cows tended to produce more milk than purebreds (Mondragon et al., 1983; Notter et al., 1978b). Cundiff et al. (1974) reported that 12-h milk production of crossbred cows was 7.5 % higher ($P < 0.05$) at six weeks and 38 % higher ($P < 0.01$) at weaning than12-h milk production of purebred cows. Jeffery et al. (1971b) reported that differences in milk production between breed-of-dam categories were highly significant. The Angus and Galloway cross and hybrid group dams were almost equal in milk production, excelling the Hereford dams by approximately 1.20 and 1.50 kg in 1966 and 1967, respectively (Jeffery et al., 1971b). Only subtle differences were observed between crossbred cows containing 0, ¼ or ½ of Brahman breeding for milk production (McCarter et al., 1991a). Chenette and Frahm (1981) studied milk yield and composition from various two-breed cross cows. They reported that milk yield was highest for Jersey x Angus and Brown Swiss x Angus dams (average 8.09 ± 0.41 kg/day), intermediate for

Jersey x Hereford, Brown Swiss x Hereford, Simmental x Angus, and Simmental x Hereford cows (average 7.38 ± 0.41 kg/day), and lowest for Hereford x Angus dams (6.52 ± 0.40 kg/day). Freetly and Cundiff (1998) found that milk production from 50 to 200-d of lactation did not differ between Brahman (1,029 ± 38 kg) and Belgian Blue (1,070 ± 30 kg) sired heifers. They reported that Brahman and Belgian Blue-sired heifers had higher ($P < 0.05$) 50 to 200-d milk production than did the Hereford (842 ± 45 kg), Angus (905 ± 40 kg), Piedmontese (879 ± 44 kg), Boran (899 ± 25 kg), and Tuli (888 ± 33 kg) sired heifers. The Hereford, Angus, Piedmontese, Boran, and Tuli sired heifers did not differ in milk production from 50 to 200-d.

Butson and Berg (1984a) investigated the lactation performance of range beef and dairy-beef cows. They reported that dairy-synthetic line (Holstein, Brown Swiss and traditional beef breeds) produced more milk than beef crossbreds and purebred Herefords. Average daily milk production was 5.7 kg for Hereford, 6.9 kg for beef-synthetic population (Charolais, Angus and Galloway breeding), 7.6 kg for dairy-beef crossbred group of dams with dairy sires and Hereford or beef-synthetic population dams, and 7.8 kg for dairy-synthetic line. The last two groups were similar in daily milk production, but were significantly different ($P = 0.001$) than Hereford and beef-synthetic population. The Hereford was also significantly different ($P = 0.001$) from beef-synthetic population for daily milk production. The authors concluded that the introduction of dairy breeds into a beef line will result in higher milk yield under range suckling conditions compared to beef breeds and crosses.

It has been reported that cow age has a significant effect on milk production (Todd et al., 1969; Rutledge et al., 1970; Jeffery et al., 1971a; Neville, Jr., et al., 1974;

Lubritz et al., 1989). Butson and Berg (1984a) reported that milk production from 3-, 4-yr-old and mature cows was approximately 25%, 35%, and 39% more milk per day than 2-yr-old cows, respectively. Bogs et al. (1980) reported that no significant differences were observed between younger (3- and 4-yr) and older (≥ 9-yr) Polled Hereford cows when comparing them based on total milk yield. Minick et al. (2001) found no significant differences between 3-, 4-, and 5-yr old cows in terms of milk production. Gaskin and Anderson (1980) reported a positive linear trend (b = 1.0 kg/yr) in daily milk production as age of cow increased from 2- to 4-yr. Rutledge et al. (1970, 1971) noted quadratic effects of age on milk yield with a maximum at 8.4-yr in Hereford cows. Lubritz et al. (1989) reported a significant curvilinear effect of cow age with sum of seven monthly observations and sum of three monthly measures of milk yield increasing for cows from 2-to 5-yr of age, but not differing for cows 6-yr and older. Clutter and Nielsen (1987) reported that differences between high and low producing dams increased as the cows aged. Christensen et al. (1973) found that age at first and second calving had more significant effects on milk production than overall age effects alone. Neville, Jr., et al. (1974) suggested that even though milk production increased for cows up to 6-yr of age before reaching a plateau, lactation number may affect milk yield as much as age of dam at calving. Rutledge et al (1972) reported a similar shape of lactation curve for various ages of cow. Todd et al. (1969) found a greater persistency of milk production for cows 6-yr or older. Jeffery et al. (1971a) reported correlations ranging from 0.22 to 0.32 between age of dam and milk yield.

The effects of cow weight on milk yield ranged from negative (Pope et al., 1963; Marston et al., 1992; Minick et al., 2001) to non-significant (Mondragon et al., 1983;

Butson and Berg, 1984b) to positive (Totusek and Arnett, 1965; Rutledge et al., 1970, 1971; Jeffery et al. 1971a; Mondragon et al., 1983). Some of the correlations reported between cow weight and milk productions were - 0.37 to - 0.22 (Pope et al., 1963), - 0.11 (Minick et al., 2001), 0.28 to 0.38 (Jeffery et al., 1971a), 0.69 ($P < 0.01$)(Totusek and Arnett, 1965), 0.80 ($P < 0.01$)(Totusek and Arnett, 1965) and 0.88 ($P < 0.01$)(Totusek and Arnett, 1965).

Milk level has been shown to influence a cow's body condition throughout the lactation. In general, higher milk production was associated with a decrease in body condition (Belcher and Frahm, 1979; Mondragon et al., 1983; Montano-Bermudez and Nielsen, 1990; Minick et al., 2001) A correlation of - 0.61 was reported by Wilson et al. (1968) between final body condition score and kg of milk produced. Marshall et al. (1976) reported no significant correlation between body condition and milk yield. Marston et al. (1992) found that Angus and Simmental breeds tended to increase in body condition score and weight during lactation, but both Angus and Simmental body condition score tended to decrease as total milk production increased. Fiss and Wilton (1992) reported that increasing cow weights were associated with increase in cow condition, milk production, and feed intake within Hereford, small rotation, or large-rotation breeding system.

The effects of calf sex on milk yield are highly variable. Rutledge et al. (1971) reported that cows nursing female calves produced more milk than those nursing males. In contrast, Pope et al. (1963), Daley et al. (1987), and Minick et al. (2001) reported an advantage for dams nursing male calves. A study by Jeffery et al. (1971a) found that the dams of male calves yielded 0.26 kg more milk per day than dams of female calves in

1966, but this was reversed in 1967 and dams of male calves produced 0.41 kg less than dams of female calves. Christian et al. (1965), Melton et al. (1967), Gleddie and Berg (1968), Reynolds et al. (1978), and MacNeil and Mott (2000) found no significant relationship between milk production of dam and sex of calf

The effect of birth weight of the calf on milk yield of the dam ranged from non-significant (Christian et al., 1965; Gleddie and Berg, 1968) to positive (Rutledge et al., 1970, 1971; Robison et al., 1978; Butson and Berg, 1984b; Minick et al., 2001). Calf birth weight was related to total milk production in Angus ($P < 0.03$) but not in Simmental (Marston et al., 1992). Gifford (1953) and Boggs et al. (1980) reported that larger calves caused their dams to produce more milk. Similarly, Rutledge et al. (1971) found the linear regression of 0.51 of total milk production on calf birth weight, explaining that heavier calves at birth either demanded more milk from their dams or had a greater capacity to consume milk. Birth weight explained only 0.0 to 2.4 % of total variance in milk production (Jeffery et al., 1971a). A 1-kg change in calf birth weight was associated with a change in total milk yield of 19.2 ± 8.6 kg in Angus vs 8.6 ± 6.9 kg in Simmental (Marston et al., 1992). Some of the correlations reported between birth weight and milk production were 0.11 (Jeffery et al., 1971a; Minick et al., 2001), 0.18 (Jeffery et al., 1971a; Robison et al., 1978), 0.241 and -0.05 in Polled Hereford and Simmental, respectively (Mallinckrodt et al., 1993).

The breed of calf can influence the dam's milk yield (Jeffery et al., 1971b; Reynolds et al., 1978; Mezzadra et al., 1989). A study by Mezzadra et al. (1989) found that Charolais calves stimulated their crossbred dams to produce more milk than Angus calves. Reynolds et al. (1978) reported that Angus cows produced 20 % ($P < 0.05$) more milk when their calves were crossbred. Reynolds et al. (1978) also reported that Brahman sired crossbred calves caused their dams to produce more milk than Angus sired crossbred calves ($P < 0.05$). Since crossbred calves grew faster than purebred calves (Reynolds et al., 1978), this may be due to larger, faster growing crossbred calves' ability to stimulate their dams to produce more milk. However, Isogai et al. (1994) found no significant effect of calf breed on milk production.

There are other factors that may influence cow milk production. It has been found that stage of lactation, or month of lactation was significant for milk production (Williams et al. 1979a; Butson and Berg, 1984b). Minick et al. (2001) reported that season and days in lactation were significant ($P < 0.05$). Spring-calving dams yielded more total milk than fall-calving dams ($P < 0.04$)(Minick et al., 2001). Averaged over six monthly measurements; 24-h milk yield was similar for spring and fall-calving cows (McCarter et al., 1991a). Butson and Berg (1984b) found no significant effect of calving interval on milk production.

Lactation Curve of Beef Cows

The lactation curve of beef cows have been varied among breeds and levels of milk produced. Higher milking cows tended to have more convex and lower milking cows tended to have more linear curve (Gaskins and Anderson, 1980). Gleddie and Berg (1968) found a significant linear decrease in milk production (average 0.02 kg per day) over the lactation, while Kress and Anderson (1974) reported a quadratic lactation curve.

Mondragon et al. (1983) found that milk production were similar throughout lactation in first parity but declined over stages of lactation in parities two and three.

Gifford (1949) reported that maximum milk yield normally occurred during the first six weeks of lactation and this was affected by the capacity of the young calves to consume milk. If milk is not removed from the udder the milk yield from high-milk cows seems to level off to 5.45 to 6.80 kg daily (Gifford, 1949).

While Brahman cross cows have been found to produce more milk than European breeds in the hotter summer months, they have produced less milk in early stages of lactation (Martin and Franke, 1982; Daley et al., 1987). Also more persistency among Brahman crosses has been observed (Daley et al., 1987). Klett et al. (1965) reported that beef cows were more adaptable to changing feed conditions according to the difference in shape of lactation curves between dairy and beef cows.

Several studies found that milk production increased rapidly until it reached a peak at approximately 50 to 65 days (Chenette and Frahm, 1981; Jenkins and Ferrell, 1984; Mallinckrodt et al., 1993). Minick et al. (2001) found that the time of peak lactation ranged from 57 to 82 days.

There has been much variation among breeds in the time of peak milk yield (Jenkins and Ferrell, 1992), and different crosses had peak lactation at different times (Jenkins and Ferrell, 1984; Butson and Berg, 1984a, 1984b). Minick et al. (2001) reported different curve shapes between breed milk level group and between seasons. Some studies reported that Herefords tend to peak relatively early compared to other breeds (Kress and Anderson, 1974; Jenkins and Ferrell, 1992). Mallinckrodt et al. (1993) reported that cows that yielded more milk had faster declines in milk production after peaking. Clutter and Nielsen (1987) found that higher producing cows peaked later than lower producing cows. But this was not the case in the study by Minick et al. (2001) that found that high-milk cows peaked earlier than the low-milk cows. McCarter et al. (1991a) reported that spring-calving cows had a more typical lactation curve, whereas the curve for fall-calving cows showed more variability in milk production during the entire lactation period.

It was found that milk yield steadily declines after the peak lactation (Kress and Anderson, 1974; Robison et al., 1978; Chenette and Frahm, 1981; Mondragon et al., 1983; Minick et al., 2001). By the time of weaning, cows produced very little to no milk (Kress and Anderson, 1974). Hardt et al. (1988) reported that much of the differences in milk yield between breeds had gone by weaning.

Robison et al. (1978) noted that milk production in first two months was important in order to meet the calf's need for maintenance and growth. By the fifth month milk yield did not supply enough energy to meet maintenance requirements.

Repeatability of Milk Yield of Beef Cows

The repeatability of milk yield of beef cows has been varied for different lactations. Marston et al. (1992) reported a total milk yield repeatability of 0.76 ($P < 0.0001$) for the cows that were machine-milked. The repeatability of the estimated milk production by machine milking (0.97) was higher ($P < 0.01$) than by weigh-suckle-weigh technique (0.35) in a study by Beal et al. (1990). Mallinckrodt et al. (1993) reported a 205-d milk yield repeatabilities of 0.67 for Polled Herefords and 0.53 for Simmental using the weigh-suckle-weigh procedure. These values were in agreement with studies in which records were not necessarily from consecutive lactations but had high degree of adjacency (Dickey et al., 1972; Dillard et al., 1978). Some other reported repeatabilities for Herefords were 0.48 ± 0.04 to 0.61 ± 0.05 (Neville, Jr., et al., 1974) and 0.58 (Dillard et al., 1978). A study by Mondragon et al. (1983) found the repeatabilities of 0.34, 0.39, and 0.42 by using simple regression approaches of second record on first, third record on first and third record on second, respectively.

Milk production estimates within the same lactation were highly repeatable (Williams et al., 1979b). Some repeatabilities of total milk production that have been reported for measurements during the same lactation were 0.38 (Rutledge et al., 1972) and 0.32 ± 0.06 (Kress and Anderson, 1974).

Techniques Used for Estimating Milk Yield in Beef Cows

There are several different techniques for measuring and estimating the total milk yield in beef cows. These techniques include weigh-suckle-weigh (WSW)(Totusek and Arnett, 1965; Wistrand and Riggs, 1966; Rutledge et al., 1971, 1972; Totusek et al., 1973; Dillard et al., 1978; Robison et al., 1978; Belcher et al., 1980; Mondragon et al., 1983; Jenkins and Ferrell, 1984; Beal et al, 1990; McCarter et al., 1991a; Jenkins and Ferrell, 1992; Mallinckrodt et al., 1993; Marshall and Long, 1993; Minick et al., 2001), machine milking with oxytocin injection (Wistrand and Riggs, 1966; Gleddie and Berg, 1968; Mondragon et al., 1983; Belcher et al., 1980; Chenette and Frahm, 1981; Beal et al, 1990; Diaz et al., 1992; Marston et al., 1992), hand-milking (Totusek et al., 1973), and udder cannulation (Lamond et al., 1969; Butson et al., 1980; Butson and Berg, 1984a). Of these techniques most widely used are WSW and machine milking. Wistrand and Riggs (1966) determined that there was no difference in milk yield between WSW and machine milking techniques. Mondragon et al. (1983) found that the estimates were larger with WSW. In contrast, Belcher et al. (1980) reported larger estimates with machine milking.

Differently from beef cows, Benson et al. (1999) compared the WSW and machine milking techniques for measuring ewe milk production. They found that both techniques were similar ($P = 0.42$) for determining the milk production estimates. They reported average 3-h milk production of 340 and 351 g for WSW and machine milking, respectively. They concluded that machine milking provides a reliable tool in evaluating the milk-producing ability of ewes that are rearing single or twin lambs. In addition they reported that machine milking provides more consistent estimate than traditional WSW methods.

Some of the correlations reported between average WSW milk yield and average machine milk yield were 0.58 (Gleddie and Berg, 1968), 0.47 ($P < 0.01$)(Belcher et al., 1980), 0.77 ($P < 0.01$)(Beal et al., 1990), and 0.56 (Rupert, 1999). Belcher et al. (1980) found that correlations between machine milkout and calf ADG or weaning weight were 0.29 ($P < 0.05$) and 0.20, respectively, while correlations between WSW and ADG or weaning weight were 0.16 and 0.09, respectively.

Beal et al. (1990) demonstrated that the mechanical milk collection technique had higher repeatability then WSW technique. They also reported that the time of separation had no effect on milk yield estimates. On the other hand Belcher et al. (1980) reported that more milk was produced during the first 6-h of separation than 9- and 12-h by using WSW and machine milking procedures. A study by Williams et al. (1979a) compared the separation intervals of 4-, 8-, and 16-h to determine their effect on estimates of milk yield in Hereford cows by using WSW technique. Correlations were 0.25, 0.46, and 0.45

between calf ADG and 4-, 8-, and 16-h production estimates, respectively. They indicated that when production was estimated to 24-h basis measurement errors were ± 1.4, ± 0.7, and ± 0.3, respectively. They suggested an 8-h separation time because 16-h was not natural and resulted in a distended condition of the udder, and 4-h had greater measurement error and lower correlation with ADG.

It was reported by Beal et al. (1990) that the mechanical milking technique was a more accurate indicator of milk yield when only one estimate was made, but WSW technique was similar to that of the mechanical milking technique when four WSW were made for estimating the milk production. Totusek et al. (1973) indicated that a limited number (2 to 4) of correctly timed, carefully obtained daily estimates of milk yield throughout the lactation provide a good indication of total milk yield of beef cows.

The variable response of cows to oxytocin was a concern with machine milking (Schwulst et al., 1966). Lamond et al. (1969) concluded that oxytocin did not affect milk secretion rate because such an effect would be expected to be dose-dependent. A concern in WSW technique is that the calf may not consume all of the milk produced by the cow.

Belcher et al. (1980) stated that the machine milking allows for milk composition traits such as butterfat, protein, and total solid content to be estimated. However, it is more time consuming than WSW. Machine milking has less stress on the calf, but more stress on the cow than calf nursing.

Totusek et al. (1973) looked at the differences between WSW and hand-milking. Weigh-suckle-weigh (WSW) estimates of milk production were higher and less variable than hand-milking estimates at every stage of lactation. Also different lactation curves were observed by two techniques. They reported that average daily milk production estimated by WSW was 29 % higher than the production estimated by hand-milking, 5.85 vs. 4.54 kg, respectively, for 210-d. Their results suggested that WSW technique is a more precise estimator of actual milk yield (milk intake by the calf) than is hand-milking. They concluded that this was probably a result of a greater release of oxytocin caused by the calf-nursing stimulus. The correlations they found between hand-milking and WSW techniques were 0.92, 0.95, and 0.95 for 70, 112, and 210-d of lactation, respectively. These high correlations indicated that hand-milking is a satisfactory procedure for estimating relative differences in milk production even though the technique underestimates the amount of milk actually consumed by the calf (Totusek et al., 1973).

More accurate estimates of total milk production could be calculated by taking repeated measurements of milk production. Totusek et al (1973) stated that for selected day samples, correlations with 210-d milk production increased as the number of days sampled increased from 1 to 4 (0.48, 0.77, 0.85, and 0.91 for WSW and 0.61, 0.80, 0.92, and 0.96 for hand milking, respectively). Also Totusek and Arnett (1965) reported correlations of 0.80 and 0.87 between total milk production and two daily estimates and correlations of 0.94 and 0.93 between total production and five daily estimates for hand-milking and WSW procedures, respectively. Early estimates indicated calf capacity while later estimates indicated cow production and persistency.

Lamond et al. (1969) stated that the usual methods (WSW, machine milking and hand milking) for estimating milk production were not completely satisfactory. They stated that the calf suckles many times each day and storage capacity of the udder is unlikely to limit milk production in the field. Therefore, conventional methods of measuring milk production, which requires overnight separation of cows from calves, could underestimate the true secretion rate in cows with small mammary glands. They concluded that any method of emptying the udder that depends on full co-operation of the cow, is unlikely to be adequate, therefore, it is necessary to use oxytocin to empty the udder in order to eliminate variation due to residual milk.

Although each of these techniques has advantages and disadvantages over one another, much debate still remains as to which method best for estimating milk production in beef cows in terms of accuracy, precision, and repeatability. One should decide to use a technique according to his/her particular situation, practicality and availability of resources.

Reproductive Performance of Beef Cows

Reproductive performance of beef cows is the dominant determinant of economic efficiency in cow-calf enterprise. Profitability of a cow-calf operation depends on the percentage of cows in the herd that consistently calve every 12 months. Therefore, in order to obtain a maximum productivity, one calf per cow per year, cows must be pregnant again before 80 to 85-d postpartum (Peters, 1984). Heritabilities of reproductive traits are low and this makes the genetic improvement of reproduction difficult (Milagres et al., 1979; Meachem and Notter, 1987; Morris and Cullen, 1988; Meyer et al., 1990; Lopez de Torre and Brinks, 1990; MacGregor, 1995). However, use of more sires through artificial insemination has increased number of progeny from these sires (Meachem and Notter, 1987). More available information improves the accuracy of sire evaluations and allows sires to be ranked for lowly heritable traits, thus allowing a more complete assessment of overall genetic merit (Meachem and Notter, 1987).

Calving interval, calving date, calving percentage, conception rate, and age at first calving are some of the indicators of reproductive efficiency in beef cattle. Calving interval has been used to measure reproduction in later life, especially in dairy cattle (Bourdon and Brinks, 1983). However, in beef cattle operations, a relatively restricted breeding season (unlike dairy cattle) is usually employed, so calving interval is a biased measure of evaluating reproductive performance due to the large negative effect of previous calving date on calving interval (Bourdon and Brink, 1983; MacGregor and Casey, 1999). Calving interval has lower heritability than calving date. Some of the reported heritabilities of calving interval and calving dates were 0.04 ± 0.05 and 0.17 ± 0.04 (Meachem and Notter, 1987), 0.01 and 0.08 (Koots et al., 1994a), 0.02 and 0.16 (Lopez de Torre and Brinks, 1990), and 0.016 ± 0.134 and 0.442 ± 0.008 (van der Westhuizen et al., 2000), respectively. Genetic correlations between calving interval and calving date range from positive (0.025 ± 0.134)(van der Westhuizen et al., 2000) to negative (- 0.83)(Koots et al., 1994b).

Werth et al (1996) studied calving intervals in crossbred Hereford, Angus, and Shorthorn cows at 2-, 3-, and 4-yr of age when breeding is not restricted after calving. They emphasized that if the mating period was begun too soon after parturition, younger cows might have less than 365-d calving interval.

Bourdon and Brinks (1983) pointed out that cows with shorter gestations have an advantage over cows with longer gestations in terms of reproductive efficiency. They reported that a 1-d increase in gestation length caused a 1.17 ± 0.08-d delay in calving date and increase in calving interval. In addition, MacGregor and Casey (2000) reported that 1-d increase in calving interval resulted in a decrease of 0.029 ± 0.01 kg for weaning weight and a decrease of 0.54 ± 0.01 kg for heifer pre-breeding weight.

Cows with earlier calving would have longer intervals between calving and the initiation of the subsequent breeding season (Azzam and Nielson, 1987). It has been shown that conception rates can be higher in cows with longer intervals from calving to mating (Nelson and Beavers, 1982). Similarly, calving date affected pregnancy rate because earlier-calving cows had a greater chance to return estrous and conceive during the breeding season than did cows that calved later in the season (Selk et al., 1988). However, Osoro and Wright (1992) found in their study that calving interval in cows that ultimately became pregnant was significantly shorter in cows calving later. They reported the regression coefficient of calving date on calving interval being - 0.75 d/d (SE = 0.06). Early calving dams would produce calves with the lowest birth weight, and allow calves to be older, and thus heavier at weaning due to higher pre-weaning ADG (Azzam and Nielsen, 1987; MacGregor and Casey, 2000). It was also reported that early calving cows were able to utilize the season-dependent range pastures to their advantage thus providing adequate milk supply to their calves (Rege and Famula, 1993). Paloma et al. (1992) concluded that the first calving date was a good predictive index of lifetime productivity.

Bourdon and Brinks (1983), Buddenberg et al. (1990), Lopez de Torre and Brinks (1990), Marshall et al (1990), and MacGregor (1995) suggested that calving date is the preferred reproduction measurement over calving interval in restricted breeding season due to greater heritability, lower birth weights, reduced incidence of dystocia, higher weaning and yearling weights and higher reconception rates.

Several researchers have studied breed effects of both beef and dairy cattle for calving interval. Hanzen et al. (1994) studied Belgian beef and dairy breeds to compare reproductive rate in overall efficiency of production. They reported that calving interval was significantly different ($P < 0.001$) among breed groups. The mean calving interval was highest in suckling beef, intermediated in milked beef, and lowest in dairy breeds (435, 401, and 395-d, respectively). It has been shown that high milk producing cows would have longer postpartum anestrous periods relative to low milk producing cows when nutrients are limited (Hansen et al., 1982). However, ample nutrient availability would shorten interval to first estrous in cows with genotypes for high milk production (Hansen et al., 1982).

McElhenney et al. (1986) studied reproduction of mature cows (5- to 10-yr-old) of Angus, Brahman, Hereford, Holstein, Jersey, and their crosses sired by Charolais and Red bulls, representing large and medium mature size, respectively. They reported that differences among breeds of dams were important for calving interval. Straightbred dairy breeds (Holstein and Jersey) showed longer calving intervals then straightbred beef breeds (Angus and Hereford). However, there were no significant differences among crossbred cows for calving interval. Crossbred cows showed intervals that were 16-d shorter ($P < 0.05$) than straightbred cows. Newman and Deland (1991) stated that calving interval was smallest with Friesian and greatest with Shorthorn cross cows among seven different breeds. Blue-Grey cows had calving interval (364-d) shorter than did Hereford x Friesian cows (374-d)(Osoro and Wright, 1992).

Age at first calving is related to both gestation length and age at puberty, with the latter having the most effect (Fiss and Wilton, 1989). Age at puberty is an important production criterion in cattle because many management systems that are currently used require that heifers be bred at 14 to 16 months old to calve at 2-yr-old during a restricted breeding system (NRC, 1996). Heifers reaching puberty early and having a number of estrous cycles prior to the breeding season would have a greater conception rate and conceive earlier in the breeding season than heifers reaching puberty later (NRC, 1996). Patterson et al. (1992) reported that heifers that were heavier at weaning reached puberty at younger ages, however, these same heifers showed larger intervals to estrous after parturition than those that were lighter at weaning.

It has been shown that there are breed differences for age at puberty in cattle. It was reported that straightbred heifers reached puberty at an older age than crossbreds, considering only heifers that reached puberty less than 15 months of age (Laster et al., 1972; Steffan et al., 1985). Wiltbank et al. (1966) reported that straightbred Hereford heifers reached puberty at a later age than straightbred Angus. Laster et al. (1972) studied the age and weight at puberty and conception in beef heifers that were produced by breeding Hereford, Angus, Charalois, Jersey, South Devon, Simmental, and Limousin bulls to Hereford and Angus cows. They reported a significant ($P < 0.005$) effect of breed of sire and breed of dam on the percentage of heifers reaching puberty by 15 months of age. They found that a higher ($P < 0.005$) percentage of heifers from Angus dams reached puberty by 15 months old age than those from Hereford dam (95.2 % ± 3.0 and 70.9 % ± 2.6, respectively). They also reported that fewer (42.4 % ± 6.1; $P < 0.001$) Limousin-sired heifers reached puberty by 15 months of age and the Jersey-sired heifers reached puberty at a significantly (96.5 % ± 6.5; $P < 0.01$) younger age than the other breed crosses.

Fiss and Wilton (1989) found that the Simmental heifers had the highest age (749.5-d; $P < 0.05$) at first calving compared to 733.5-d in Hereford, 730.0-d in large rotational beef, 731.7-d in small rotational dual purpose, and 727.3-d in small rotational beef breeding systems. The Hereford, large rotational beef, small rotational dual purpose, and small rotational beef breeding systems were statistically similar for age at first calving. Freetly and Cundiff (1998) reported that heifer's age at parturition differed with sire breed. The ages at parturition were 703 ± 2^{ab}-d, 706 ± 2^{a}-d, 699 ± 2^{b}-d, 699 ± 3^{b}-d, 705 ± 2^{a}-d, 699 ± 2^{b}-d, and 701 ± 2^{ab}-d for the heifers sired by Hereford, Angus, Belgian Blue, Piedmontese, Brahman, Boran, and Tuli, respectively. Hanzen et al. (1994) found no difference between beef and dairy herds in terms of age at first calving. They reported the lowest and highest average herd values, respectively, as 30 to 34 months for suckler beef herds, 27 to 36 months for beef herds and 27 to 35 months for dairy herds. van der Westhuizen (2000) and Martinez-Velazquez (2002) reported the heritabilities of 0.464 ± 0.0012 and 0.11 for age at first calving, respectively. Genetics correlations between age at first calving and calving interval and between age at first calving and calving date were 0.468 ± 0.089 and 0.600 ± 0.019, respectively (van der Westhuizen et al., 2000).

Conception rate is one of the key factors affecting the productivity of a cow. Wiltbank et al. (1962) stated that maximum conception rates could be obtained only if a high percentage of the females show estrous cycles during the breeding season. Low energy intake prior to calving causes a delay on the onset of estrous following calving and reduces the proportion of females cycling during the breeding season (Wiltbank et al., 1962; Dunn et al., 1969). Another study by Wiltbank et al. (1964) showed the influence of postpartum energy level (described as 12.5 lb. of TDN for group I; 16.5 lb.

of TDN for group II; 25.0 lb. of TDN for group III; 8.5 lb. of TDN for 28-d, then 16.5 lb. of TDN thereafter for group IV; 8.5 lb. of TDN for 28-d, then 25.0 lb. of TDN thereafter for group V) on reproductive performance of Hereford cows restricted in energy level intake (4.7 lb. of TDN daily for approximately 140-d) prior to calving. Conception rate at first service was 54, 31, 83, 46, and 87 %, and percent of cows diagnosed pregnant was 71, 78, 92, 69, and 100 for groups I through V, respectively.

Gregory et al. (1992) studied breed effects of nine parental breeds and found large differences ($P < 0.01$) among parental breeds for percentage pregnant, with Limousin lowest (74.8 %) and Red Poll highest (86.6 %). The Limousin and Hereford did not differ ($P > 0.05$) from each other, and neither did the Red Poll, Braunvieh, Angus, Simmental, Charolais, Gelbvieh, and Pinzgauer. Newman et al. (1993) observed that pregnancy and calving rate tended to be grater from matings of Red Angus cows to Charolais sires than from matings of Red Angus cows to Tarentaise sires. They also stated that pregnancy rate, calving difficulty, and gestation lengths were affected significantly by age of dam. Older cows tended to exhibit higher pregnancy rates and longer gestation lengths than did younger cows ($P < 0.01$)(Newman et al., 1993). Olson et al. (1985) also reported that pregnancy rate were affected significantly by year, age and breed of dam and averaged 79, 95, and 92 % for Brown Swiss, Angus x Brown Swiss, and Angus cows, respectively.

Montano-Bermudez and Nielsen (1990) reported that pregnancy rate was highest for the low level milk group (Hereford x Angus)(94.8 %) and lowest for the high level milk group (Milking Shorthorn x Angus)(91.6 %).

Olson et al. (1990) compared pregnancy rate, calf survival rate to weaning and calf age at weaning of several types of crossbred cows (2/3 or more Brahman) to those of straightbred Brahman and Angus cows. They reported that the superior reproductive rates observed in Brahman crossbred cows were due to nonadditive effects on pregnancy rate. Results by McCarter et al. (1991b) also indicated that Brahman-cross dams could be used effectively in a commercial crossbreeding system to increase reproductive rate, compared with *Bos taurus*-cross dams. Fiss and Wilton (1989) found no differences ($P > 0.05$) among five breeding systems (purebred Hereford, purebred Simmental, large rotational beef, small rotational dual purpose, and small rotational beef) for percentage of heifers pregnant by 18 months, heifer gestation length, cow pregnancy rate, cow services per pregnancy, cow days to pregnancy, and cow gestation length.

Newman and Deland (1991) found that calving percentage was not affected by breed. However, parity ($P < 0.01$) and interaction between breed and parity ($P < 0.05$) were important sources of variation in calving percentage. The mean calving percentages were 72 in parities 1-3 and 88 in parities 4-9 for Zebu cross cows (Brahman and Sahiwal), 82 in both intervals (parities 1-3 and parities 4-9) for European cross cows (Charolais and Simmental), 85 in both intervals (parities 1-3 and parities 4-9) for dairy cross cows (Friesian and Jersey), and 79 in parities 1-3 and 68 in parities 4-9 for Shorthorn cross cows.

Freetly and Cundiff (1998) found no differences in calving percentages of heifers sired by Hereford (89 ± 4), Angus (84 ± 4), Belgian Blue (84 ± 4), Piedmontese (92 ± 5), Brahman (80 ± 3), Boran (92 ± 4), and Tuli (89 ± 4) bulls. These results suggest that a high proportion of Tuli- and Boran-sired heifers conceived on their first estrous since they had calving percentages similar to those of Continental and British breeds and were among the younger heifers at calving (Freetly and Cundiff, 1998). Comerford et al.

(1987) found that calving percentage was highest in Limousin among four different beef breeds (Limousin, Brahman, Simmental, and Polled Hereford) because Limousin produced heavy calves with higher survival ratios.

Effect of Body Condition on Reproductive Performance of Beef Cows

The amount of body fat in beef cows at specific stages of their production cycles is an important factor determining their reproductive performance and overall productivity (Herd and Sprott, 1998). As mentioned before, productivity of a cow-calf operation depends on the percentage of cows in the herd that consistently calve every 12 months. A cost of production per pound of calf increases in the herd if cows fail to calve or take longer calving interval (Herd and Sprott, 1998). Some of the reasons for cows failing to calve on a 12-month schedule are disease, harsh weather, and low fertility in herd sires, but more importantly most reproductive failures in the beef female can be attributed to improper nutrition and thin body condition (Herd and Sprott, 1998).

Overconditoning of cows is expensive and causes calving problems and lower dry matter intake during early lactation. In contrast, thin cows may not have adequate reserves for optimum milk production and will not likely rebreed on schedule (NRC, 1996).

Research has well reported that dietary energy levels in both the prepartum and postpartum periods affect subsequent reproductive performance in cattle (Wiltbank et al., 1962, 1964; Dunn et al., 1969; Wiltbank, 1970; Holness and Hopley, 1978; Dziuk and Bellows, 1983). Many researchers (Richards et al., 1986; Selk et al., 1988; Spitzer et al., 1995; Minick et al., 2001) have used a 9-point body condition scoring system which ranges from 1 = severally emaciated and physically weak to 5 = good overall appearance or moderate to 9 = very obese and extremely wasty.

Richards et al. (1986) reported that cows with body condition scores of ≥ 5 at calving returned to estrous 12-d earlier than those with body condition scores of ≤ 4 at calving ($P < 0.01$)(49 v. 61-d). Boggs et al (1980) indicated that when level of nutrition is not adequate, the cow would attempt to maintain her potential for milk production at the expense of body reserves, thus inhibiting rebreeding performance. Minick et al. (2001) reported that high-milk cows had lower body condition score than low-milk cows at month 1, 2, 3, 5, 6, and 7 ($P < 0.05$) because high-milk cows partitioned available body stores to milk rather than fat.

A regression analysis showed that a cubic response best described ($P < 0.07$) the relationship between precalving body condition score and pregnancy rate. This suggests that if cows have body condition score between 4 and 6, the effect of one unit of body condition score on pregnancy rate is greater than cows that are thinner or fatter (Selk et al., 1988).

Spitzer et al. (1995) found that, unlike in mature cows, a greater percentage of primiparous cows calving with body condition scores of 6 became pregnant than did cows calving with body condition scores of 5. Bellows and Short (1978) also indicated that nutrient intake during the last 90-d of gestation affects pregnancy rate of first-calf cows.

Generally, body condition scores are given at breeding, calving, and weaning. Osoro and Wright (1992) reported that body condition at calving had a greater effect on reproductive performance than body condition at other times. Selk et al. (1988) reported that body condition scores precalving and at the start of breeding season, along with body weight changes between 2 and 4 months before parturition, were major factors that affect pregnancy rate of range beef cows. However, some reports found that alteration in body condition after calving (Warnick et al., 1981; Rutter and Randel, 1984; Hancock et al., 1981) is more important.

CHAPTER III

MATERIALS AND METHODS

Source of Data

All cows and calves in this study were from the beef research range at North Lake Carl Blackwell, located west of Stillwater, Oklahoma. An existing herd of crossbred cows (½ Hereford - ½ Angus; ¼ Brahman - ¼ Angus - ½ Hereford; and ¼ Brahman - ¼ Hereford - ½ Angus) was mated to Angus or Hereford (polled) sires (n = 38) that were either very high or very low for milk EPD at the time of selection. Nine low milk Polled Hereford bulls, 9 high milk Polled Hereford bulls, 10 low milk Angus bulls, and 10 high milk Angus bulls were used. Average EPD for these bulls are shown in Table 1. Milk EPD averages for the four groups differed 14.92 and 12.38 kg for Angus and Hereford sire groups, respectively. Each bull had an accuracy greater than 0.50 at the time of selection. Heifers (n = 232) from these matings were born from 1989 through 1993. In this study, daughters of high-milk EPD bulls will be referred to as high-milk EPD cows, and daughters of low-milk EPD bulls will be referred to as low-milk EPD cows. These heifers were mated to Angus, Gelbvieh, Polled Hereford, Salers, Limousin, Charolais, Maine-Anjou, or crossbred bulls (not more than three each breeding season) to calve starting in 1991. Heifers and cows were artificially inseminated for a period of approximately 55 days and then turned out with crossbred bulls for 20 days clean up period. If females were not able to conceive during a mating period of 75 days, they were moved to the opposite breeding season. However, if cows failed to conceive in two consecutive breeding seasons they were culled from the herd. Cows calved in spring or fall from 1995 to 2000 and yielded a total of 701 records. Spring calving was from February through April, and fall calving was from September through November. The same sires were used for spring and fall calving seasons within a single year.

Table 1. Average Expected Progeny Difference (kg) for high and low Milk EPD Angus and Hereford bulls

Breed	Milk Level	n	BW EPD	WW EPD	Milk EPD
Angus	High	10	1.13	9.66	8.71
Angus	Low	10	2.31	12.15	-6.21
Hereford	High	9	1.18	10.11	7.62
Hereford	Low	9	2.54	11.93	-4.76

Measurements

At the time of calving all calves were weighed within 24 hours of birth and male calves were castrated. The cows were given a condition score, and a difficulty score was assigned to the calving. Cows and calves were placed on pasture and the calves did not receive creep feed. Milk production was evaluated at seven monthly intervals (approximately at an average of days 37, 65, 93, 121, 149, 177, and 205 after calving) throughout the lactation by the weigh-suckle-weigh method (McCarter et al., 1991a; Minick et al., 2001). Cows and calves were gathered from pastures and separated on the afternoon of the previous day. At 5:45 a.m. the day of measurement, calves were allowed to suckle the cows. This ensured that all cows were milked out at the beginning of the separation period and the cows were weighed and scored for body condition. The body condition scores ranged from 1 = very thin to 9 = very fat (Table 2) (Richards et al., 1986). Two observers assigned the body condition scores and the scores were averaged. After weighing and scoring, the cows were returned to pens and kept separate from their calves. At 11:45 a.m., calves were weighed, allowed to suckle, and reweighed. This procedure was repeated at 5:45 p.m. These measurements of 6-h yield were summed and doubled to estimate 24-h milk production for each cow. Calves were weaned an average of 205 days of age in the spring and 240 days of age in the fall.

Table 2. System of body condition scoring (BCS) for beef cattle

BCS	Description
1	EMACIATED – Cow is extremely emaciated with no palpable fat detectable over spinous processes, transverse processes, hip bones or ribs. Tail-head and ribs project quite prominently
2	POOR – Cows still appears somewhat emaciated but tail-head and ribs are less prominent. Individual spinous processes are still rather to the touch but some tissue cover exists along the spine.
3	THIN – Ribs are still individually identifiable but not quite as sharp to the touch. There is obviously palpable fat along spine and over tail-head with some tissue cover over dorsal portion of ribs.
4	BORDERLINE – Individual ribs are no longer visually obvious. The spinous processes can be identified individually on palpation but feel rounded rather than sharp. Some fat cover over ribs, transverse processes and hip bones.
5	MODERATE – Cow has generally good overall appearance. Upon palpation, fat cover over ribs feels spongy and areas on either side of tail-head now have palpable fat cover.
6	HIGH MODERATE – Firm pressure now needs to be applied to feel spinous processes. A high degree of fat is palpable over ribs and around tail-head.
7	GOOD – Cow appears fleshy and obviously carries considerable fat. Very spongy fat cover over ribs and around tail-head. In fact, "rounds" or "pones" beginning to be obvious.
8	FAT – Cow is very fleshy and over-conditioned. Spinous processes almost impossible to palpate. Cow has large fat deposits over ribs, around tail-head and below vulva.
9	EXTREMELY FAT – Cow obviously extremely wasty and patch and looks blocky. Tail-head and hips buried in fatty tissue and "rounds" or "pones" of fat are protruding. Bone structure no longer visible and barely palpable. Animal's motility may even be impaired by large fatty deposits.

Adapted from Richards et al. (1986)

Calving interval, calving date, calving percentage, and calving rate were calculated. Calving interval was calculated as the number of days between subsequent calvings without regard to the season. Calving date was calculated as the number of days following the beginning of the calving season. Calving percentage was calculated as the proportion of cows that gave birth to a calf (alive or dead) during the same calving season one year following their previous calf. Calving rate was calculated as the proportion of cows that were bred and gave birth to a calf.

Management

Cows and calves that were used in this study were maintained on native grasses, including big bluestem (*Andropogon gerardi*), little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorgastrum nutans*), switchgrass (*Panicum virgatum*), and introduced grasses such as cheatgrass (*Bromus tectorum*) and bermudagrass (*Cynodon dactylon*) at the North Lake Carl Blackwell Range. During the winter, dry cows were supplemented with 41 % crude protein cubes three times a week. They were fed approximately 0.5 kg, 1kg, and 1.5 kg of cubes/head/day in October, November, and from December to calving, respectively. After calving cows were fed approximately 2.5 kg of cubes/head/day until mid-April. Cows nursing fall-born calves were also supplemented with 41 % crude protein cubes. They were fed approximately 0.5 kg, 1 kg, 2 kg, and 2.5 kg of cubes/head/day in October, November, December, and from January to mid-April, respectively. In addition, cows were given approximately 14 kg of grass hay every day when grass was not available.

Statistical Analysis

The data were analyzed using generalized least squares. Analyzed traits included seven monthly measurements of milk production, calf weights and cow weights, body condition scores of dams, calf birth weight, 205-d weight, calving interval, calving percentage, calving date, and calving rate. Terms included in the statistical models were cow sire breed, milk EPD level, year, season, sire of calf, sex of calf, sire of cow within breed and milk EPD level, and age of cow within year. Age of calf was included in the model as a covariate. Sire of cow within breed and milk EPD level and sire of calf were considered to be random and all other effects in the model were considered fixed. All interactions among cow sire breed, milk EPD level, year, season, sex of calf, age of cow within year were included in the initial model. Those interactions that were clearly non-significant ($P > 0.2$) were eliminated from the model. The models for the monthly cow weights and BCS did not include sire of calf, sex of calf, or age of calf. The model for calf birth weight, 205-d weight, calving date, calving interval, and calving percentage did not include age of calf. The model for calving rate did not include age of calf and sex of calf.

Lactation curves were estimated by the method of Jenkins and Ferrell (1982, 1984). Amount of milk produced was divided by days in lactation, and the natural log of that value was regressed on day of lactation to estimate parameters of the curve. The curve defined by those parameters was integrated from day 37 to day 205 to estimate the amount of milk produced between those days. This measure of milk production from month 1 to month 7 will be referred to as total milk yield. The Jenkins and Ferrell (1982, 1984) curve was also used to find the time and yield at peak lactation for each cow.

CHAPTER IV

RESULTS AND DISCUSSION

Milk Production

Monthly milk production: Least squares means and standard errors for the seven monthly milk production estimates by breed and milk level (High, Low), least squares means and standard errors for the seven monthly milk production estimates main effects, and significance levels of model terms for the seven monthly milk productions are given in Table 3, 4 and 5, respectively.

Breed exhibited a significant effect in month 1 ($P < 0.03$) and month 3 ($P < 0.04$) at which time Angus-sired cows had higher estimates of daily milk production than Hereford-sired cows. Milk production estimates of Angus sired cows were higher at every measurement throughout lactation. This agreed with the results of Melton et al. (1967), Jenkins and Ferrell (1992) and Minick et al. (2001). They found that Angus cows produced more milk than Herefords.

High-milk cows produced more milk than low-milk cows in month 1 through 6 ($P < 0.03$). This was consistent with differences in the sire's milk EPD and agreed with the results of Marston et al. (1992), Marshall and Long (1993), and Minick et al. (2001) but disagreed with Marshall and Freking (1988) whose results showed that milk production of daughters of high- and low- milk EPD sires was not significantly different.

Breed x milk EPD level interaction was not significant throughout the lactation ($P > 0.4$). High-milk Angus cows produced more milk than low-milk Angus in month 2, 3, 5, and 6 ($P < 0.04$) whereas high-milk Hereford produced more milk than low-milk Hereford in month 1, 2, 3, and 4 ($P < 0.05$). Figure 1 shows the lactation curves from the least squares means for the seven monthly milk productions for the high- and low-milk Angus and Hereford cows.

Season had a significant effect in month 1, 3, 4, 6, and 7. Spring-calving cows had higher estimated milk production in month 1 ($P < 0.0001$), month 3, 4, and 6 ($P < 0.02$). Fall-calving cows produced more milk in month 7 ($P < 0.0001$). These differences can be attributed to the quality of forage available to cows at these times.

Steer calves received more milk than heifer calves in month 1 through 6 but significant differences were observed only in month 2, 3, 4, and 6 ($P < 0.03$). Previous reports have confirmed with these findings indicating that male calves receive more milk (Pope et al., 1963; Jeffrey et al., 1971a (in year 1966); Daley et al., 1987; Minick et al., 2001). Even though the difference was not significant ($P > 0.1$) heifers received more milk in month 7. Jeffrey et al. (1971a)(in year 1967) and Rutledge et al. (1971) reported that female calves receive more milk. Christian et al. (1965), Melton et al. (1967), Gleddie and Berg (1968), Reynolds et al. (1978), and MacNeil and Mott (2000) found no significant relationship between milk production of dam and sex of calf.

Year affected milk production in all months ($P < 0.02$). Age of calf was significant ($P \leq 0.003$) for all months except month 7 ($P > 0.1$). Cow age within year was not significant in any month ($P > 0.05$) and this agreed with the results of Minick et al. (2001) but disagreed with Gifford (1953), Christian et al. (1965), Todd et al. (1969), Jefferry et al. (1971a), Robison et al. (1978), Williams et al (1979a). However, results from Minick et al. (2001) were from 3-, 4-, and 5-year old cows and results from this study are from 6-, 7-, and 8-year-old cows only. Therefore, this limitation in age range may not have allowed differences in milk production to be expressed due to age.

Significant interactions for monthly milk productions were breed x calf sex in month 2 ($P < 0.01$), milk EPD level x year in month 3 and 4 ($P < 0.02$), milk EPD level x season in month 3 and 6 ($P < 0.05$), year x season in month 1, 3, 4, 5, 6, and 7 ($P < 0.003$), year x calf sex in month 1, 2, 3, 4, 6, and 7 ($P < 0.04$), season x calf sex in month 4 and 6 ($P < 0.05$), calf sex x cow age (year) in month 2 and 3 ($P < 0.03$), breed x milk EPD level x year in month 1 ($P < 0.002$), breed x milk EPD level x calf sex in month 2 ($P < 0.02$), breed x season x calf sex in month 2 ($P < 0.02$), breed x season x cow age (year) in month 5 ($P < 0.02$), milk EPD level x season x cow age (year) in month 1 ($P < 0.03$), year x season x calf sex in month 4 and 5 ($P < 0.0001$), and season x calf sex cow age (year) in month 3, 6, and 7 ($P < 0.05$).

Table 3. Least squares means and standard errors by breed and milk level (High, Low) for the seven monthly measurements of 24-h milk production (kg)

Cow Group	1[a]	2	3	4	5	6	7
High Angus	7.18 ± 0.33	6.09 ± 0.30	5.80 ± 0.28	5.09 ± 0.25	4.45 ± 0.29	3.53 ± 0.23	3.08 ± 0.32
Low Angus	6.58 ± 0.31	4.84 ± 0.29	4.55 ± 0.26	4.51 ± 0.24	3.36 ± 0.28	2.84 ± 0.22	2.59 ± 0.31
High Hereford	6.65 ± 0.37	5.89 ± 0.36	5.05 ± 0.32	5.12 ± 0.30	3.66 ± 0.34	3.28 ± 0.28	2.38 ± 0.39
Low Hereford	5.78 ± 0.32	4.92 ± 0.30	4.15 ± 0.27	4.17 ± 0.25	2.97 ± 0.30	2.75 ± 0.23	2.11 ± 0.33
P-values							
Breed	0.0231	0.7977	0.0346	0.5288	0.0657	0.4441	0.0808
Level[b]	0.0098	0.0006	0.0003	0.0070	0.0043	0.0211	0.2591
Breed x level	0.6403	0.6437	0.4755	0.4560	0.4904	0.7204	0.7560
Level (Angus)	0.1199	0.0026	0.0007	0.1032	0.0076	0.0356	0.2770
Level (Hereford)	0.0494	0.0339	0.0225	0.0197	0.1225	0.1477	0.5809

[a] 28-d intervals beginning approximately 1 mo after average calving date.

[b] Milk EPD level.

Table 4. Least squares means and standard errors for the seven monthly measurements of 24-h milk production (kg)

Effect		1[1]	2	3	4	5	6	7
Breed	Angus	6.88 ± 0.25[a]	5.47 ± 0.22	5.18 ± 0.21[a]	4.80 ± 0.17	3.91 ± 0.21	3.18 ± 0.16	2.83 ± 0.23
	Hereford	6.21 ± 0.27[b]	5.41 ± 0.25	4.60 ± 0.23[b]	4.65 ± 0.20	3.32 ± 0.23	3.01 ± 0.18	2.24 ± 0.26
Milk EPD Level	High	6.92 ± 0.28[a]	5.99 ± 0.24[a]	5.43 ± 0.23[a]	5.11 ± 0.21[a]	4.06 ± 0.22[a]	3.40 ± 0.19[a]	2.73 ± 0.26
	Low	6.18 ± 0.25[b]	4.88 ± 0.21[b]	4.35 ± 0.21[b]	4.34 ± 0.18[b]	3.17 ± 0.21[b]	2.79 ± 0.17[b]	2.35 ± 0.23
Season[c]	Fall	5.88 ± 0.24[a]	4.47 ± 0.39[c]	4.64 ± 0.20[a]	4.47 ± 0.16[a]	3.58 ± 0.18	2.83 ± 0.15[a]	3.10 ± 0.21[a]
	Spring	7.22 ± 0.27[b]	6.24 ± 0.52[c]	5.14 ± 0.22[b]	4.98 ± 0.19[b]	3.65 ± 0.21	3.37 ± 0.18[b]	1.97 ± 0.24[b]
Sex of calf	Heifers	6.31 ± 0.25	5.13 ± 0.22[a]	4.44 ± 0.21[a]	4.41 ± 0.18[a]	3.56 ± 0.19	2.79 ± 0.17[a]	2.74 ± 0.23
	Steers	6.79 ± 0.25	5.74 ± 0.22[b]	5.33 ± 0.21[b]	5.04 ± 0.18[b]	3.66 ± 0.19	3.40 ± 0.17[b]	2.34 ± 0.23

[1] 28-d intervals beginning approximately 1 mo after average calving date.

[a,b] Means within a column and model term with different superscripts differ ($P < 0.04$).

[c] A variable "YRS = Year x 10 + season" was used in the second milk production model because the second milk production in year 2000 fall was not taken due to cold weather. YRS was considered as year.

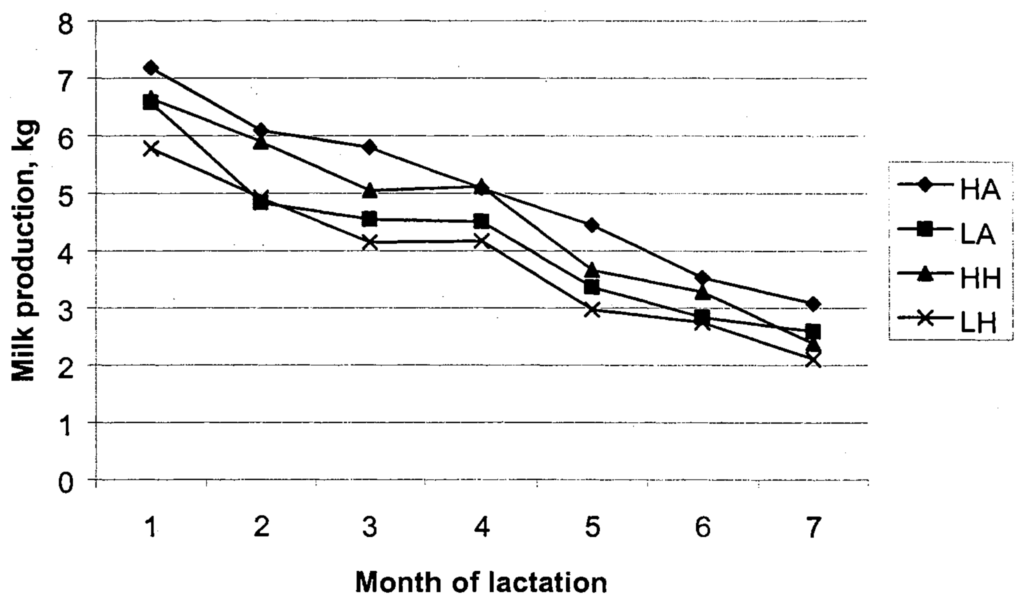
Table 5. Significance levels of model terms for 24-h milk production in the seven months of lactation

Models terms	1	2	3	4	5	6	7
Breed	0.0231	0.7977	0.0346	0.5288	0.0657	0.4441	0.0808
Level[b]	0.0098	0.0006	0.0003	0.0070	0.0043	0.0211	0.2591
Breed x level	0.6403	0.6437	0.4755	0.4560	0.4904	0.7204	0.7560
Year[c]	0.0057	< 0.0001[c]	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0107
Season[c]	< 0.0001	-	0.0164	0.0180	0.8903	0.0119	< 0.0001
Calf Sex	0.0562	0.0217	0.0002	0.0062	0.5127	0.0081	0.1825
Cow age (year)	0.6179	0.0547[c]	0.7309	0.5940	0.9503	0.1524	0.8715
Calf Age	< 0.0001	< 0.0001	0.0006	< 0.0001	0.0030	0.0001	0.1641
Breed x year	0.2266		0.6045		0.9491		0.0827
Breed x season		0.5307[c]	0.6205		0.9208		
Breed x calf sex	0.1362	0.0012	0.3595		0.7487		
Breed x cow age (year)		0.1639[c]			0.7569		
Level x year	0.5019		0.0163	0.0111		0.1773	0.7580
Level x season	0.5072		0.0499	0.0581	0.1134	0.0349	
Level x calf sex	0.4029	0.5460	0.0759	0.3416	0.0573	0.6965	0.1198
Level x cow age (year)	0.6033			0.2000			
Year x season	< 0.0001		< 0.0001	0.0022	0.0001	< 0.0001	< 0.0001
Year x calf sex	0.0301	0.0018[c]	0.0002	0.0006	0.5353	0.0003	0.0089
Season x calf sex	0.2948		0.0741	0.0426	0.7205	0.0271	0.7932
Season x cow age (year)	0.5730		0.9335	0.0591	0.6285	0.3694	0.1029
Calf sex x cow age (year)	0.2894	0.0061[c]	0.0242	0.7593	0.1769	0.7873	0.3947
Breed x level x year	0.0016						0.0840
Breed x level x calf sex		0.0115	0.0633				
Breed x year x season			0.1336		0.4152		
Breed x year x calf sex					0.0982		
Breed x season x calf sex		0.0131[c]					
Breed x season x cow age (year)					0.0189		
Level x year x season	0.1800			0.8638		0.0939	
Level x year x calf sex							
Level x season x calf sex	0.0881					0.1279	
Level x season x cow age (year)	0.0273						
Level x calf sex x cow age (year)				0.0701			
Year x season x calf sex	0.7117		0.0955	< 0.0001	< 0.0001	0.2549	0.7135
Season x calf sex x cow age (year)	0.0859		0.0497			0.0039	0.0414

[b] Milk EPD level.

[c] A variable "YRS = Year x 10 + season" was used in the second milk production model because the second milk production in year 2000 fall was not taken due to cold weather. In this table year = YRS and breed x season = breed x YRS.

Figure 1. Average milk production over the lactation for high (H) and low (L) milk Angus (A) and Hereford (H) cows



Total milk production, yield at peak lactation, and time of peak lactation: Least squares means and standard errors by breed and milk level (High, Low) for total milk production, yield at peak lactation and time of peak lactation estimates, least squares means and standard errors for total milk production, yield at peak lactation and time of peak lactation estimates main effects, and significance levels of model terms for total milk production, yield at peak lactation and time of peak lactation are given in Table 6, 7, and 8, respectively.

Breed showed a significant effect in total milk production ($P < 0.05$). Angus-sired cows produced more total milk than Hereford-sired cows. Melton et al. (1967), Jenkins and Ferrell (1992), and Minick et al. (2001) also reported that Angus cows produced more total milk than Hereford cows.

As expected, high-milk cows produced more total milk than low-milk cows ($P< 0.0001$). This supports the concept of using sire milk EPD to select for increased milk production. This agreed with the results of Minick et al. (2001) but disagreed with Marshall and Freking (1988).

Spring-calving cows produced more total milk than fall-calving cows ($P = 0.004$). Male calves received more total milk than female calves but the difference was not significant ($P > 0.08$). Christian et al. (1965), Melton et al. (1967), Gleddie and Berg (1968), Reynolds et al. (1978), and MacNeil and Mott (2000) also found no significant relationship between milk production of dam and sex of calf. Year ($P < 0.0001$) and age of calf (days in lactation)($P = 0.0007$) were significant for total milk production. Breed x milk EPD level interaction was not significant for total milk production ($P > 0.75$). High-

Angus cows produced more total milk than low-Angus cows (P = 0.0001) and high-Hereford cows produced more milk than low-Hereford cows (P < 0.003)

Significant interactions for total milk production were milk EPD level x year (P < 0.02), year x season (P < 0.002), year x calf sex (P < 0.02), and year x season x calf sex (P < 0.05).

The Jenkins and Ferrell (1982, 1984) lactation equation was able to predict milk yield at peak lactation and time of peak lactation. No breed differences were existed for yield at peak lactation (P > 0.05). At peak, high-milk cows produced more milk than low-milk cows (P < 0.0001), spring-calving cows produced more milk than fall-calving cows (P < 0.02) and steers received more milk than heifers (P < 0.01). These results were in agreement with the results of Minick et al. (2001). Year (P = 0.0006) and age of calf (days in lactation)(P < 0.0001) were significant for yield at peak lactation. Breed x milk EPD level was not significant (P > 0.3) for yield at peak lactation.

Significant interactions for yield at peak lactation were milk EPD level x year (P = 0.03), year x season (P < 0.003), and year x calf sex (P < 0.002).

No significant differences existed between breed, milk EPD level, season and sex of calf in the time of peak lactation (P > 0.06). Peak lactation in this study occurred later than the 50 to 65 days reported by Gifford (1949), Dawson et al. (1960), Chenette and Frahm (1981), Williams et al. (1979a), Jenkins and Ferrell (1984), Mallinckrodt et al. (1983), and Minick et al. (2001). Year and age of calf (days in lactation) were significant (P < 0.0001) for the time of peak lactation. There was no breed x milk EPD level interaction for the time of peak lactation (P > 0.09). Peak lactation occurred earlier in low-Angus cows than high-Angus cows ($P < 0.02$). Significant interaction for the time of peak lactation was milk EPD level x year ($P < 0.02$).

Table 6. Least squares means and standard errors by breed and milk level (High, Low) for total milk production (kg), yield at peak lactation (kg) and time of peak lactation (days)

Cow group	Total milk	Peak yield	Peak time
High Angus	783.58 ± 19.18	6.42 ± 0.15	92.20 ± 3.66
Low Angus	669.73 ± 18.60	5.36 ± 0.15	78.87 ± 3.48
High Hereford	735.31 ± 23.63	5.92 ± 0.20	88.23 ± 4.74
Low Hereford	634.22 ± 19.81	5.21 ± 0.16	88.05 ± 3.67
P-values			
Breed	0.0487	0.0555	0.5026
Level[b]	< 0.0001	< 0.0001	0.1000
Breed x level	0.7537	0.3153	0.0961
Level (Angus)	0.0001	< 0.0001	0.0124
Level (Hereford)	0.0022	0.0078	0.9769

[b] Milk EPD level.

Table 7. Least squares means and standard errors for total milk production (kg), yield at peak lactation (kg) and time of peak lactation (days)

Effect		Total Milk	Peak yield	Peak time
Breed	Angus	726.66 ± 13.38^a	5.89 ± 0.11	85.53 ± 2.53
	Hereford	684.77 ± 15.60^b	5.56 ± 0.13	88.14 ± 3.00
Milk EPD Level	High	759.45 ± 15.13^a	6.17 ± 0.12^a	90.22 ± 3.06
	Low	651.98 ± 13.78^b	5.28 ± 0.11^b	83.46 ± 2.57
Season	Fall	680.06 ± 12.54^a	5.54 ± 0.10^a	87.50 ± 2.52
	Spring	731.37 ± 14.58^b	5.92 ± 0.12^b	86.17 ± 3.05
Sex of calf	Heifers	690.52 ± 13.64	5.54 ± 0.11^a	83.32 ± 2.80
	Steers	720.91 ± 13.55	5.92 ± 0.11^b	90.35 ± 2.76

[a,b] Means within a column and model term with different superscripts differ ($P < 0.05$).

Table 8. Significance levels of model terms for total milk production, yield at peak lactation and day of peak lactation

Model terms	Total milk	Peak yield	Peak time
Breed	0.0487	0.0555	0.5026
Level[b]	< 0.0001	< 0.0001	0.1000
Breed x level	0.7537	0.3153	0.0961
Year[c]	< 0.0001[c]	0.0006[c]	< 0.0001[c]
Season	0.0040	0.0105	0.7357
Calf sex	0.0871	0.0092	0.0690
Calf age	0.0007	< 0.0001	< 0.0001
Breed x season	0.4076	0.1833	
Breed x calf sex	0.2154	0.3433	
Level x year	0.0132[c]	0.0300[c]	0.0155[c]
Level x season		0.4039	0.0883
Year x season	0.0015[c]	0.0026[c]	
Year x calf sex	0.0103[c]	0.0012[c]	
Season x calf sex	0.8762	0.7638	0.1753
Breed x level x season		0.1168	
Breed x season x calf sex	0.0771	0.0790	
Year x season x calf sex	0.0499[c]	0.0632[c]	

[b] Milk EPD level.

[c] A variable "DYR = Year x 10 + cow age" was used in total milk, peak yield, and peak time models because not all cow ages in each year were represented. In this table year = DYR.

Calf Weight

Least squares means and standard errors by breed and milk level (High, Low) for the seven monthly calf weight estimates, least squares means and standard errors for the seven monthly calf weight estimates main effects, and significance levels of model terms for the seven monthly calf weights are given in Table 9, 10 and 11, respectively.

Angus-sired cows had heavier calves than Hereford-sired cows throughout lactation but significant differences were observed only in month 2, 3, 4, and 5 ($P < 0.04$). Most studies reported that cow breed had an effect on calf gain (Jeffery et al., 1971b; Lawson, 1976; Nelson et al., 1985; Freetly and Cundiff, 1998; Minick et al., 2001).

High-milk cows had heavier calves than low milk cows in all months ($P < 0.03$). This was expected, and agreed with the findings of Butson and Berg (1984b), Clutter and Nielsen (1987), and Minick et al. (2001).

Breed x milk EPD level interaction was not significant in any month for the calf weights ($P > 0.5$). High-Angus cows had heavier calves than low-Angus cows in all months except the first ($P < 0.02$). Similarly, high-Hereford cows had heavier calves than low-Hereford cows in all months except the first ($P < 0.04$). Figure 2 shows the growth curves of calves from the four breed milk EPD level groups of cows.

Season had a significant effect in month 3, 4, 5, 6, and 7 ($P < 0.0001$). Spring born calves were heavier than fall born calves. This is probably because the grass was better in these months for spring calves (June through October). This agreed with the results of Marlowe and Gaines (1958), Brown (1960), and Minick et al. (2001).

Steer calves were heavier than heifers in all months ($P < 0.0001$). This was expected and agreed with the findings of Neville, Jr. (1962), Christian et al. (1965), Melton et al. (1967), Rutledge et al. (1971), Reynolds et al. (1978), and Minick et al. (2001).

Year was significant in all months except the first ($P < 0.0001$). Age of calf was significant in all months ($P < 0.0001$). Cow age within year was not significant in any months ($P > 0.1$). This disagreed with the findings of Minick et al. (2001) who found that age of dam was significant for calf weight in months 2 through 4. Neville, Jr. (1962) has found no relationship between cow age and calf gain. It is important to remember that this study used only 6-, 7-, and 8-year-old cows.

Significant interactions for calf weights were year x season in all months except the second ($P \leq 0.0003$), year x calf sex in month1, 3, and 5 ($P < 0.04$), season x calf sex in month 5 and 6 ($P < 0.04$), season x cow age (year) in month 3, 4, 5, 6, and 7 ($P < 0.04$), calf sex x cow age (year) in month 2 and 4 ($P < 0.04$), breed x milk EPD level x season in month 2 ($P< 0.02$), breed x season x calf sex in month 2 ($P < 0.05$), breed x season x cow age (year) in month 1 and 3 ($P < 0.05$), and season x calf sex x cow age (year) in month 5 ($P < 0.05$).

Table 9. Least squares means and standard errors by breed and milk level (High, Low) for the seven monthly measurements of calf weight (kg)

Cow Group	1[a]	2	3	4	5	6	7
High Angus	81.86 ± 1.50	105.85 ± 1.83	129.54 ± 2.22	155.80 ± 2.41	181.08 ± 2.60	203.09 ± 3.11	228.44 ± 3.31
Low Angus	79.56 ± 1.45	98.47 ± 1.72	122.26 ± 2.17	146.05 ± 2.30	169.17 ± 2.49	190.71 ± 3.05	210.89 ± 3.14
High Hereford	80.48 ± 1.68	101.12 ± 2.12	125.26 ± 2.49	151.11 ± 2.74	176.21 ± 2.95	197.21 ± 3.54	220.38 ± 3.81
Low Hereford	76.60 ± 1.53	95.36 ± 1.82	116.99 ± 2.29	140.44 ± 2.42	163.68 ± 2.61	184.78 ± 3.22	206.73 ± 3.34
P-values							
Breed	0.1380	0.0330	0.0327	0.0316	0.0340	0.0681	0.0653
Level[b]	0.0252	0.0011	0.0006	<0.0001	<0.0001	0.0001	<0.0001
Breed x level	0.5578	0.6521	0.8101	0.8287	0.8964	0.9940	0.5440
Level (Angus)	0.1985	0.0038	0.0127	0.0023	0.0010	0.0031	0.0002
Level (Hereford)	0.0578	0.0378	0.0106	0.0025	0.0016	0.0068	0.0071

[a] 28-d intervals beginning approximately 1 mo after average calving date.

[b] Milk EPD level.

Table 10. Least squares means and standard errors for the seven monthly measurements of calf weight (kg)

Effect		1[1]	2	3	4	5	6	7
Breed	Angus	80.71 ± 1.18	102.16 ± 1.32^{a}	125.90 ± 1.70^{a}	150.93 ± 1.83^{a}	175.12 ± 1.94^{a}	196.90 ± 2.40	219.66 ± 2.42
	Hereford	78.54 ± 1.27	98.24 ± 1.46^{b}	121.13 ± 1.84^{b}	145.77 ± 2.00^{b}	169.95 ± 2.11^{b}	191.00 ± 2.61	213.55 ± 2.68
Milk EPD Level	High	81.17 ± 1.23^{a}	103.49 ± 1.46^{a}	127.40 ± 1.76^{a}	153.46 ± 1.99^{a}	178.65 ± 2.18^{a}	200.15 ± 2.49^{a}	224.41 ± 2.66^{a}
	Low	78.08 ± 1.16^{b}	96.92 ± 1.32^{b}	119.63 ± 1.68^{b}	143.25 ± 1.83^{b}	166.42 ± 2.00^{b}	187.75 ± 2.37^{b}	208.81 ± 2.44^{b}
Season[c]	Fall	78.11 ± 1.08	95.63 ± 2.04^{c}	112.85 ± 1.49^{a}	131.04 ± 1.68^{a}	147.52 ± 1.83^{a}	162.23 ± 2.14^{a}	187.22 ± 2.20^{a}
	Spring	80.13 ± 1.17	104.01 ± 2.65^{c}	134.17 ± 1.64^{b}	165.66 ± 1.87^{b}	197.55 ± 2.04^{b}	225.67 ± 2.37^{b}	246.00 ± 2.46^{b}
Sex of calf	Heifers	77.69 ± 1.11^{a}	97.05 ± 1.22^{a}	120.17 ± 1.55^{a}	144.73 ± 1.77^{a}	168.72 ± 1.93^{a}	189.64 ± 2.23^{a}	210.59 ± 2.33^{a}
	Steers	81.56 ± 1.11^{b}	103.35 ± 1.23^{b}	126.86 ± 1.56^{b}	151.98 ± 1.77^{b}	176.35 ± 1.92^{b}	198.26 ± 2.24^{b}	222.62 ± 2.32^{b}

[1] 28-d intervals beginning approximately 1 mo after average calving date.

[a,b] Means within a column and model term with different superscripts differ ($P < 0.04$).

[c] A variable "YRS = Year x 10 + season" was used in the second calf weight because the second calf weight in year 2000 fall was not taken due to cold weather. YRS was considered as year.

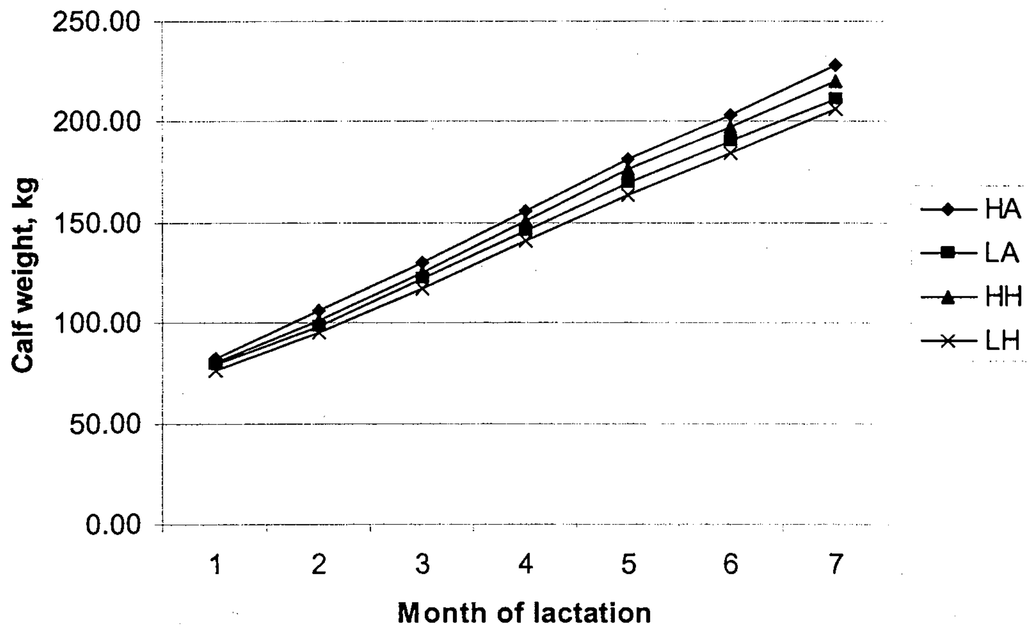
Table 11. Significance levels of model terms for calf weight in the seven months of lactation

Models terms	1	2	3	4	5	6	7
Breed	0.1380	0.0330	0.0327	0.0316	0.0340	0.0681	0.0653
Level[b]	0.0252	0.0011	0.0006	<0.0001	<0.0001	0.0001	<0.0001
Breed x level	0.5578	0.6521	0.8101	0.8287	0.8964	0.9940	0.5440
Year[c]	0.1915	<0.0001[c]	<0.0001	0.0001	<0.0001	<0.0001	<0.0001
Season[c]	0.1886	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Calf Sex	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cow age (year)	0.7976	0.1116[c]	0.9628	0.5151	0.6341	0.6275	0.8022
Calf Age	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Breed x year	0.9678		0.9560	0.9839		0.9778	0.8015
Breed x season	0.2455	0.1986[c]	0.4248	0.8613		0.8656	0.1341
Breed x calf sex		0.4117	0.5543	0.8765			
Breed x cow age (year)	0.5517	0.1415[c]	0.3223				
Level x year				0.1178	0.1700		0.0685
Level x season		0.5628[c]					
Level x calf sex	0.0595						
Level x cow age (year)		0.0756[c]		0.0844	0.1161		0.1440
Year x season	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	0.0003
Year x calf sex	0.0164		0.0214	0.1249	0.0365	0.0722	0.1206
Season x calf sex		0.0734[c]	0.1438	0.0767	0.0221	0.0380	0.0568
Season x cow age (year)	0.1470		0.0272	0.0080	0.0167	0.0188	0.0381
Calf sex x cow age (year)	0.0818	0.0134[c]	0.1259	0.0325	0.0603	0.1341	0.0384
Breed x level x year							0.1274
Breed x level x season		0.0118[c]					
Breed x year x season	0.2118		0.0972	0.1045		0.1212	
Breed x year x calf sex			0.1165	0.1324			
Breed x season x calf sex		0.0453[c]	0.1235	0.1150			
Breed x season x cow age (year)	0.0428		0.0455				
Year x season x calf sex				0.4692	0.5558		0.1175
Season x calf sex x cow age (year)				0.0509	0.0491		0.0714

[b] Milk EPD level.

[c] A variable "YRS = Year x 10 + season" was used in the second calf weight model because the second calf weight in year 2000 fall was not taken due to cold weather. In this table year = YRS and breed x season = breed x YRS.

Figure 2. Average calf weights over the lactation for high (H) and low (L) milk Angus (A) and Hereford (H) cows



Cow Weight

Least squares means and standard errors by breed and milk level (High, Low) for the seven monthly cow weight estimates, least squares means and standard errors for the seven monthly cow weight estimates main effects, and significance levels of model terms for the seven monthly cow weights are given in Table 12, 13 and 14, respectively.

Even though there was no significant breed effect ($P > 0.1$) on cow weights in any month Angus-sired cows were lighter than Hereford-sired cows throughout lactation. Angus-sired cows may have been lighter because they tend to produce more milk throughout lactation. Therefore, this increased milk production may have caused them to lose more weight than the Hereford-sired cows.

Low-milk cows were heavier than high-milk cows only in month 7 ($P < 0.04$). Minick et al. (2001) reported no differences between low-and high-milk cows weight in all months.

Breed x milk EPD level interaction was not significant for the cow weights ($P > 0.1$). High-Angus cows were lighter than low-Angus cows only in month 1 and 7 ($P < 0.03$) whereas no significant differences were detected between high-Hereford and low-Hereford cow weights ($P > 0.4$). Figure 3 shows the changes in cow weight over the lactation for the four breed milk level groups.

Season affected cow weight in month 1, 4, 5, 6, and 7 ($P < 0.0001$). Even though season did not affect cow weight in month 2 and 3, fall-calving cows were heavier than spring-calving cows in first three months. In last four months spring-calving cows were heavier than fall-calving cows. This is probably because there was better grass for cows during these months.

Year was significant in all months except the first ($P < 0.006$). Cow age within year was significant in all months except the second and the seventh month ($P < 0.04$). As expected, cow weight usually increased with age (Table 15).

Significant interactions for cow weights were breed x season in all months except the second ($P < 0.003$), and year x season in month 3, 4, and 6 ($P < 0.02$).

Table 12. Least squares means and standard errors by breed and milk level (High, Low) for the seven monthly measurements of cow weight (kg)

Cow Group	1[a]	2	3	4	5	6	7
High Angus	521.85 ± 7.81	518.64 ± 8.56	525.67 ± 8.74	527.02 ± 8.78	524.26 ± 7.99	521.85 ± 8.38	524.33 ± 7.78
Low Angus	547.70 ± 7.55	540.72 ± 8.44	549.56 ± 8.57	549.37 ± 8.61	545.79 ±7.82	544.41 ± 8.21	548.85 ± 7.60
High Hereford	544.86 ± 8.86	532.26 ± 9.76	548.96 ± 9.78	547.50 ± 9.83	542.94 ± 9.08	539.02 ± 9.43	543.22 ± 8.83
Low Hereford	548.33 ± 8.06	542.42 ± 8.94	553.51 ± 9.10	551.92 ± 9.14	551.84 ± 8.31	549.48 ± 8.72	553.77 ± 8.09
P-values							
Breed	0.1476	0.4077	0.1372	0.2091	0.1412	0.2040	0.1451
Level[b]	0.0729	0.0721	0.1188	0.1430	0.0704	0.0610	0.0336
Breed x level	0.1682	0.4985	0.2851	0.3236	0.4441	0.4838	0.3849
Level (Angus)	0.0208	0.0686	0.0552	0.0731	0.0582	0.0582	0.0279
Level (Hereford)	0.7699	0.4347	0.7310	0.7391	0.4656	0.4118	0.3747

[a] 28-d intervals beginning approximately 1 mo after average calving date.
[b] Milk EPD level.

Table 13. Least squares means and standard errors for the seven monthly measurements of cow weight (kg)

Effect		1[1]	2	3	4	5	6	7
Breed	Angus	534.77 ± 5.53	529.68 ± 6.16	537.61 ± 6.22	538.20 ± 6.25	535.03 ± 5.69	533.13 ± 5.97	536.59 ± 5.54
	Hereford	546.59 ± 6.09	537.34 ± 6.81	551.24 ± 6.80	549.71 ± 6.83	547.39 ± 6.28	544.25 ± 6.54	548.50 ± 6.11
Milk EPD Level	High	533.35 ± 5.98	525.45 ± 6.51	537.32 ± 6.64	537.26 ± 6.67	533.60 ± 6.14	530.43 ± 6.39	533.77 ± 5.97[a]
	Low	548.02 ± 5.61	541.57 ± 6.16	551.53 ± 6.34	550.65 ± 6.37	548.81 ± 5.80	546.95 ± 6.09	551.31 ± 5.64[b]
Season[c]	Fall	564.51 ± 4.76[a]	553.12 ± 8.34[c]	545.21 ± 5.18	531.15 ± 5.21[a]	521.73 ± 4.73[a]	501.53 ± 5.03[a]	506.34 ± 4.60[a]
	Spring	516.86 ± 5.32[b]	517.16 ± 10.61[c]	543.64 ± 5.72	556.76 ± 5.74[b]	560.68 ± 5.26[b]	575.85 ± 5.59[b]	578.74 ± 5.12[b]

[1] 28-d intervals beginning approximately 1 mo after average calving date.

[a,b] Means within a column and model term with different superscripts differ ($P < 0.04$).

[c] A variable "YRS = Year x 10 + season" was used in the second cow weight model because the second cow weight in year 2000 fall was not taken due to cold weather. YRS was considered as year.

Table 14. Significance levels of model terms for cow weight in the seven months of lactation

Models terms	1	2	3	4	5	6	7
Breed	0.1476	0.4077	0.1372	0.2091	0.1412	0.2040	0.1451
Level[b]	0.0729	0.0721	0.1188	0.1430	0.0704	0.0610	0.0336
Breed x level	0.1682	0.4985	0.2851	0.3236	0.4441	0.4838	0.3849
Year[c]	0.2659	< 0.0001[c]	< 0.0001	0.0053	< 0.0001	0.0005	0.0003
Season[c]	< 0.0001	-	0.7723	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Cow age (year)	0.0113	0.1055[c]	0.0106	0.0039	0.0182	0.0357	0.0995
Breed x season	< 0.0001	0.0552[c]	0.0002	0.0001	0.0011	0.0017	0.0021
Year x season	0.1288		0.0010	0.0009		0.0147	

[b] Milk EPD level.

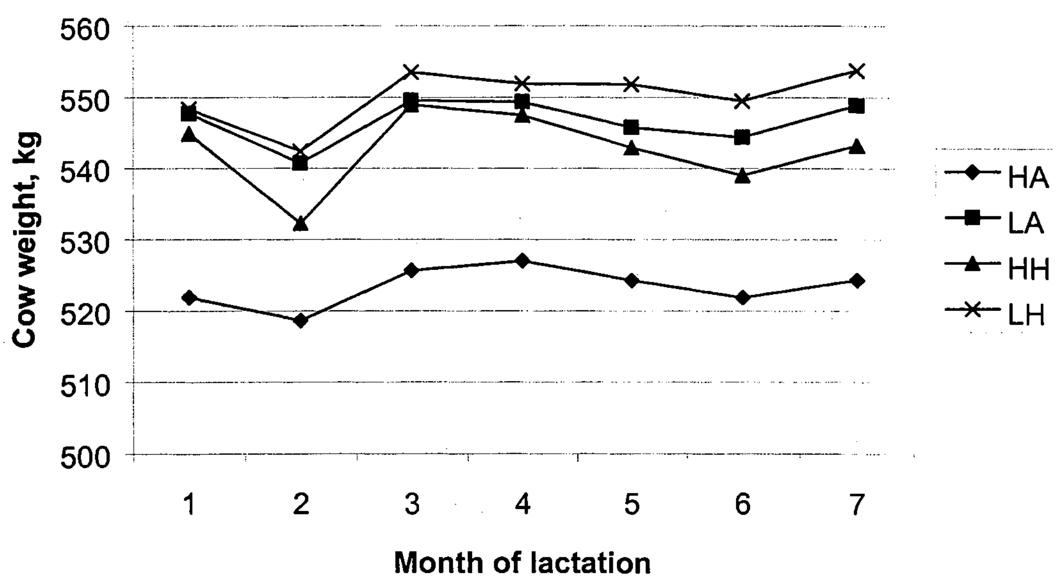
[c] A variable "YRS = Year x 10 + season" was used in the second cow weight model because the second cow weight in year 2000 fall was not taken due to cold weather. In this table year = YRS and breed x season = breed x YRS.

Table 15. Least squares means and standard errors by cow age within year for the seven monthly measurements of cow weight (kg)

Cow age (year)	1[a]	2	3	4	5	6	7
6 (1995)	545.06 ± 9.39	536.60 ± 11.96	541.16 ± 9.59	549.94 ± 9.64	543.75 ± 8.97	550.44 ± 9.45	542.87 ± 8.73
6 (1996)	530.22 ± 8.88	523.82 ± 11.74	524.46 ± 9.25	527.91 ± 9.29	523.87 ± 8.87	530.08 ± 9.10	540.19 ± 8.63
7 (1996)	559.42 ± 9.24	546.89 ± 12.21	550.64 ± 9.57	556.49 ± 9.62	543.37 ± 9.20	549.29 ± 9.48	556.55 ± 8.95
6 (1997)	538.88 ± 9.74	535.77 ± 12.57	562.69 ± 9.93	560.31 ± 9.98	563.59 ± 9.55	552.83 ± 9.75	550.89 ± 9.35
7 (1997)	538.11 ± 9.71	529.73 ± 12.52	550.96 ± 9.61	549.22 ± 9.66	553.76 ± 9.29	543.02 ± 9.47	538.04 ± 9.00
8 (1997)	562.05 ± 9.18	553.02 ± 11.84	574.54 ± 9.36	571.35 ± 9.40	575.89 ± 9.96	563.33 ± 9.21	557.56 ± 8.72
6 (1998)	518.37 ± 10.00	501.81 ± 13.41	510.57 ± 10.00	517.69 ± 10.05	511.95 ± 9.91	505.07 ± 9.97	505.55 ± 9.65
7 (1998)	543.68 ± 9.82	529.82 ± 12.85	542.68 ± 10.14	551.11 ± 10.20	544.89 ± 9.77	535.25 ± 9.97	533.03 ± 9.50
8 (1998)	532.14 ± 9.41	523.67 ± 12.57	532.20 ± 9.72	545.10 ± 9.77	537.38 ± 9.42	529.11 ± 9.59	526.14 ± 9.16
7 (1999)	519.46 ± 10.21	517.74 ± 14.02	528.02 ± 10.44	521.40 ± 10.49	519.80 ± 10.36	520.32 ± 10.41	534.96 ± 10.08
8 (1999)	547.21 ± 9.68	545.61 ± 13.11	559.23 ± 10.32	553.44 ± 10.37	547.52 ± 9.95	547.29 ± 10.14	556.51 ± 9.68
8 (2000)	543.15 ± 10.03	545.43 ± 14.56	553.00 ± 10.37	535.91 ± 10.42	540.40 ± 10.26	532.01 ±10.34	547.87 ± 9.99
P-value	0.0113	0.1055	0.0106	0.0039	0.0182	0.0357	0.0995

[a] 28-d intervals beginning approximately 1 mo after average calving date.

Figure 3. Average cow weights over the lactation for high (H) and low (L) milk Angus (A) and Hereford (H) cows



Cow BCS

Least squares means and standard errors by breed and milk level (High, Low) for the seven monthly cow BCS estimates, least squares means and standard errors for the seven monthly cow BCS estimates main effects, and significance levels of model terms for the seven monthly cow BCS are given in Table 16, 17 and 18, respectively.

Breed had significant effect in month 3, 4, and 5 ($P < 0.04$). Month 6 and 7 approached significance ($P < 0.06$). During these months Angus-sired cows had lower BCS than Hereford-sired cows. This was expected because Angus-sired cows produced more milk than Hereford-sired cows throughout lactation even though not all months were significant in milk production. Therefore, increased milk production could be expected to cause a decrease in body condition.

High-milk cows had lower BCS than low-milk cows in all months except the first ($P < 0.04$). This was expected, because high-milk cows partitioned available body stores to milk rather than fat. These findings agreed with the results of Belcher and Frahm (1979), Mondragon et al. (1983), and Minick et al. (2001).

Breed milk EPD level interaction was not significant in any month ($P > 0.3$). High-Angus cows had lower BCS than low-Angus cows in all months except the first ($P < 0.05$). High-Hereford cows had lower BCS than low-Hereford in month 4 through 7 ($P \leq 0.02$). Figure 4 shows the changes in BCS over the lactation for the four breed milk level groups.

Season was significant in month 1, 3, 4, 5, 6, and 7 ($P < 0.003$). The effect of season on body condition followed the same pattern as it did in cow weight. Cows that were on the better grass were in higher condition regardless of stage in lactation.

Year was significant in all months ($P < 0.03$). Cow age within year was not significant in any month ($P > 0.1$) and disagreed with the findings of Minick et al. (2001) who reported a significant cow age within year for cow body condition in all months of lactation.

Significant interactions for BCS were breed x season in month 1 and 2 ($P < 0.004$), breed x cow age (year) in month 2 ($P < 0.003$), milk EPD level x season in month 4 and 5 ($P < 0.02$), year x season in all months except the second ($P < 0.006$), breed x year x season in month 1, 3, 4 and 7 ($P < 0.007$), and breed x season x cow age (year) in all months except the second ($P < 0.007$).

Table 16. Least squares means and standard errors by breed and milk level (High, Low) for the seven monthly measurements of cow body condition score (1-9 scale)

Cow Group	1[a]	2	3	4	5	6	7
High Angus	5.13 ± 0.07	5.06 ± 0.07	5.07 ± 0.07	5.03 ± 0.07	4.92 ± 0.08	4.93 ± 0.07	4.97 ± 0.07
Low Angus	5.25 ± 0.06	5.28 ± 0.07	5.27 ± 0.07	5.27 ± 0.07	5.15 ± 0.07	5.14 ± 0.06	5.27 ± 0.06
High Hereford	5.22 ± 0.08	5.19 ± 0.08	5.23 ± 0.08	5.15 ± 0.08	5.06 ± 0.09	5.03 ± 0.08	5.10 ± 0.08
Low Hereford	5.34 ± 0.07	5.28 ± 0.07	5.42 ± 0.07	5.42 ± 0.07	5.36 ± 0.08	5.29 ± 0.07	5.39 ± 0.07
P-values							
Breed	0.1346	0.2122	0.0299	0.0336	0.0219	0.0526	0.0530
Level[b]	0.0728	0.0319	0.0100	0.0018	0.0019	0.0022	0.0002
Breed x level	0.9970	0.3520	0.9426	0.9056	0.7071	0.7537	0.8914
Level (Angus)	0.1706	0.0229	0.0438	0.0145	0.0254	0.0246	0.0016
Level (Hereford)	0.2233	0.3909	0.0826	0.0200	0.0140	0.0171	0.0066

[a] 28-d intervals beginning approximately 1 mo after average calving date.
[b] Milk EPD level.

Table 17. Least squares means and standard errors for the seven monthly measurements cow body condition score (1-9 scale)

Effect		1[1]	2	3	4	5	6	7
Breed	Angus	5.19 ± 0.05	5.17 ± 0.05	5.17 ± 0.05[a]	5.15 ± 0.05[a]	5.04 ± 0.05[a]	5.03 ± 0.05	5.12 ± 0.05
	Hereford	5.28 ± 0.05	5.24 ± 0.05	5.32 ± 0.06[b]	5.28 ± 0.06[b]	5.21 ± 0.06[b]	5.16 ± 0.05	5.24 ± 0.05
Milk EPD Level	High	5.17 ± 0.05	5.13 ± 0.05[a]	5.15 ± 0.05[a]	5.09 ± 0.06[a]	4.99 ± 0.06[a]	4.98 ± 0.05[a]	5.03 ± 0.05[a]
	Low	5.30 ± 0.05	5.28 ± 0.05[b]	5.34 ± 0.05[b]	5.34 ± 0.05[b]	5.26 ± 0.05[b]	5.21 ± 0.05[b]	5.33 ± 0.05[b]
Season[c]	Fall	5.42 ± 0.04[a]	5.18 ± 0.07[c]	5.16 ± 0.04[a]	5.09 ± 0.04[a]	4.92 ± 0.04[a]	4.76 ± 0.04[a]	4.93 ± 0.04[a]
	Spring	5.05 ± 0.05[b]	5.22 ± 0.09[c]	5.33 ± 0.05[b]	5.34 ± 0.05[b]	5.32 ± 0.05[b]	5.43 ± 0.05[b]	5.43 ± 0.05[b]

[1] 28-d intervals beginning approximately 1 mo after average calving date.

[a,b] Means within a column and model term with different superscripts differ ($P < 0.04$).

[c] A variable "YRS = Year x 10 + season" was used in the second cow body condition model because the second cow body condition in year 2000 fall was not taken due to cold weather. YRS was considered as year.

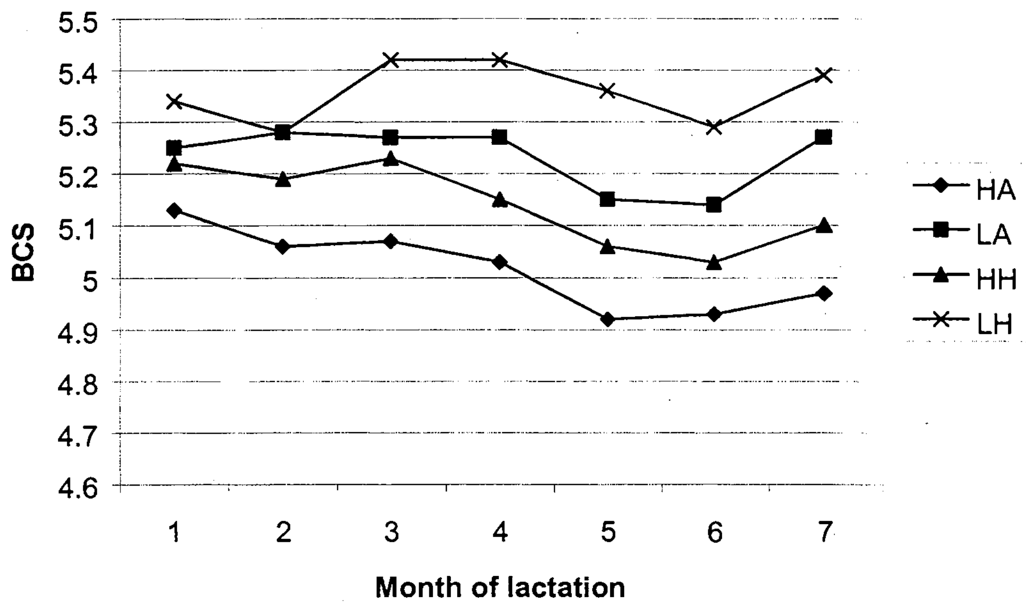
Table 18. Significance levels of model terms for cow body condition score in the seven months of lactation

Models terms	1	2	3	4	5	6	7
Breed	0.1346	0.2122	0.0299	0.0336	0.0219	0.0526	0.0530
Level[b]	0.0728	0.0319	0.0100	0.0018	0.0019	0.0022	0.0002
Breed x Level	0.9970	0.3520	0.9426	0.9056	0.7071	0.7537	0.8914
Year[c]	<0.0001	<0.0001[c]	0.0262	<0.0001	0.0003	0.0004	<0.0001
Season[c]	<0.0001	-	0.0023	<0.0001	<0.0001	<0.0001	<0.0001
Cow age (year)	0.4162	0.1909[c]	0.6230	0.7747	0.9273	0.6798	0.6408
Breed x year	0.0835		0.2662	0.0696	0.0627	0.3509	0.3423
Breed x season	0.0017	0.0037[c]	0.1171	0.1224	0.3512	0.9623	0.8992
Breed x cow age (year)	0.3812	0.0022[c]	0.1653	0.2580	0.0817	0.1504	0.2280
Level x year				0.1091	0.0458	0.1251	0.1228
Level x season	0.1408			0.0141	0.0133	0.0999	0.1262
Level x cow age (year)							0.9010
Year x season	<0.0001		0.0055	<0.0001	<0.0001	<0.0001	<0.0001
Season x cow age (year)	0.3537		0.5729	0.2473	0.1163	0.2565	0.3052
Breed x year x season	0.0028		0.0002	0.0063	0.0607	0.1255	0.0041
Breed x season x cow age (year)	0.0014		0.0054	0.0008	<0.0001	0.0006	0.0069
Level x season x cow age (year)							0.1399

[b] Milk EPD level.

[c] A variable "YRS = Year x 10 + season" was used in the second cow body condition model because the second cow body condition in year 2000 fall was not taken due to cold weather. In this table year = YRS and breed x season = breed x YRS.

Figure 4. Average cow body condition score (BCS) over the lactation for high (H) and low (L) milk Angus (A) and Hereford (H) cows



Calf Birth Weight and 205-d Weight

Least squares means and standard errors by breed and milk level (High, Low) for calf birth weight and 205-d weight estimates, least squares means and standard errors for calf birth weight and 205-d weight estimates main effects, and significance levels of model terms for calf birth weight and 205-d weight are given in Table 19, 20 and 21, respectively.

Breed had no significant effect on birth weight ($P > 0.2$). Milk EPD level was not significant for birth weight ($P > 0.3$). Sex of calf had significant effect on birth weight ($P < 0.0001$). As expected steer calves were heavier at birth than heifer calves. Breed x milk EPD interaction was not significant for birth weight ($P > 0.9$). Significant interactions for birth weight were season x calf sex ($P < 0.05$), breed x milk EPD level x season ($P < 0.04$) and milk EPD level x calf sex x cow age (year) ($P < 0.04$).

The effects of breed approached significance for 205-d weight ($P < 0.06$). Angus-sired cows had calves with a higher 205-d weight than Hereford-sired cows. High-milk cows had calves with a higher 205-d weight than low-milk cows ($P < 0.0001$). Breed x milk EPD interaction was not significant for 205-d weight ($P > 0.9$). High-Angus cows had calves with a higher 205-d weight than low-Angus cows ($P < 0.002$). High-Hereford cows had also calves with a higher 205-d weight than low-Hereford cows ($P < 0.005$). Season and sex of calf had significant effect on 205-d weight ($P < 0.0001$). Spring-calving cows had a higher 205-d weight than fall-calving cows. Spring-calving cows spent most of their lactation on summer grass, and fall-calving cows spent most of their lactation on winter feed. Steer calves were heavier at d-205 than heifer calves.

Significant interactions for 205-d weight were year x season ($P < 0.006$), year x calf sex ($P < 0.03$), season x calf sex ($P < 0.02$), and year x season x calf sex ($P < 0.04$).

These findings of birth weight and 205-d weight agreed with the findings of Minick et al., (2001).

Table 19. Least squares means and standard errors by breed and milk level (High, Low) for calf birth weight and 205-d weight

Cow Group	Calf birth weight (kg)	205-d weight (kg)
High Angus	37.81 ± 0.70	224.73 ± 3.32
Low Angus	38.31 ± 0.66	210.76 ± 3.24
High Hereford	38.53 ± 0.79	217.99 ± 3.74
Low Hereford	39.03 ± 0.69	204.30 ± 3.43
P-values		
Breed	0.2329	0.0520
Level[b]	0.3867	< 0.0001
Breed x level	0.9947	0.9632
Level (Angus)	0.5542	0.0017
Level (Hereford)	0.5919	0.0049

[b] Milk EPD level.

Table 20. Least squares means and standard errors for calf birth weight and 205-d weight

Effect		Calf birth weight (kg)	205-d weight (kg)
Breed	Angus	38.06 ± 0.54	217.75 ± 2.57
	Hereford	38.78 ± 0.58	211.14 ± 2.78
Milk EPD	High	38.17 ± 0.60	221.36 ± 2.67[a]
Level	Low	38.67 ± 0.55	207.53 ± 2.54[b]
Season	Fall	38.55 ± 0.51	186.62 ± 2.29[a]
	Spring	38.29 ± 0.56	242.27 ± 2.52[b]
Sex of calf	Heifers	37.16 ± 0.54[a]	208.29 ± 2.38[a]
	Steers	39.68 ± 0.53[b]	220.60 ± 2.40[b]

[a,b] Means within a column and model term with different superscripts differ ($P < 0.0001$).

Table 21. Significance levels of models terms for calf birth weight and 205-d weight

Models terms	Calf birth weight	205-d weight
Breed	0.2329	0.0520
Level[b]	0.3867	< 0.0001
Breed x level	0.9947	0.9632
Year	0.2022	< 0.0001
Season	0.5762	< 0.0001
Calf Sex	< 0.0001	< 0.0001
Cow age (year)	0.6326	0.9238
Breed x year		0.5745
Breed x season	0.0533	0.4049
Breed x calf sex		0.9414
Level x year	0.9244	
Level x season	0.1748	
Level x calf sex	0.3001	
Level x cow age (year)	0.1138	
Year x season		0.0052
Year x calf sex	0.4645	0.0242
Season x calf sex	0.0435	0.0150
Season x cow age (year)		0.0835
Calf sex x cow age (year)	0.3320	0.1733
Breed x level x season	0.0363	
Breed x year x season		0.1148
Breed x year x calf sex		0.1866
Breed x season x calf sex		0.1178
Level x year x calf sex	0.3522	
Level x calf sex x cow age (year)	0.0302	
Year x season x calf sex		0.0313

[b] Milk EPD level

Reproductive Performance

Least squares means and standard errors by breed and milk level (High, Low) for calving date, calving interval, calving percentage and calving rate estimates, least squares means and standard errors for calving date, calving interval, calving percentage and calving rate estimates main effects, and significance levels of model terms for calving date, calving interval, calving percentage and calving rate are given in Table 22, 23 and 24, respectively.

Calving date: Breed was not significant for calving date ($P > 0.7$). Milk EPD level had also no significant effect on calving date ($P > 0.2$). Similar results were reported by Buchanan et al. (1996b). Season did not have significant effect on calving date ($P > 0.4$). Sex of calf was significant for calving date ($P < 0.007$). Cows that gave birth to heifer calves had shorter calving date than cows that gave birth to steer calves. Newman et al. (1993) also reported that the sex effect were critical for calving day. Year had a significant effect on calving date ($P < 0.05$). Cow age within year was not significant ($P > 0.9$). Lopez de Torre and Brinks (1990) and Macgregor (1995) also reported that age of dam had no significant effect on calving date. Breed x milk EPD level interaction was not significant for calving date ($P > 0.4$). Significant interactions for calving date were milk EPD level x year ($P < 0.03$), milk EPD level x cow age (year) ($P < 0.05$), year x season ($P < 0.0001$), and season x calf sex ($P < 0.04$).

Calving interval: Breed was not significant for calving interval ($P > 0.3$). Milk EPD level had also no effect on calving interval ($P > 0.3$). This agreed with the findings of Buchanan et al. (1996b). However, McElhenney et al. (1986) reported that differences among breeds of dams were important for calving interval. Hansen et al. (1982) reported that high-milk cows would have longer postpartum anestrous periods relative to low-milk cows when nutrients are limited. Year, sex of calf, and cow age within year were not significant for calving interval ($P > 0.2$). However, Bourdon and Brinks (1983) reported that age of dam had significant effect on calving interval ($P < 0.01$). Breed x milk EPD level interaction was not significant for calving interval ($P > 0.7$). Significant interaction for calving interval was year x season ($P < 0.05$).

Calving percentage: Breed and milk EPD level had no significant effect on calving percentage ($P > 0.3$). Newman and Deland (1991) also found that calving percentage was not affected by breed. Year, season, sex of calf, and cow age within year had no significant effect on calving percentage ($P > 0.08$). Breed x milk EPD level interaction was not significant for calving percentage ($P > 0.1$). Significant interactions for calving percentage were breed x year ($P < 0.05$), milk EPD level x calf sex ($P = 0.01$), season x calf sex ($P < 0.007$), and breed x milk EPD level x year ($P < 0.05$).

Calving rate: Breed and milk EPD level had no significant effect on calving rate ($P > 0.3$). Gregory et al. (1992) reported that there was a difference in calving rate between Angus and Hereford cows. Burris and Priode (1958) stated that calving rate was higher in Angus than in Hereford and Shorthorn. No year, season and cow age within year effects were observed ($P > 0.2$) and none of the interactions were significant for calving rate ($P > 0.06$).

Even though they were not different ($P > 0.2$), cows by high milk EPD sires had slightly lower calving percentage and calving rate, longer calving interval, and later birth dates than cows by low milk EPD sires indicating a decline in reproductive performance in conjunction with the loss in condition score reported previously by Buchanan et al. (1996a) and Minick et al. (2001).

Table 22. Least squares means and standard errors by breed and milk level (High, Low) for calving date (CD), calving interval (CI), calving percentage (CP), and calving rate (CR)

Cow Group	CD (days)	CI (days)	CP (%)	CR (%)
High Angus	34.50 ± 3.21	383.11 ± 5.60	82.60 ± 3.82	90.80 ± 2.77
Low Angus	32.59 ± 3.16	379.47 ± 5.12	90.55 ± 3.46	93.64 ± 2.61
High Hereford	33.27 ± 3.26	379.41 ± 6.40	87.95 ± 4.42	89.47 ± 3.37
Low Hereford	32.84 ± 3.17	373.21 ± 5.39	84.18 ± 3.52	89.94 ± 2.63
P-values				
Breed	0.7289	0.3581	0.5480	0.3051
Level[b]	0.2648	0.3958	0.3876	0.6608
Breed x level	0.4611	0.7827	0.1569	0.6782
Level (Angus)	0.1861	0.5853	0.0683	0.4238
Level (Hereford)	0.7877	0.4069	0.4392	0.9073

[b] Milk EPD level.

Table 23. Least squares means and standard errors for calving date(CD), calving interval (CI), calving percentage (CP), and calving rate (CR)

Effect		CD (days)	CI (days)	CP (%)	CR (%)
Breed	Angus	33.54 ± 3.11	381.29 ± 4.24	86.58 ± 2.97	92.22
	Hereford	33.06 ± 3.12	376.31 ± 4.62	86.04 ± 3.19	89.70
Milk EPD	High	33.89 ± 3.14	381.26 ± 4.66	85.28 ± 3.29	90.14
Level	Low	32.71 ± 3.08	376.34 ± 4.14	87.37 ± 2.87	91.79
Season	Fall	33.87 ± 3.07	383.38 ± 3.98	88.16 ± 2.89	92.37
	Spring	32.73 ± 3.14	374.22 ± 4.77	84.49 ± 3.32	89.55
Sex of calf	Heifers	31.93 ± 3.10[a]	376.59 ± 4.40	83.58 ± 3.08	
	Steers	34.67 ± 3.10[b]	381.00 ± 4.34	89.07 ± 3.08	

[a,b] Means within a column and model term with different superscripts differ ($P < 0.007$).

Table 24. Significance levels of models terms for calving date (CD), calving interval (CI), calving percentage (CP), and calving rate (CR)

Models terms	CD	CI	CP	CR
Breed	0.7289	0.3581	0.5480	0.3051
Level[b]	0.2648	0.3958	0.3876	0.6608
Breed x level	0.4611	0.7827	0.1569	0.6782
Year	0.0450	0.2884	0.3048	0.2485
Season	0.4365	0.0799	0.2543	0.4707
Calf Sex	0.0062	0.2348	0.0836	
Cow age (year)	0.9785	0.3621	0.2724	0.4541
Breed x year	0.7095	0.1276	0.0465	0.3318
Breed x season	0.5168	0.3787	0.1875	
Breed x calf sex	0.3785	0.2003		
Breed x cow age (year)	0.1101		0.7637	0.4214
Level x year	0.0263	0.3921	0.2395	0.3105
Level x season			0.0834	0.2123
Level x calf sex		0.0773	0.0100	
Level x cow age (year)	0.0410	0.0522	0.2359	0.8678
Year x season	< 0.0001	0.0478	0.9407	0.1960
Year x calf sex	0.0577	0.5770	0.1927	
Season x calf sex	0.0324	0.5280	0.0069	
Season x cow age (year)	0.1849		0.4490	0.5645
Calf sex x cow age (year)		0.5536		
Breed x level x year			0.0464	0.7341
Breed x level x season			0.1626	
Breed x level x cow age (year)			0.0775	0.1364
Breed x year x calf sex	0.0867			
Breed x season x calf sex	0.1671	0.1348		
Level x year x season			0.5067	0.3171
Level x year x calf sex		0.7741	0.1250	
Level x season x cow age (year)			0.0571	0.0651
Level x calf sex x cow age (year)		0.1214		
Year x season x calf sex			0.1250	

[b] Milk EPD level.

Implications

These results verify that milk EPD is an accurate predictor of daughter milk production between Polled Hereford and Angus sires. Producers who use sire milk EPD values as a selection tool should be able to rank bulls with some confidence and make a selection or culling decision in purebred or commercial beef herds. Milk production differences affect calf performance and subsequent increases in calf weaning weight comes with a cost in condition score, which may lead, under challenging environmental condition, to a decline in reproductive performance. Therefore, beef producers who use high milk EPD bulls should be aware of their feed resources and cow maintenance cost. These results also indicate that high-milk cows had significantly heavier calves at d-205 with less cost to cow BCS under spring-calving management than under fall-calving management. This advantage is probably due to the better nutrition during the spring season. However, it should be noted that calves are typically weaned at 240 – 270 days of age under fall-calving management.

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VITA 2

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