

MILK PRODUCTION OF CROSSBRED DAUGHTERS OF
HIGH AND LOW MILK EPD ANGUS
AND HEREFORD BULLS

By

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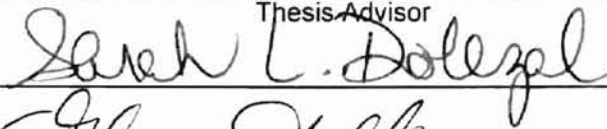
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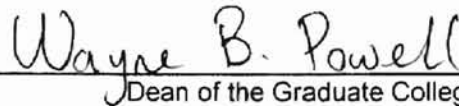
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LIST OF NOMENCLATURE

avg	average
BCS	Body Condition Score
BWEPD	birth weight expected progeny difference
d	day
EPD	expected progeny difference
h	hour
kg	kilogram
m	meter
std	standard
WSW	weigh-suckle-weigh
WWEPD	weaning weight expected progeny difference

REVIEW OF LITERATURE

Expected Progeny Differences in purebred cattle

Expected Progeny Differences (EPD) were developed as a tool to make genetic improvement in livestock. The EPD of two animals predicts the performance difference in a trait between the progeny of those two animals. EPD can only be used to predict differences between animals and not absolute performance. The milk EPD is unique because it predicts the genetic merit of a bull for maternal traits that will be expressed in his daughters. The milk EPD predicts differences in weaning weights of calves out of a bull's daughters. This EPD is measured in units of calf weaning weight, not units of milk.

Several recent studies have looked at the relationship between EPD and cow and calf performance in purebred and crossbred herds. These studies have concentrated on Angus, Hereford, Simmental and crossbred cows.

Marston et al. (1990) reported that a one kg increase in milk EPD increased total milk production for the lactation by 69.9 ± 19.8 kg in Angus and 70.7 ± 16.9 kg in Simmental. A one kg increase in milk EPD of cows increased weaning weight of calves by 3.8 ± 1.0 kg in Angus and 2.9 ± 1.1 kg in Simmental (Marston et al., 1990). Another study with Angus showed the difference in actual weaning weights of calves of daughters of high and low milk EPD bulls was 10.19 kg, which was less than the expected 18.14 kg predicted from the grandsire EPD (Baker, 1997).

A further study by Marston et al. (1992) studied the effects of milk EPD on milk yield and calf performance in Angus and Simmental. Authors found that total milk yield was influenced by the dam's milk EPD ($P < .01$) (Marston et al., 1992). A one kg change in dam's milk EPD was associated with a 42.1 ± 16.6 kg change in Angus total milk yield, and a 69.3 ± 10.6 kg change in Simmental total milk yield (Marston et al., 1992). Dam's milk EPD was also related to weaning

weight in both breeds ($P < .0001$) (Marston et al., 1992). A one kg change in dam's milk EPD, holding calf weaning weight EPD constant, was associated with a 4.85 ± 1.14 kg change in Angus adjusted weaning weight, and a 3.74 ± 1.73 kg change in Simmental adjusted weaning weight (Marston et al., 1992). These results were not significantly different than the expectation of two kg change in calf weaning weight for every one kg change in dam's milk EPD (Marston et al., 1992). The expectation was two kg of calf weaning weight for every one kg of dam milk EPD because the calf directly expresses the breeding value of the cow, which is two times her EPD (Marston et al., 1992). The milk EPD tended to be a little conservative in predicting calf weaning weight (Marston et al., 1992). Weaning weight EPD was related to weaning weight in both breeds ($P < .0001$) (Marston et al., 1992). A one kg change in weaning weight EPD, with dam's milk EPD held constant, was associated with a 4.37 ± 9.4 kg change in Angus adjusted weaning weight, and a $2.65 \pm .94$ kg change in Simmental adjusted weaning weight (Marston et al., 1992). These were greater than the expected one to one ratio (Marston et al., 1992). Total milk production was a major influence on calf performance (Marston et al., 1992). Milk EPD tended to be conservative and underestimate true genetic differences between cows (Marston et al., 1992).

Another study of Angus and Simmental, by Marston et al. (1989), found that a one kg increase in cow milk EPD increased total milk production by 56.6 kg in Angus and 70.2 kg in Simmental. A one kg increase in cow milk EPD increased weaning weight $1.8 \pm .7$ kg in both breeds (Marston et al., 1989).

The correlation between dam's milk EPD and total milk yield has been reported to be .32 ($P < .001$) (Marston et al., 1992), .37 (Marston et al., 1990) and .41 (Marston et al., 1989) for Angus, and .44 ($P < .001$) (Marston et al., 1992), .46 (Marston et al., 1990) and .55 (Marston et al., 1989) for Simmental. The correlation between dam's milk EPD and adjusted weaning weight of her calf have been reported to be .23 (Marston et al., 1990), .30 (Marston et al., 1989) and .38 ($P < .001$) (Marston et al., 1992) for Angus, and .39 ($P < .001$) (Marston et al., 1992), .47 (Marston et al., 1989) and .48 (Marston et al., 1990) for Simmental. This indicated that milk production and calf weaning weight are moderately correlated with milk EPD.

Mallinckrodt et al. (1990) studied Hereford and Simmental and found that changes in adjusted weaning weight were greater than those predicted by the milk EPD of dams ($P < .02$). Hereford maternal grandsire milk EPD also underestimated adjusted weaning weights ($P < .02$), but Simmental maternal grandsire milk EPD closely predicted adjusted weaning weights ($P > .5$) (Mallinckrodt et al., 1990). Changes in adjusted weaning weights were greater than those predicted by the total maternal EPD of Hereford dams and maternal grandsires ($P < .02$), but similar to those predicted by the total maternal EPD of Simmental dams and maternal grandsires ($P > .38$) (Mallinckrodt et al., 1990). A positive relationship was found between the calculated 205-d milk EPD and the milk EPD from the national evaluation (Mallinckrodt et al., 1990). Genetic differences in milk production and weaning weight were reasonably predicted by milk EPD and total maternal EPD (Mallinckrodt et al., 1990).

Further analysis of the earlier study by Mallinckrodt et al. (1990) with Herefords and Simmentals confirmed that calf adjusted weaning weights were greater than those predicted from the dam's milk EPD (Mallinckrodt et al., 1993). These results showed that the dam's total maternal EPD was a more accurate predictor of calf adjusted weaning weight (Mallinckrodt et al., 1993). Hereford calves had adjusted weaning weights that were greater than those expected from the dam's weaning weight direct EPD (Mallinckrodt et al., 1993). Simmental male calves had weaning weights close to those expected from dams' weaning weight direct EPD, but Simmental heifer calves had lower weaning weights as the dam's weaning weight direct EPD increased (Mallinckrodt et al., 1993). The only explanation given for this sex by EPD interaction was a small sample size (Mallinckrodt et al., 1993). Differences in weaning weights were similar to or greater than those predicted by maternal milk or total maternal EPD (Mallinckrodt et al., 1993). Maternal milk EPD was positively related to genetic potential for milk yield, as measured by weight-suckle-weight and calf weaning weight, but the strength of that relationship was unable to be estimated (Mallinckrodt et al., 1993).

Diaz et al. (1992), in a Hereford study, found that the relationship between the milk EPD of sires and the actual milk production of daughters was positive and linear. This study found correlations of .26 ($P < .01$) and .20 ($P < .05$) between sire's milk EPD and daughter's milk

production, and grandsire's milk EPD and calf's weaning weight, respectively (Diaz et al., 1992). They also concluded that EPD on purebred sires can be used to predict performance of crossbred daughters (Diaz et al., 1992).

In a study involving several breeds, Marshall and Freking (1988) found that daughters of high milk EPD sires ranked higher than daughters of low milk EPD sires for weaning weight and milk production, but the differences were not significant. The differences between the weaning weights of the calves of daughters from high and low milk EPD sires were greater than the differences in the sires' milk EPD (Marshall and Freking, 1988). Hereford maternal weaning weight EPD of grandsires was a good predictor of the weaning weight of calves (Marshall and Freking, 1988). Angus and Tarentaise maternal weaning weight EPD didn't predict the differences in weaning weight as accurately, but they did predict in the right direction (Marshall and Freking, 1988). Differences in performance were not significant (Marshall and Freking, 1988).

Expected Progeny Differences in crossbred cattle

Mahrt et al. (1990) studied daughters of Angus cows bred to four groups of Hereford sires: high yearling weight EPD high maternal EPD, high yearling weight EPD low maternal EPD, low yearling weight EPD high maternal EPD and low yearling weight EPD low maternal EPD. The high yearling weight EPD cows had calves that were 2.1 kg heavier at birth ($P < .01$) and 7.5 kg heavier at weaning ($P < .01$) than the low yearling weight EPD cows (Mahrt et al., 1990). Weaning weights were not significantly different between the high and low maternal EPD groups (Mahrt et al., 1990). Hip height at weaning was .019 m higher for the high yearling weight EPD group than the low yearling weight EPD group ($P < .001$) (Mahrt et al., 1990). There was no difference in hip height at weaning between maternal EPD groups (Mahrt et al., 1990). Yearling weight was 16.4 kg heavier for calves from cows in the high yearling weight EPD group than in the low yearling weight EPD group ($P < .001$) (Mahrt et al., 1990). There was no difference in yearling weight between maternal EPD groups (Mahrt et al., 1990). The correlation between

performance in registered herds and performance in this herd was .78 for birth weight, .61 for weaning weight, and .93 for yearling weight (Mahrt et al., 1990). This showed that an EPD on a purebred sire can predict performance in crossbred offspring (Mahrt et al., 1990). A one kg increase in yearling weight EPD was associated with a 1.79 kg increase in yearling weight (Mahrt et al., 1990). A one kg increase in weaning weight EPD was associated with a .75 kg increase in weaning weight (Mahrt et al., 1990). A one kg increase in birth weight EPD was associated with a 1.18 kg increase in birth weight (Mahrt et al., 1990).

Notter and Mahrt (1991) studied calves from Hereford sires and Angus dams and found that a one kg increase in grandsire birth weight EPD increased birth weight by $1.13 \pm .16$ kg. A one kg increase in grandsire weaning weight EPD increased 135-d weight by $.26 \pm .16$ kg, increased weaning weight by $.55 \pm .16$ kg, and increased weaning hip height by $.0016 \pm .0003$ m (Notter and Mahrt, 1991). A one kg increase in grandsire yearling weight EPD increased yearling weight by $1.14 \pm .22$ kg (Notter and Mahrt, 1991). Grandsire milk EPD didn't affect any calf traits (Notter and Mahrt, 1991).

Diaz and Notter (1991) found a $.69 \pm .19$ kg change in adjusted weaning weight for every one kg change in grandsire milk EPD ($P < .0004$) in calves from Hereford Angus cross cows. This was less than the expected value of one (Diaz and Notter, 1991). Selection of purebred sires by use of EPD was able to predict performance of their crossbred progeny (Diaz and Notter, 1991).

Marshall and Long (1993) studied the effect of sire EPD on crossbred cows. They found that a one kg change in sire's milk EPD was associated with a 13.4 kg ($P = .012$) change in daughter 214-d milk yield (Marshall and Long, 1993). The differences in daughter's milk yield were positively related to differences in sires' milk EPD, but were not as much as expected (Marshall and Long, 1993). A one kg change in grandsire's total maternal weaning weight EPD was associated with a 1.18 kg ($P = .004$) change in calf weaning weight (Marshall and Long, 1993). This is slightly greater than the expected value of one (Marshall and Long, 1993). The correlation between sire's milk EPD and daughter's 214-d milk production was .14 ($P < .05$), and the correlation between sire's total maternal weaning weight EPD and daughter's 214-d milk yield

was .14 ($P < .05$) (Marshall and Long, 1993). The correlation between grandsire's milk EPD and 214-d calf weight was .18 ($P < .01$), and the correlation between grandsire's total maternal weaning weight EPD and 214-d calf weight was .17 ($P < .001$) (Marshall and Long, 1993). After eliminating all daughters from sires with low accuracy (less than .86), those correlations were .15, .11, .21 and .18, respectively (Marshall and Long, 1993).

Milk production and weaning weight

Milk production of dams is a significant factor affecting weaning weights of calves (Mondragon et al., 1983; Neville, Jr., 1962; Gifford, 1953). Comerford et al. (1978) reported a linear relationship ($P < .05$) within breed between milk yield of Angus, Hereford x Angus, and Simmental x Angus cows and the weaning weight of their calves. There is some disagreement about the degree of importance that milk production has on weaning weight. In Herefords, the amount of variability in weaning weight that is explained by milk yield has been reported as 40% (Robison et al., 1978), 60% (Rutledge et al., 1971) and 66% (Neville, Jr., 1962). For crossbred cows, the amount of variation in weaning weight due to milk yield was 42% and 57% (Jeffery et al., 1971b). Butson et al. (1980) found that milk production explained six percent to 10% ($P < .05$) of variance in weaning weight after removing the effects of cow breed, cow age, calf age and calf sex. This may be low because some of the variance in milk production was accounted for by removing the effects of cow breed, cow age and calf sex.

Cows with higher levels of milk production weaned heavier calves (Totusek et al., 1971; Butson et al., 1980; Clutter and Nielsen, 1987; McGinty and Frerichs, 1971). Totusek et al. (1971) found weaning weights of 176.9 kg, 206.8 kg and 228.6 kg for Hereford, Hereford x Holstein and Holstein cows, respectively. Butson et al. (1980) reported that dairy x dairy cross cows weaned heavier calves than dairy x beef cows ($P < .01$). In a study with Hereford x Angus, Red Poll x Angus and Milking Shorthorn x Angus representing high, medium and low milk production, Clutter and Nielson (1987) found that the high milk cows weaned calves that were 16.9 kg heavier than calves weaned by the low milk cows. McGinty and Frerichs (1971) reported

that calves out of Brown Swiss x Hereford cows had heavier weaning weights (261 kg versus 236 kg) than calves out of Hereford cows ($P < .01$).

Estimates of the correlation between the milk yield of cows and the weaning weight of their calves vary greatly. This correlation for Herefords has been reported as .395 (Mallinckrodt et al., 1993), .63 ($P < .01$) (Robison et al., 1978) and .64 ($P < .0001$) (Diaz et al., 1992). In Angus, this correlation was .30 ($P < .001$) (Marston et al., 1992), .39 (Marston et al., 1990) and .62 (Marston et al., 1989). Correlations between milk yield and weaning weight were .355 (Mallinckrodt et al., 1993), .47 ($P < .001$) (Marston et al., 1992), .52 (Marston et al., 1990) and .62 (Marston et al., 1989) for Simmentals. In crossbred cows, this correlation has been reported as .20 ($P < .1$) (Chenette and Frahm, 1981), .52 ($P < .001$) (Marshall and Long, 1993), .60 ($P < .01$) (Butson et al., 1980), .62 ($P < .01$) (Butson et al., 1980), .69 (Belcher and Frahm, 1979) and .94 (Nelson et al., 1985).

Creep feeding of calves tends to decrease the correlation between milk production and weaning weight because those calves are less dependent on their dams for nutrients. The correlation between milk production and weaning weight in creep fed calves was .33 ($P < .05$) for Herefords (Hohenboken et al., 1973) and .44 ($P < .05$) for crossbreds (Marshall et al., 1976).

The correlation between milk production and weaning weight also varies depending on stage of lactation when the measurement was taken. A study involving Herefords found correlations between weaning weight and seven monthly milk production estimates of .49 ($P < .05$), .38 ($P < .05$), .36 ($P < .05$), .38 ($P < .05$), .37 ($P > .05$), .29 ($P > .05$) and .25 ($P > .05$) (Rutledge et al., 1970b). Robison et al.'s (1978) Hereford study reported correlations between bimonthly milk yields and weaning weight ranging from .44 to .48 ($P < .01$). Baker (1997) reported correlations of .37 ($P < .05$), .16 ($P > .05$), .44 ($P < .05$) and .37 ($P < .05$) between weaning weight of Angus calves and cow's milk production at approximately 45, 100, 150 and 205 days post calving, respectively.

The regression of total lactation milk yield on weaning weight was variable. Using Angus and Simmental cows, Marston et al. (1990) found that one kg of additional calf weaning weight was associated with 62 kg and 40 kg of additional milk. Another study combined the results of

Angus and Simmental cows and found that 26.8 kg of milk was required for one additional kg of weaning weight (Marston et al., 1989). For crossbred cows, one kg of additional calf weaning weight was associated with 20.4 kg of additional milk (Marshall and Long, 1993). In a study involving Herefords, Bogg et al. (1980) found that one additional kg of daily milk led to 7.20 kg more weaning weight ($P < .001$). For crossbreds, a one kg increase in average daily milk yield caused an increase of 7.5 kg (Butson et al., 1980), 7.8 kg (Butson et al., 1980), 11.3 kg (Jeffery et al., 1971b), 11.3 ± 1.0 kg (Butson et al., 1980), 12.4 kg (Nelson et al., 1985), 12.4 ± 1.2 kg (Butson et al., 1980), 13.7 kg (Beals et al., 1988) and 14.6 kg (Jeffery et al., 1971b) in weaning weight. A further study by Marston et al. (1992) reported that a one kg change in total milk yield of the dam was associated with a $.014 \pm .006$ and $.032 \pm .009$ kg change in adjusted weaning weight for Angus and Simmental, respectively.

Milk production and calf gain

Milk production is an important factor affecting calf gain (Beal et al., 1990). There are many different estimates of the influence of milk production of the cow on gain of her calf. These ranged from no effect (Martin and Franke, 1982; Ansotegue et al., 1991) to significant positive effects (Melton et al., 1967a; Butson and Berg, 1984a; Neville, Jr., 1962). The amount of variation in calf gain that is explained by variation in dam's milk production has been reported as 36% to 49% (Pope et al., 1963), 40% to 46% (Koch, 1972) and 56% to 61% (Jeffery et al., 1971b) in crossbred cows. Stage of lactation has been found to affect this relationship. In a study by Pope et al. (1963), the amount of variation in calf gain accounted for by milk production was 42% to 64%, 30% to 49%, nine percent to 20% and two percent to six percent at one, three, four, and six months respectively. Comerford et al. (1978) reported a linear relationship ($P < .05$) between milk yield and average daily gain.

The correlation between cow milk yield and calf average daily gain differs between breeds. For Herefords, this correlation has been found to be .36 ($P < .05$) (Carpenter, Jr., et al., 1972), .383 (Meyer et al., 1994), .41 ($P < .05$) (Franke et al., 1975), .517 ($P < .01$) (Knapp, Jr. and

Black, 1941) and .67 (Cobb et al., 1978a). These correlations for Angus were .45 ($P < .05$) (Franke et al., 1975), .46 (Cobb et al., 1978a), .4953 ($P < .01$) (Drewry et al., 1959) and .54 ($P < .001$) (Reynolds et al., 1978). Others have reported these correlations as .36 ($P < .05$) (Carpenter, Jr., et al., 1972) for Charolais, .517 ($P < .01$) (Knapp, Jr. and Black, 1941) for Shorthorns, .326 (Meyer et al., 1994) for Wokalups, .51 ($P < .01$) (Reynolds et al., 1978) for Brahman and .60 ($P < .01$) (Reynolds et al., 1978) for Brangus. In crossbred cows, this correlation has been reported as .14 ($P < .05$) (Todd et al., 1968), .29 ($P < .05$) (Chenette and Frahm, 1981), .36 ($P < .05$) (Carpenter, Jr., et al., 1972), .46 (Wilson et al., 1968), .49 ($P < .05$) (Wilson et al., 1969), .58 ($P < .01$) (Reynolds et al., 1978), .60 ($P < .01$) (Clutter and Nielsen, 1987), .60 to .70 (Pope et al., 1963), .67 to .71 ($P < .01$) (Butson et al., 1980), .71 (Belcher and Frahm, 1979), .76 (Jeffery et al., 1971b), .78 (Jeffery et al., 1971b), .82 ($P < .001$) (Holmes et al., 1968) and .84 ($P < .01$) (Gleddie and Berg, 1968).

There is some difference in the correlation between milk production and average daily gain depending on the stage of lactation. This correlation may have been less important very early in lactation when the cow was producing more milk than the calf could consume (Sprivulis et al., 1980). However, in general, the correlation tended to be higher early in lactation, and to decrease in importance over time (Neville, Jr., 1962; Clutter and Nielsen, 1987; Sprivulis et al., 1980). This is because, as lactation progressed, the calf became increasingly dependent on food sources other than milk (pasture or creep feed). In a study with Angus in the first few weeks after birth, Schwulst et al. (1980) reported correlations between average milk consumption and average daily gain of .41 ($P > .05$) for birth to two weeks, .63 ($P < .01$) for birth to three weeks and .58 ($P < .01$) for birth to five weeks. A study conducted by Franke et al. (1975) found correlations between milk production and average daily gain of .45 ($P < .05$), .32 ($P < .05$) and .17 ($P > .05$) for Angus and .26 ($P < .05$), .30 ($P < .05$) and .13 ($P > .05$) for Herefords from birth to three months, three to five months and five to seven months, respectively. In another Hereford study, Christian et al. (1965) reported correlations between milk yield and average daily gain of .77 ($P < .01$) from zero to 60 days and .64 ($P < .01$) from 60 to 240 days. In an Australian study of Herefords and Wokalups, Sprivulis et al. (1980) found correlations between average daily gain

and milk production for six monthly periods to be .91 ($P < .01$), .12 ($P > .05$), .71 ($P < .01$), .61 ($P < .05$), .73 ($P < .01$) and .00 ($P > .05$) for Herefords and .12 ($P > .05$), -.08 ($P > .05$), .47 ($P > .05$), .68 ($P < .05$), .55 ($P > .05$) and -.19 ($P > .05$) for Wokalups. Melton et al. (1967b), in a study with Angus, Hereford and Charolais, reported correlations between daily milk yield and average daily gain for six monthly periods of .58 ($P < .05$), .38 ($P > .05$), .01 ($P > .05$), .19 ($P > .05$), .27 ($P > .05$) and .03 ($P > .05$). Gifford's (1953) study with Hereford, Angus and Shorthorn cows reported correlations between calf gains and eight monthly daily milk productions of .60 ($P < .01$), .71 ($P < .01$), .52 ($P < .01$), .35 ($P < .01$), .19 ($P > .05$), .24 ($P > .05$), .39 ($P < .01$) and .57 ($P < .01$). Daley et al. (1987), in a study with crossbred cows, found that the correlation between milk yield and average daily gain was .45 ($P < .01$) at 60 days, .36 ($P < .01$) at 105 days and .41 ($P < .01$) at 150 days. Gleddie and Berg's (1968) study with crossbred cows reported correlations between average daily gain and milk yield in months one, two, three and five of .73, .83, .81 and .82 (all $P < .01$), respectively. Another study of crossbreds and purebreds, by Todd et al. (1969) found the correlation between milk production and average daily gain to be .95 in the first month and .25 in the third month.

Creep feeding calves causes this correlation to be lower than expected. In a study involving Herefords, Hohenboken et al. (1973) reported a correlation between milk production and creep fed calf gain of .34.

The regression of milk production and calf gain is variable. In Herefords, the amount of milk needed to produce one kg of calf gain was 4.7 kg (Melton et al., 1967b), 12.3 to 16.8 kg (Williams et al., 1979b) and 12.5 to 23.5 kg (Neville, Jr., 1962). In other breeds, the amount of milk needed to produce one kg of calf gain was 5.7 kg in Angus (Melton et al., 1967b) and 5.3 kg in Charolais (Melton et al., 1967b). One kg increase in daily milk production caused an increase of .05 to .09 kg/day in average daily gain of the calf for Santa Gertrudis (Wistrand and Riggs, 1966), and an increase of .34 kg/day ($P < .001$) in average daily gain of Herefords (Boggs et al., 1980). For crossbred cows, the amount of milk that was required to produce one additional kg of calf was 11.2 kg (Wilson et al., 1969).

The amount of milk required for calf gain also depends on the stage of lactation. In a study of Angus cows, Drewry et al. (1959) reported that 12.5 kg, 10.8 kg and 6.3 kg of milk were required to produce one kg of calf gain in the first, third and sixth month respectively. Using crossbred cows, Butson and Berg (1984a) found that a .1 kg increase in average daily gain was associated with a .480 kg and a .211 kg increase in June and September milk production, respectively.

Intermediate milk production and calf weight

Kress and Anderson's (1974) Hereford study reported the average correlation between milk yield and calf weight at the same time to be .49. The correlations between milk yield at five evenly spaced periods and calf weight at those times were .50, .53, .52, .59 and .31 (all $P < .01$) (Kress and Anderson, 1974). Klett et al. (1965) found correlations between milk production and calf weight at the same time that ranged from .67 to .81 (all $P < .01$) in Angus. The same correlations for Herefords were non-significant (Klett et al., 1965). Gifford's (1953) study with Hereford, Angus and Shorthorn cows reported correlations between accumulated milk yield and calf weight to range from .52 to .67 ($P < .01$). Using Santa Gertrudis, Wistrand and Riggs (1966) found a correlation between calf weight and milk yield at 120 days of .68 ($P < .01$).

Breed of cow and milk production, calf gain and weaning weight

There are breed differences in the amount of milk produced by the cow (Notter et al., 1978; Comerford et al., 1978). At peak yield, Jenkins and Ferrell (1992) found that Braunvieh, Gelbvieh, Pinzgauer and Simmental ($11.9 \pm .3$ kg, $11.5 \pm .3$ kg, $11.1 \pm .3$ kg and $10.9 \pm .3$ kg) produced more daily milk ($P < .05$) than Charolais, Limousin, Angus and Hereford ($9.8 \pm .3$ kg, $9.5 \pm .3$ kg, $9.4 \pm .3$ kg and $8.5 \pm .3$ kg). This study also reported breed differences in total milk produced over the lactation, with a range of 1,200 to 1,800 kg (Jenkins and Ferrell, 1992). Total

yields were: Braunvieh ($1,803 \pm 60$ kg)^c, Gelbvieh ($1,697 \pm 57$ kg)^{cd}, Pinzgauzer ($1,640 \pm 56$ kg)^{de}, Red Poll ($1,566 \pm 47$ kg)^{de}, Charolais ($1,433 \pm 63$ kg)^e, Simmental ($1,604 \pm 61$ kg)^{ef}, Angus ($1,423 \pm 56$ kg)^{ef}, Limousin ($1,349 \pm 54$)^{fg} and Hereford ($1,191 \pm 57$ kg)^g (Jenkins and Ferrell, 1992).

Butson and Berg (1984a) found that Herefords ($4.4 \pm .7$ kg/day) produced less milk than other breeds and crosses ($7.0 \pm .1$ kg/day). Sprivulis et al. (1980) reported that Wokalups produced more milk ($P < .01$) than Herefords. In a study by Reynolds et al. (1978), the average daily milk production for Brangus (3.8 kg/day) was higher than Angus (3.3 kg/day), which was higher than Brahman (2.8 kg/day) ($P < .01$). Melton et al. (1967b) found that for total milk yield, Charolais (784.8 kg) produced more ($P < .05$) than Angus (663.7 kg), which produced more ($P < .05$) than Hereford (581.0 kg). Klett et al. (1965) reported average daily yields of 3.90 kg for Angus and 2.92 kg for Herefords. Nelson et al. (1985) also found differences in milk production among breeds ($P < .01$), with daily milk for the Hereford being lowest (4.8 kg) and Simmental highest (8.0 kg).

Different crosses have been found to produce different amounts of milk at peak lactation (Jenkins and Ferrell, 1984; Hardt et al., 1988), to produce different amounts of average daily milk (Daley et al., 1987; Chenette and Frahm, 1981; Gaskins and Anderson, 1980; Totusek et al., 1971; Jeffery et al., 1971b; Hardt et al., 1988; Mondragon et al., 1983; Cobb et al., 1978b; McGinty and Frerichs, 1971; Todd et al., 1968; Gleddie and Berg, 1968; Belcher and Frahm, 1979), and to produce different amounts of total milk (Jenkins and Ferrell, 1984; Butson and Berg, 1984b). There were also breed differences in persistency (Butson and Berg, 1984a). The differences between the crosses were greatest early in lactation and tended to decrease as lactation progressed (Jenkins and Ferrell, 1984). Dairy cross cows produced more milk (Butson and Berg, 1984a; Mondragon et al., 1983) and were more persistent (Butson and Berg, 1984a) than straight beef cross cows. Also, crossbred cows tended to produce more milk than purebreds (Wingert et al., 1984; Mondragon et al., 1983; Todd et al., 1969). Cundiff et al. (1974) found that 12-h milk production from crossbred cows was 7.5% higher at six weeks ($P < .05$) and 38% higher at weaning ($P < .01$) than 12-h milk from purebred cows. The amount of heterosis for milk production differed between different crosses (Cundiff et al., 1974). Also, reciprocal crosses were

different because of the effects of the maternal granddam (Cundiff et al., 1974). There has been some evidence of a negative effect of high milking dams on their heifer progeny. Heifers from high milking cows tended to give less milk when they produced calves than heifers from lower milking cows (Koch, 1972). This could be because heifers from higher milking cows deposit more udder fat than heifers from lower milking cows. Christian et al. (1965) reported a non-significant negative relationship between a heifer's weaning weight and her later milk production.

The effect of cow breed on the gain and weaning weight of her calf ranged from no effect (Wingert et al., 1984) to a significant effect (Freetly and Cundiff, 1998; Sprivulis et al., 1980; Todd et al., 1968; Melton et al., 1967b; Belcher and Frahm, 1979; Lawson, 1976; Jeffery et al., 1971b; Brown et al., 1970; Turner, 1969; Nelson et al., 1985; Notter et al., 1978; Nelms et al., 1978; Comerford et al., 1978). Cundiff et al. (1974) found that crossbred cows tended to have faster gaining calves ($P < .05$) that were heavier at 135 days ($P < .01$) and weaning ($P < .01$) than purebred cows. Similarly, Todd et al. (1968) reported that crossbred cows weaned calves that were 19% heavier than calves from purebred cows.

Breed of calf and milk production, calf gain and weaning weight

The breed of calf can affect the cow's milk production (Reynolds et al., 1978; Mezzadra et al., 1989; Jeffery et al., 1971b). Mezzadra et al. (1989) reported that Charolais calves caused their crossbred dams to produce more milk than Angus calves. Reynolds et al. (1978) found that Angus cows produced 20% ($P < .05$) more milk when their calves were crossbred. Brahman sired crossbred calves caused their dams to produce more milk than Angus sired crossbred calves ($P < .05$) (Reynolds et al., 1978). Further, Afrikaner x Angus cows produced 26% ($P < .01$) more milk when their calves were sired by bulls of another breed (Reynolds et al., 1978). Crossbred calves grew faster than purebred calves (Reynolds et al., 1978). This may be because larger, faster growing calves could consume more milk and therefore stimulate their dams to produce more milk.

Birth weight and milk production, calf gain and weaning weight

The effect of birth weight of the calf on milk production of the dam ranged from non-significant (Christian et al., 1965; Gleddie and Berg, 1968) to moderately positive (Martin and Franke, 1982; Rutledge et al., 1970a; Rutledge et al., 1971; Robison et al., 1978; Butson and Berg, 1984b). Larger calves tended to cause their dams to produce more milk because they could consume more (Marston et al., 1992; Drewry et al., 1959). Birth weight of the calf explained zero percent to 2.4% ($P < .05$) of the variance in milk yield of the dam (Jeffery et al., 1971a). Correlations between birth weight and milk production in Herefords have been reported to be .11 (Hohenboken et al., 1973), .18 ($P < .01$) (Robison et al., 1978), .22 ($P < .05$) (Kress and Anderson, 1974) and .241 (Mallinckrodt et al., 1993). Angus and Simmental cows had a correlation of .50 ($P < .01$) and -.05 between birth weight and milk production, respectively (Schwulst et al., 1966; Mallinckrodt et al., 1993). This correlation for crossbred cows was .11 to .18 (Jeffery et al., 1971a), .14 (Pope et al., 1963) and .45 to .46 ($P < .01$) (Butson et al., 1980). The correlation between birth weight and milk production tends to decrease through the lactation. The correlations of birth weight with bimonthly milk yields were .19, .12 and .09 (all $P < .01$) (Robison et al., 1978). Another study reported correlations of .43, .29 and .12 in months one, three and six, respectively (Drewry et al., 1959). A one kg change in birth weight was associated with a 19.2 ± 8.6 kg change ($P < .03$) in total milk yield in Angus, and a 8.6 ± 6.9 kg change ($P > .05$) in total milk yield in Simmental (Marston et al., 1992). In crossbred cows, a one kg increase in birth weight led to a .04 kg increase ($P < .05$) in average daily milk yield (Butson and Berg, 1984b).

The effect of birth weight on average daily gain ranged from non-significant (Gregory et al., 1950) to moderately positive (Boggs et al., 1980; Neville, Jr., 1962; Rutledge et al., 1970b; Brown et al., 1970). The correlation between birth weight and average daily gain was reported as .07 ($P > .05$) (Gregory et al., 1950), .32 ($P < .05$) (Christian et al., 1965) and .44 ($P < .01$) (Gregory et al., 1950) for Herefords. For crossbred cows, this correlation was .23 (Jeffery et al.,

1971b), .28 ($P < .05$) (Holmes et al., 1968), .32 (Jeffery et al., 1971b), .24 to .45 (Jeffery and Berg, 1972a) and .38 to .51 ($P < .01$) (Butson et al., 1980).

Birth weight had a positive effect on weaning weight as well (Singh et al., 1970; Boggs et al., 1980; Rutledge et al., 1971). The correlation between birth weight and weaning weight was reported as .27 ($P < .01$) and .60 ($P < .01$) in Herefords (Gregory et al., 1950). This correlation in crossbred cows was .37 (Jeffery et al., 1971b), .41 (Jeffery et al., 1971b) and .40 to .53 ($P < .01$) (Butson et al., 1980). A one kg change in birth weight was associated with a $1.89 \pm .58$ kg change in adjusted weaning weight in Angus ($P < .001$), and was not related in Simmental (Marston et al., 1992). For crossbred cows, a one kg change in birth weight was associated with a 1.5 to 1.9 kg increase in weaning weight (Butson et al., 1980).

The correlation between birth weight and calf weight at different times in lactation was moderate as well. In Angus, the correlation between birth weight and calf weight was reported as .30, .37 and .32 for the first, third and sixth month, respectively (Drewry et al., 1959). It's possible that calves which were born heavier didn't gain more, but simply maintained their weight advantage throughout the suckling period (Drewry et al., 1959; Boggs et al., 1980; Nelms and Bogart, 1956). Also, much of the variation in birth weight can be explained by calf sex and cow age (Butson et al., 1980).

Calf sex and milk production, calf gain and weaning weight

The effect of calf sex on milk production is highly variable. It ranges from females receiving more milk (Jeffery et al., 1971a; Rutledge et al., 1971) to no effect (Lawson, 1981; Butson and Berg, 1984a; Williams et al., 1979a; Robison et al., 1978; Marshall et al., 1976; Christian et al., 1965; Reynolds et al., 1978; Todd et al., 1968; Gledde and Berg, 1968; Melton et al., 1967b; Neville, Jr., et al., 1974) to males receiving more milk (Daley et al., 1987; Jeffery et al., 1971a; Pope et al., 1963; Wingert et al., 1984).

The effect of sex on average daily gain ranged from non-significant (Gregory et al., 1950; Holmes et al., 1968) to males having significantly faster gains than heifers (Jeffery and Berg,

1972b; Franke et al., 1975; Jeffery et al., 1971b; Christian et al., 1965; Knapp, Jr. and Black, 1941; Wingery et al., 1984; Nelms et al., 1978; Melton et al., 1967b; Neville, Jr., 1962; Marlowe and Gaines, 1958; Reynolds et al., 1978; Rutledge et al., 1971). Bulls gained five percent faster than steers, which gained eight percent faster than heifers (Marlowe and Gaines, 1958), and male calves gained .1 kg/day faster than heifers (Jeffery and Berg, 1972b).

Most studies reported that male calves were significantly heavier at weaning than female calves (Rutledge et al., 1970b; Butson et al., 1980; Lawson, 1976; Brown et al., 1970; Linton et al., 1968; Cundiff et al., 1966; Christian et al., 1965; Brown, 1960; Wingert et al., 1984). Sex accounted for 8.41% (Linton et al., 1968) and 17% ($P < .01$) (Cundiff et al., 1966) of the variance in weaning weight. However, there were also studies that reported that sex did not affect weaning weight (Gregory et al., 1950; Marston et al., 1992). The difference between males and females at weaning was 23.4 ± 3.70 kg ($P < .0001$) for Simmental (Marston et al., 1992). In a crossbred study, bulls were 7.3 kg heavier than steers, which were 13.6 kg heavier than heifers (Marlowe and Gaines, 1958). Males were also heavier than females ($P < .01$) at day 135 (9.3 kg) and day 200 (13.7 kg) of lactation (Cundiff et al., 1974).

Cow age and milk production, calf gain and weaning weight

Cow age has been found to have a significant effect on milk production (Williams et al., 1979a; Robison et al., 1978; Jeffery et al., 1971a; Rutledge et al., 1970a; Christian et al., 1965; Drewry et al., 1959; Sprivulis et al., 1980; Reynolds et al., 1978; Nelms et al., 1978; Melton et al., 1967a; Gifford, 1953; Neville, Jr., et al., 1974; Todd et al., 1969). There is some disagreement as to at what age a cow has her peak production. Most sources agree that milk yield rises rapidly from two to three years old, and then increases at a slower rate to six to nine years old, after which, production begins to decline (Robison et al., 1978; Pope et al., 1963; Dawson et al., 1960; Christian et al., 1965; Wingert et al., 1984; Gifford, 1953; Neville, Jr., et al., 1974; Todd et al., 1969). Butson and Berg (1984a) reported that the daily milk production of three-year-old, four-year-old, and mature crossbred cows was 25%, 35% and 39% more than that of two-year-olds.

The shape of the lactation curve was similar for cows of different ages (Rutledge et al., 1972). There was a linear increase in milk production between two and four years of age (Gaskins and Anderson, 1980). Rutledge et al. (1970) reported a quadratic effect of cow age on milk production. Greater persistency of production was found by Todd et al. (1969) for cows six years old or older. The correlation between age of dam and milk production ranged from .22 to .32 (Jeffery et al., 1971a). By combining cow age and post calving weight, Jeffery et al. (1971a) explained 15.3% to 21.1% of the variation in milk yield. Clutter and Nielsen (1987) found that differences between high and low producing cows increased as the cows aged.

The relationship between cow age and calf gain ranged from no effect (Sprivulis et al., 1980; Neville, Jr., 1962) to a significant effect (Singh et al., 1970; Williams et al., 1979a; Franke et al., 1975; Reynolds et al., 1978; Marlowe and Gaines, 1958). Similar to milk production, calf gains increased as cow age increased up to a peak of six to nine years, and then began to decline (Singh et al., 1970; Wingert et al., 1984; Marlowe and Gaines, 1958). The correlation between cow age and gain of the calf ranged from .3063 ($P < .05$) (Drewry et al., 1959) to .32 (Jeffery et al., 1971a). The effects of cow age on gain may have been more important in early lactation, when the calf was more dependent on its dam for nutrition (Franke et al., 1975).

Similarly, the relationship between age of dam and weaning weight ranged from no effect (Rutledge et al., 1970b; Neville, Jr., 1962) to a significant effect (Singh et al., 1970; Butson et al., 1980; Lawson, 1976; Brown et al., 1970; Turner, 1969; Linton et al., 1968; Wingert et al., 1984; Neville, Jr., et al., 1974). The weaning weights of calves increased as dam age increased up to four to nine years, and then decreased (Singh et al., 1970; Butson et al., 1980; Brown et al., 1970; Cundiff et al., 1966; Minyard and Dinkel, 1965; Swiger et al., 1962; Wingert et al., 1984; Neville, Jr., et al., 1974; Christian et al., 1965). Age of the cow has been reported to account for 5.67% (Linton et al., 1968) and seven percent (Cundiff et al., 1966) of the variation in calf weaning weight for Herefords and Angus, and 45% to 48% (Butson et al., 1980) of the variation in calf weaning weight for crossbreds. Brown et al. (1970) found significant linear and quadratic relationships between cow age and calf weaning weight.

Neville, Jr., et al. (1974) reported that lactation number may influence milk production and weaning weight as much as age. Cows that first calved as two-year-olds produced less milk than cows that first calved as three-year-olds, but their lifetime productivity was higher (Cundiff et al., 1974). It's also important to remember that there is a selection bias for older cows. In most situations, poorer producers are gradually culled from the herd. Also, by culling cows with low weaning weights (low milkers) and cows that don't breed (probably high milkers), producers remove both ends of the distribution (Wingert et al., 1984).

Cow weight and milk production, calf gain and weaning weight

The effects of cow weight on milk production ranged from negative (Marston et al., 1992; Pope et al., 1963) to non-significant (Hohenboken et al., 1973; Wilson et al., 1969; Kress and Anderson, 1974; Marshall et al., 1976; Mondragon et al., 1983; Todd et al., 1968; Butson and Berg, 1984b) to positive (Rutledge et al., 1970a; Jeffery et al., 1971a; Totusek and Arnett, 1965; Mondragon et al., 1983; Rutledge et al., 1971). Correlations of -.37 to -.22 (Pope et al., 1963), -.29 (Pope et al., 1963), .28 to .38 (Jeffery et al., 1971a), .69 ($P < .01$) (Totusek and Arnett, 1965), .80 ($P < .01$) (Totusek and Arnett, 1965) and .88 ($P < .01$) (Totusek and Arnett, 1965) have been reported between cow weight and milk production.

Heavier cows tended to have calves that gained faster (Miquel et al., 1972; Hohenboken et al., 1973). Further, Benyshek and Marlowe (1973) reported a linear relationship between cow weight and calf gain. Other studies have also found positive correlations (Jeffery and Berg, 1972b; McDonald and Turner, 1969) of .29 to .38 (Jeffery and Berg, 1972a) between cow weight and calf gain. One kg of cow weight has been associated with $.3 \pm .04$ g/day to $.46 \pm .05$ g/day (Benyshek and Marlowe, 1973) of calf average daily gain. However, other studies have reported no relationship between cow weight and calf gain (Carpenter et al., 1972; Wilson et al., 1969; Fitzhugh et al., 1967; Singh et al., 1970; Vaccaro and Dillard, 1966; Brinks et al., 1962; Melton et al., 1967b; Neville, Jr., 1962), or a negative relationship between cow weight and calf gain (Carpenter, Jr. et al., 1972). Breed of cow affected the relationship between cow weight and calf

gain (Fitzhugh et al., 1967; Nelson and Cartwright, 1967; Godley and Tennant, Jr., 1969; Carpenter, Jr. et al., 1972; Tanner et al., 1965). Heifer size at eight months and 15 months, and the gain between these measurements had a slightly positive correlation with progeny gain (Hohenboken et al., 1973).

Heavier cows tended to have calves that were heavier at weaning (Miquel et al., 1972; Hohenboken et al., 1973). Positive correlations (Godley and Tennant, Jr., 1969; Smith and Fitzhugh, Jr., 1968; Brinks et al., 1962; Rutledge et al., 1970b; McDonald and Turner, 1969) of .20 (Gregory et al., 1950), .21 (Urlick et al., 1971), .34 (Tanner et al., 1965) and .51 (O'Mary et al., 1959) have been reported between cow weight and calf weaning weight. One kg of cow weight has been associated with .04 kg ($P < .01$) (Urlick et al., 1971), .07 kg (Jeffery and Berg, 1972b; Jeffery et al., 1971b) and $.08 \pm .02$ kg to $.10 \pm .02$ kg (Benyshek and Marlowe, 1973) of calf weaning weight. However, other studies have reported no relationship between cow weight and weaning weight (Carpenter, Jr. et al., 1972; Godley and Tennant, Jr., 1969; Singh et al., 1970; Brinks et al., 1962; Melton et al., 1967b; Neville, Jr., 1962), or a negative relationship between cow weight and weaning weight (Carpenter, Jr. et al., 1972; Gregory et al., 1950). Breed of cow affected the relationship between cow weight and calf weaning weight (Fitzhugh et al., 1967; Nelson and Cartwright, 1967; Godley and Tennant, Jr., 1969; Carpenter, Jr. et al., 1972; Tanner et al., 1965).

Weight change of the cow throughout lactation also affected milk production, calf gain and calf weaning weight. Generally, cows that gained weight during lactation did so at the expense of milk production (Hohenboken et al., 1973; Jeffery et al., 1971a; Pope et al., 1963). Some correlations that have been reported between cow gain during lactation and milk production were -.21 to -.12 (Jeffery et al., 1971a), -.24 to .1 (Pope et al., 1963), -.16 (Wilson et al., 1968) and -.10 to -.07 (Butson et al., 1980). Jeffery et al. (1971a) found that cow summer weight change accounted for 8.4% of the variation in milk production. According to Montaño-Bermudez and Nielsen (1990), lower milking cows tended to have the most weight fluctuation. There were also differences in yearly weight lows and highs between high and low milking cows (Montaño-Bermudez and Nielsen, 1990).

Weight gain of the cow had a variable effect on calf gain and weaning weight. Some studies have found that cows that lost weight during lactation had calves that grew faster (Singh et al., 1970; Vaccaro and Dillard, 1966; Brinks et al., 1962) and were heavier at weaning (Singh et al., 1970), while others have found that cows that gained weight during lactation had calves that were heavier at weaning (Spitzer et al., 1995). Still others have reported no relationship between cow gain and milk yield or calf performance (Butson and Berg, 1984b). Some correlations that have been reported between cow weight gain and calf gain were -.34 (Gregory et al., 1950), -.20 ($P < .01$) to -.12 (Butson et al., 1980) and -.12 (Gregory et al., 1950). Correlations between cow weight gain and calf weaning weight were -.35 ($P < .01$) (Todd et al., 1968) and -.22 ($P < .01$) to -.16 ($P < .05$) (Butson et al., 1980). Singh et al. (1970) found that for every 10% of body weight that was lost by the cow, calf average daily gain increased by .03 kg/day. Also, for every one percent of body weight that was lost by the cow, calf weaning weight increased by .9 kg (Singh et al., 1970).

Winter weight gain of the cow may have had an effect on milk production, calf gain, and calf weaning weight. Brinks et al. (1962) found that the fastest gaining calves came from cows that gained the most (or lost the least) weight during the previous winter. Other studies reported no relationship between winter weight gain and milk yield, calf gain, or calf weaning weight (Butson and Berg, 1984b; Jeffery et al., 1971a). Butson et al. (1980) reported correlations of .16 ($P < .05$) to .21 ($P < .01$) between cow winter weight gain and milk production, .09 to .17 ($P < .05$) between cow winter weight gain and calf gain and .14 ($P < .05$) to .24 ($P < .01$) between cow winter weight gain and weaning weight.

Cow Body Condition Score (BCS) and milk production, calf gain and weaning weight

Level of milk production has been shown to affect a cow's body condition throughout the lactation. Usually, higher milk production was associated with a decrease in condition (Belcher and Frahm, 1979; Montaño-Bermudez and Nielsen, 1990; Mondragon et al., 1983). Wilson et al., (1968) found a correlation between final body condition score and kg of milk produced of -.61.

Marshall et al., (1976) showed that there was no significant correlation between body condition and milk production. Contrary to these reports, Marston et al. (1991) found that body condition score increased throughout lactation. Some of the variability in these correlations is probably due to differences in management and feeding conditions.

Body condition of the cow also affected the weight of the calf at different times. Spitzer et al. (1995) found that cows with a higher body condition score had calves with higher birth weights, but had no differences in dystocia. The effect of cow body condition on calf gain and weaning weight was variable. Graham (1982), Hohenboken et al. (1973), and Spitzer et al. (1995) reported little or no effect of cow condition at calving or during lactation on calf gain or weaning weight. Cow condition before calving had a positive effect on calf growth. Warnick et al. (1981) found that cows with a higher condition score the previous fall weaned heavier calves ($P < .01$).

Freetly and Cundiff (1988) reported that sire breed affected cow condition score ($P < .001$). According to Williams et al. (1979b), the correlation between cow weight to hip height ratio and cow body condition score was .6.

Other measurements of the cow and milk production, calf gain and weaning weight

Jeffery and Berg (1972b) reported that a .01 m increase in cow height was associated with an increase of .97 kg in calf weaning weight. However, other studies have found the correlation between cow height and milk production to be non-significant (Kress and Anderson, 1974; Williams et al., 1979b). Tanner et al. (1965) studied different measurements of the cow and their correlation with calf weight. The correlations between calf weight and these measurements were: .33 for heart girth, .36 for hook width, .45 for wither height, back length, and rump length, and .45 for all measurements (Tanner et al., 1965). Other correlations between calf weaning weight and cow measurements, reported by O'Mary et al. (1959) were .46 ($P < .05$) for foreshank length, .48 ($P < .05$) for forearm circumference and .46 ($P < .05$) for rump length. The multiple correlation coefficient for these measurements was .91 (O'Mary et al., 1959).

Other factors and milk production, calf gain and weaning weight

There are other factors that may affect cow milk yield and calf performance. Most studies have found that stage of lactation, or month of lactation was significant for milk production and gain (Butson and Berg, 1984b; Williams et al., 1979a; Sprivulis et al., 1980). Butson and Berg (1984b) found that calving interval had no effect on milk production. Brown et al. (1970) found that open cows weaned calves that were 50.8 kg heavier than pregnant cows. Season of birth can affect gain and weaning weight (Brown, 1960; Marlowe and Gaines, 1958). Brown (1960) reported that fall-born calves had lower weaning weights than spring-born calves. Date of birth within season has been shown to have a significant effect on milk yield, gain and weaning weight (Nelms and Bogart, 1956; Neville, Jr. et al., 1974). Nelms and Bogart (1956) found that calves born earlier in the breeding season had higher average daily gains.

Lactation curves

The lactation curve of beef cows varied among breeds and levels of milk produced. The curve tended to be more convex for higher milking cows and more linear for lower milking cows (Gaskins and Anderson, 1980). Kress and Anderson (1974) reported a quadratic lactation curve. Gleddie and Berg (1968) found a significant linear decrease in milk yield over the lactation. Mondragon et al. (1983) found a flatter lactation curve for two-year-old cows. Brahman cross cows have been found to produce more milk than European breeds in the hotter summer months, but less in the earlier portions of lactation (Martin and Franke, 1982; Daley et al., 1987). Brahman crosses have also been found to be more persistent (Daley et al., 1987). The difference in shape of lactation curves between dairy and beef suggested that beef cows are more adaptable to changing feed conditions (Klett et al., 1965). The peak production was lower in beef than in dairy because of the inability of the calf to consume all of the milk produced

(Gifford, 1949; Gifford, 1953). Milk production of the cow in early lactation was more than the calf could consume, so it was not a limiting factor in calf growth (Holmes et al., 1968). When the calf couldn't consume all of the milk produced, future production was inhibited (Heynes, 1960). For breeds that produce more milk than the calf can consume in early lactation, the peak occurred earlier (Drewry et al., 1959).

Milk production increased rapidly until it reached a peak at approximately 50 to 65 days (Mallinckrodt et al., 1993; Jenkins and Ferrell, 1984; Dawson et al., 1960; Chenette and Frahm, 1981; Williams et al., 1979a; Gifford, 1949). There are breed differences in the time of peak milk production (Jenkins and Ferrell, 1992). Different crosses have also been found to peak at different times (Jenkins and Ferrell, 1984; Butson and Berg, 1984b; Butson and Berg, 1984a). Some studies have reported that Herefords peak relatively early compared to other breeds (Jenkins and Ferrell, 1992; Kress and Anderson, 1974). Cows that have a higher peak tend to decline at a faster rate after peak (Mallinckrodt et al., 1993). Clutter and Nielsen (1987) found that higher producing cows had a later peak than lower producing cows. After peak, milk production steadily declines (Chenette and Frahm, 1981; Robison et al., 1978; Kress and Anderson, 1974; Mondragon et al., 1983; Reynolds et al., 1978; Gifford, 1953). Gifford's (1949) Hereford study reported monthly average daily yields of 3.9 kg, 3.5 kg, 3.3 kg, 2.7 kg, 2.8 kg, 2.1 kg, 2.1 kg and 1.9 kg. Rutledge et al. (1970a), also using Herefords, found a similar pattern with monthly average daily milk yields of 5.8 kg, 5.7 kg, 5.1 kg, 4.8 kg, 4.4 kg and 4.0 kg. Another Hereford study by Robison et al. (1978) reported daily yields of 5.82 kg, 5.81 kg, 5.54 kg, 5.14 kg, 4.75 kg and 4.09 kg for months one to six. By weaning, cows were producing very little to no milk (Kress and Anderson, 1974). Also, by weaning, much of the difference between breeds was gone (Hardt et al., 1988). Robison et al. (1978) found that the first month was the only one in which the cow produces enough milk to meet the energy needs of the calf.

Repeatability of milk yield

There has been considerable variation in the repeatability of milk yield for different lactations, including non-significant repeatability (Beal et al., 1990), but for the most part, it was highly repeatable (Marston et al., 1992). For Herefords, repeatabilities were $.48 \pm .04$ to $.61 \pm .05$ (Neville, Jr. et al., 1974), .58 (Dillard et al., 1978) and .67 (Mallinckrodt et al., 1993); for Simmental it was .53 (Mallinckrodt et al., 1993). For an across breed study, repeatability was .76 ($P < .0001$) (Marston et al., 1992). In crossbred studies, repeatabilities of milk production were .21 to .67 (Wingert et al., 1984), .34 to .42 (Mondragon et al., 1983) and .85 (Lawson, 1981).

Milk yield estimates within the same lactation were highly repeatable (Williams et al., 1979b). Some repeatabilities that have been reported for measurements within the same lactation were $.32 \pm .06$ (Kress and Anderson, 1974), .38 (Rutledge et al., 1972), .55 ($P < .05$) (Butson and Berg, 1984a), .6 (Pope et al., 1963), .49 to .76 ($P < .01$) (Reynolds et al., 1978) and .93 to 1.0 (Dillard et al., 1978). The highest correlations were usually between adjacent measurements (Kress and Anderson, 1974). Rutledge et al. (1970a) found correlations between monthly milk yields and total milk yield of .61, .67, .72, .74, .74, .72 and .63. Another study reported correlations between individual measurements and total milk production of .83 to .94 ($P < .01$) (Reynolds et al., 1978). These high repeatabilities indicated that most of the same genes affect milk production in early and late lactation (Dillard et al., 1978).

Gain and weaning weight were moderately repeatable from one lactation to another. Some studies have found the repeatability for average daily gain to be .16 to .50 (Wingert et al., 1984) in crossbreds, and the repeatability for weaning weight to be .16 in Angus (Meade et al., 1959), $.29 \pm .06$ to $.45 \pm .06$ (Neville, Jr. et al., 1974) and .42 (Meade et al., 1959) in Hereford and .06 to .45 (Wingert et al., 1984) in crossbreds.

Milking procedure

Time of separation from the calf had an effect on the amount of milk produced by the cow. It has been reported that longer separation times actually result in significantly lower milk production estimates (Chenette and Frahm, 1981; Belcher and Frahm, 1979; Williams et al., 1979a). Daily yields with different separation times have been reported as 9.2 kg (Williams et al., 1979a) for a four-hour separation; $7.86 \pm .24$ kg (Chenette and Frahm, 1981), 7.9 kg (Belcher et al., 1980) and 6.1 kg (Belcher et al., 1980) for a six-hour separation; 7.6 kg (Williams et al., 1979a) for an eight-hour separation; $7.34 \pm .25$ kg (Chenette and Frahm, 1981) for a nine-hour separation; $6.82 \pm .24$ kg (Chenette and Frahm, 1981), 6.8 kg (Belcher et al., 1980), and 5.8 kg (Belcher et al., 1980) for a 12-h separation; and 5.9 kg (Williams et al., 1979a) for a 16-h separation. The most milk was produced in the first six hours of separation (Chenette and Frahm, 1981; Belcher et al., 1980). It is also possible, that with longer separation times, udder capacity was being measured instead of milk production (Williams et al., 1979b). However, daily production calculated from shorter separation times was less precise (Williams et al., 1979a). To get 24-h production from shorter separation intervals, the measured milk yield was multiplied by a larger number (Williams et al., 1979a). Any error associated with the measurement was also multiplied by that larger number (Williams et al., 1979a). Holding cows for longer than six hours caused stress that may have decreased milk production (Lamond et al., 1969). Correlations between milk yield with different separation times and calf daily gain were .27 for four-hour separation, .46 for eight-hour separation and .45 for 16-h separation (Williams et al., 1979a). The repeatabilities of milk production estimates at different separation intervals were .55 for four-hour separation, .61 for eight-hour separation and .79 for 16-h separation (Williams et al., 1979a). This suggests that an eight-hour separation may have been better than a four-hour separation because of a higher correlation with gain and less measurement error (Williams et al., 1979a).

There were several different methods for measuring milk yield including weigh-suckle-weigh (WSW), machine milking with oxytocin injection, hand milking and udder cannulation. The most widely used were WSW and machine milking. Some studies have reported no differences in yield between these two methods (Wistrand and Riggs, 1966; Schwulst et al., 1966). Others have found the estimates were greater with WSW (Mondragon et al., 1983) or greater with machine milking (Belcher et al., 1980). Some correlations between average WSW milk yield and average machine milk yield that have been reported were .469 ($P < .01$) (Belcher et al., 1980), .58 (Gleddie and Berg, 1968) and .77 ($P < .01$) (Beal et al., 1990). Correlations between average WSW milk yield and average daily gain were .157 ($P > .05$) (Belcher et al., 1980) and .76 ($P < .01$) (Beal et al., 1990); and between average WSW milk yield and weaning weight was .086 ($P > .05$) (Belcher et al., 1980). Correlations between average machine milk yield and average daily gain were .291 ($P < .05$) (Belcher et al., 1980) and .75 ($P < .01$) (Beal et al., 1990); and between average machine milk yield and weaning weight was .204 ($P > .05$) (Belcher et al., 1980). Totusek et al. (1973) studied the differences between WSW and hand milking. The WSW estimates were higher than the hand milking estimates, and each method had a different lactation curve (Totusek et al., 1973). The WSW method was more precise (Totusek et al., 1973). The correlation between the two methods at three evenly spaced measurements was .92 ($P < .01$), .95 ($P < .01$) and .95 ($P < .01$) (Totusek et al., 1973).

A concern with machine milking was the variable response of cows to oxytocin (Schwulst et al., 1966). Lamond et al., (1969) found that oxytocin didn't affect the rate of milk secretion. A concern with WSW is that the calf was not consuming all of the milk produced by the cow. Schwulst et al. (1966) found that at two and three weeks, residual milk (milk left in the udder after the calf had finished nursing) was 15% and 11% of the total milk yield.

By taking repeated measurements of milk yield, a more accurate prediction of total milk production could be calculated. The correlation between repeated milk yield estimates ranged from .35 ($P < .01$) to .96 ($P < .01$) (Beal et al., 1990; Gleddie and Berg, 1968; Wilson et al., 1968). For hand milking, the correlation between three evenly spaced measurements and total milk yield was .84 ($P < .01$), .90 ($P < .01$) and .95 ($P < .01$) (Totusek and Arnett, 1965). The correlation

between measured milk yield and total milk production was .80 ($P < .01$) (Totusek and Arnett, 1965) and .87 (Totusek et al., 1973) for two estimates; .91 (Totusek et al., 1973) for four estimates; and .93 (Totusek et al., 1973) to .94 ($P < .01$) (Totusek and Arnett, 1965) for five estimates. For WSW, the correlation between measured milk yield and total milk production was .81 ($P < .01$) for two estimates and .94 ($P < .01$) for five estimates (Totusek and Arnett, 1965). There was greater variation in milk yield estimates later in lactation (Totusek et al., 1973). Using WSW, early estimates indicated calf capacity, while later estimates indicated cow production and persistency (Totusek et al., 1973). Repeated measures of calf gain were also highly correlated. Reynolds et al. (1978) reported a range over three periods of .74 to .99 ($P < .01$).

Correlation of average daily gain with individual estimates of milk yield by WSW ranged from .24 ($P > .05$) to .44 ($P < .01$) (Beal et al., 1990) and from .82 ($P < .01$) to .88 ($P < .01$) (Totusek et al., 1973), with individual estimates of milk yield by machine milking ranged from .70 ($P < .01$) to .74 ($P < .01$) (Beal et al., 1990) and with individual estimates of milk yield by hand milking ranged from .73 ($P < .01$) to .83 ($P < .01$) (Totusek et al., 1973).

Calf milk consumption and forage intake

Calves consumed 10% to 15.3% of their body weight in milk (Gifford, 1953). Calves from lower milking cows started off slower, but were able to catch up somewhat to calves from higher milking cows (Gifford, 1953). Calves from the higher milking cows came back to the average somewhat (Gifford, 1953). Drewry et al. (1959) studied suckling time and found a correlation between suckling time and total gain of -.2868 ($P < .05$). Calves suckled longer and harder on lower producing cows (Drewry et al., 1959).

Boggs et al., (1980) studied forage consumption of calves and how it related to milk consumption and average daily gain. Bull calves ate .23 kg/day more grass than heifers ($P < .05$) (Boggs et al., 1980). Calves that consumed more milk ate less grass (Boggs et al., 1980). For the first two months, calves with increased grass intake had decreased average daily gain (Boggs et al., 1980). These calves were probably trying, unsuccessfully, to compensate for dams that

produced less milk (Boggs et al., 1980). Other studies also found that calves from lower milking cows ate more grass than calves from higher milking dams (Ansotegui et al., 1991; Wood, 1972). At three to five months, increased grass intake tended to increase average daily gain ($P < .1$) (Boggs et al., 1980). One kg more grass increased average daily gain by .02 kg/day (Boggs et al., 1980). Further, Pope et al. (1963) reported that fall calves were more dependent on milk than spring calves because there was less grass to supplement their diet.

Calf body condition score and conformation score

There was a moderate correlation between milk production and calf condition score. This correlation was .52 for Herefords and .38 for Angus (Cobb et al., 1978a). Cow breed had a non-significant effect on calf condition score (Brown et al., 1970). Brown et al. (1970) found that calves with heavier birth weights had higher weaning condition scores. Also, cow age had a significant linear and quadratic effect on weaning condition score (Brown et al., 1970). Cow size has been found not to affect calf body condition score and calf conformation score (Wilson et al., 1969).

Cow and calf efficiency

Milk production affected efficiency of the cow and calf. Wyatt et al. (1977) found that as milk intake and gain increased, efficiency decreased. Clutter and Nielsen's (1987) study with high, medium and low milk producing crossbred cows found that 31.25 kg of milk was needed for one kg of calf gain for the high and medium groups, while only 18.81 kg of milk was needed for one kg of calf gain for the low group. Drewry et al. (1959) also reported that calves from higher milking dams were less efficient, requiring more milk per unit of gain. However, in a study by McGinty and Frerichs (1971), calves from higher milking cows were more efficient in the

utilization of milk and creep. Smaller cows were more efficient, having greater calf weight to cow weight ratios (Urlick et al., 1971).

Previous work at the Oklahoma State University North Range

Performance of cows used in this study as calves indicates that milk EPD level and breed group had little effect on performance (Ziehe et al., 1992). This was as expected, because the sires were chosen to have similar growth EPD and divergent milk EPD. In the first calving season of these heifers, there were no significant differences in birth weight between the groups (Buchanan et al., 1992). Calves out of high milk cows were heavier at 205 days than calves out of low milk cows ($P < .05$) (Buchanan et al., 1992). The high milk Angus cows weaned calves that were 38.1 kg heavier than the low milk Angus cows (Buchanan et al., 1992). This was much higher than the 12.8 kg difference predicted by the grandsire EPD (Buchanan et al., 1992). The high milk Hereford cows weaned calves that were 21.3 kg heavier than the low milk Hereford cows (Buchanan et al., 1992). This was higher than the 9.3 kg predicted by the grandsire EPD (Buchanan et al., 1992). When the first two seasons of data were analyzed together, the high milk cows had heavier birth weight calves than the low milk cows ($P < .05$) (Buchanan et al., 1993). Calves from the high milk Angus cows were 25.6 kg heavier at weaning than calves from the low milk Angus cows ($P < .05$) (Buchanan et al., 1993). The difference predicted by the grandsire EPD was 12.8 kg (Buchanan et al., 1993). Calves from the high milk Hereford cows were 3.9 kg heavier than calves from the low milk Hereford cows (Buchanan et al., 1993). Unlike the Angus, this difference was less than the 9.3 kg predicted by the grandsire EPD (Buchanan et al., 1993). There were no differences in cow weight at weaning, however, the high milk Angus and high milk Hereford had lower body condition scores than the low milk Angus and low milk Hereford ($P < .05$) (Buchanan et al., 1993).

When data from 1993 were analyzed, high milk cows had calves with heavier birth weights than low milk cows, but the difference was significant only in Angus ($P < .01$) (Buchanan et al., 1995). Weaning weights were significantly different between high and low milk groups in

both breeds ($P < .01$), with a 18.8 kg difference in Angus, and a 16.1 kg difference in Hereford (Buchanan et al., 1995). Both of the differences in weaning weights were greater than predicted by the grandsire EPD (Buchanan et al., 1995). The body condition scores of the high milk groups were lower than the low milk groups, but the difference was significant only in Angus cows ($P < .01$) (Buchanan et al., 1995). High milk cows tended to be lighter, but the difference was not significant (Buchanan et al., 1995).

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CHAPTER II

MILK PRODUCTION OF CROSSBRED DAUGHTERS OF HIGH AND LOW MILK EPD ANGUS AND HEREFORD BULLS

ABSTRACT

Milk production is a major factor in the weaning weight of calves which, in turn, affects profitability of cow-calf enterprises. The objective of this study was to determine how accurately milk EPD of Angus and Hereford sired predicted milk production of crossbred daughters and subsequent calf performance. Bulls were chosen from each breed ($n = 41$) to represent high or low milk EPD. Mean EPD in kg for high Angus (HA), low Angus (LA), high Hereford (HH) and low Hereford (LH) were +8.7, -6.1, +7.4 and -3.9. Cows ($n = 273$) calved in spring or fall from 1992-97 for a total of 660 records. Twenty-four hour milk production of the cows was estimated by two weigh-suckle-weigh measurements at monthly intervals. Cow weight and body condition score (BCS, 1 – 9) were obtained at weaning. The least squares model included breed, milk EPD level, sire of cow within breed and milk EPD level, year, season, cow age, calf sire, sex and all two- and three-way interactions. Means were obtained for monthly milk production, birth and 205-d weight and final cow weight and BCS. The least squares means for 24-h milk production, in kg, for HA, LA, HH and LH with P-values for high versus low, across breeds, were: period 1) 6.88, 5.87, 6.59 and 5.70 ($P < .01$); period 2) 7.20, 6.12, 6.92 and 5.74 ($P < .01$); period 3) 6.12, 5.11, 5.07 and 4.25 ($P = .01$); period 4) 6.07, 4.92, 4.87 and 4.78 ($P = .01$); period 5) 4.80, 3.97, 4.15 and 3.75 ($P = .01$); period 6) 4.70, 3.36, 3.18 and 2.96 ($P < .01$); period 7) 3.72, 2.53, 3.02 and 2.97 ($P = .05$). Similarly, least squares means for birth weight were 37.07, 37.85, 38.33 and 38.78 ($P = .31$); for 205-d weight were 237.26, 218.23, 222.17 and 214.12 ($P < .01$); for final cow weight were 482.40, 505.39, 509.49 and 511.65 ($P = .11$); and for final cow BCS were 4.90, 5.25, 5.09

and 5.20 ($P < .01$). Daughters of high milk EPD sires produced more milk and weaned heavier calves than those of low milk EPD sires. However, it is at the expense of body condition. Producers can use milk EPD with confidence to influence calf weight.

Introduction

Milk production of beef cows is a major factor in the weaning weight of calves which, in turn, affects the profitability of cow-calf enterprises. High milking cows should produce calves that are heavier at weaning, but they may do this at the expense of body condition and reproductive efficiency. Expected Progeny Differences (EPD) have been developed to predict the genetic merit of cattle for different traits. The milk EPD describes the maternal ability of dams. The milk EPD of two bulls predicts the difference in weaning weights of calves from those bulls' daughters, due to the milk production of the daughters. This EPD is measured in units of calf weaning weight, not units of milk. The objective of this study was to evaluate how well the milk EPD predicts actual differences in milk production and calf performance and to determine its relationship to cow body condition and weight.

Materials and Methods

An existing herd of crossbred cows was mated to Angus or Hereford (polled) sires that were either very high or very low for milk EPD. The crossbred cows were Hereford – Angus, $\frac{1}{4}$ Brahman – $\frac{1}{4}$ Angus – $\frac{1}{2}$ Hereford and $\frac{1}{4}$ Brahman – $\frac{1}{4}$ Hereford – $\frac{1}{2}$ Angus. Nine low milk Polled Hereford bulls, nine high milk Polled Hereford bulls, 11 low milk Angus bulls and 12 high milk Angus bulls were used. EPD for these bulls are presented in Table 1. At the time of selection, each bull had an accuracy greater than .50. Heifers from these matings were born from 1989 through 1993. These heifers were mated to Angus, Gelbvieh, Polled Hereford, Salers, Limousin, Charolais, Maine-Anjou or crossbred bulls to calve starting in 1991. Not all breeds

TABLE 1. AVERAGE EXPECTED PROGENY DIFFERENCE (KG) FOR HIGH AND LOW MILK
EPD ANGUS AND HEREFORD BULLS

Breed	Milk Level	n	BWEPD	WWEPD	MILKEPD
Angus	High	12	1.13	9.66	8.71
Angus	Low	11	2.31	12.15	-6.21
Hereford	High	9	1.18	10.11	7.62
Hereford	Low	9	2.54	11.93	-4.76

were used in any one year. Heifers and cows were artificially inseminated and then turned out with crossbred bulls for a 75-d total breeding season. Spring calving took place from February through April and fall calving took place from September through November. The same sires were used for spring and fall calving seasons within a single year.

At the time of calving, all calves were weighed and males were castrated. The cows were scored for condition, and a difficulty score was assigned to the calving. Cows and calves were placed on pasture and the calves did not receive any creep feed. At seven monthly intervals (approximately at an average of days 37, 65, 93, 121, 149, 177 and 205 after calving), a weigh-suckle-weigh measurement of milk production was performed. Cows and calves were separated on the afternoon of the previous day. At 0545 hours on the day of the measurement, calves were paired with cows and allowed to nurse. This ensured that all cows were milked out at the beginning of the separation period. After the cows were nursed out, they were weighed and a body condition score was assigned. The scores ranged from one (emaciated) to nine (extremely fat) (Table 2) (Richards et al., 1986). Two observers scored the cows and the scores were averaged. After weighing and scoring, the cows were returned to pens and kept separate from their calves. At 1145 hours, calves were weighed, returned to their dams, allowed to nurse, and reweighed. The difference between the two weights was the 6-h milk production of the cow. This weighing procedure was repeated at 1745 hours to obtain two estimates of 6-h milk production. These 6-h estimates were used to calculate a 24-h estimate of milk production for each cow.

Calves were weaned at approximately 205 days and 240 days for spring- and fall- born calves, respectively. Weights, body condition scores, conformation scores and hip heights were collected on the calves at weaning. Condition scores were assigned based on the same scale used for the cows. Conformation scores were a measure of muscling and ranged from 11 (light

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- Cow still appears somewhat emaciated but tail-head and ribs are less prominent. Individual spinous processes are still rather sharp 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 the 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. Some fat around vulva and in crotch.
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. "Rounds" or "pones" are obvious.
9	EXTREMELY FAT- Cow obviously extremely wasty and patchy 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.

(Richards et al., 1986)

muscling) to 15 (heavy muscling). Two observers determined condition and conformation scores, and the scores were averaged. Two hip height measurements were taken and averaged.

Cows and calves were pastured at the North Lake Carl Blackwell Range on native grasses. During the winter, dry cows were supplemented with 41% crude protein cubes three times per week. In October, they were fed approximately .45 kg/(head·day); from November to December they received approximately .91 kg/(head·day); and from January to calving they were fed approximately 2.72 kg/(head·day). Cows nursing fall-born calves were also supplemented with 41% crude protein cubes. They received .45 kg/(head·day) in October, .91 kg/(head·day) in November, 1.81 kg/(head·day) in January and 2.27 kg/(head·day) in February. An addition, cows received approximately 13.61 kg of grass hay every day when grass was not available.

Data were analyzed using ordinary least squares. Analyzed traits included seven monthly measurements of milk production, calf weight and cow weight, and eight measurements of cow BCS. In addition, calf birth weight, 205-d weight, and weight, hip height, condition score and conformation score at weaning were analyzed. Terms included in the models were cow sire breed, milk EPD level, sire of cow, year, season, age of cow within year, sire of calf, sex of calf, age of calf and all two- and three-way interactions. The models for the monthly cow weights and BCS did not include sire of calf, sex of calf or age of calf. The models for birth weight and 205-d weight did not include age of calf. The error term used to test breed, milk level and breed x milk level was cow sire (breed x milk level).

Lactation curves were estimated by the method of Jenkins and Ferrell (1982, 1984). Amount of milk produced was divided by day 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. Because the earliest measurement of milk production was at an average of 37 days after calving, it was inappropriate to estimate the total amount of milk produced in the lactation. However, a curve was fitted for each lactation and an estimate of milk production between the first measurement and weaning was calculated for each cow. This measure of milk production from month one to month seven will be referred to as total milk production. The Jenkins and Ferrell curve was also used to find the time and yield at peak lactation for each cow. Partial correlations were computed between total milk and the monthly milk production estimates, birth weight, 205-d weight, weaning weight, weaning hip height, weaning calf conformation score, weaning calf BCS, weaning cow weight and weaning cow BCS.

Results and Discussion

Milk production

High milk cows produced more milk than low milk cows in months one through seven, and produced more total milk ($P < .05$) (Table 3, Appendix Tables 1 and 2). Angus cows produced more milk than Hereford cows throughout the lactation and in months three, four and six ($P < .05$) (Table 3, Appendix Tables 1 and 2). 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. Steers received more milk than heifers in months three and six ($P < .05$) (Table 4, Appendix Tables 1 and 2). Season was significant for total milk production and in month six ($P < .05$) (Table 5, Appendix Tables 1 and 2). Spring-calving cows produced more total milk than fall-calving cows. Sire of cow affected total milk production and milk production in month two ($P < .05$) (Appendix Tables 1 and 2). Year affected milk production in months two, five and six ($P < .05$) (Appendix Tables 1 and 2). Age of calf, or days in lactation, was significant in months one, two, three, four and six ($P < .05$) (Appendix Tables 1 and 2). Cow age within year and sire of calf were not significant in any month ($P > .2104$) (Appendix Tables 1 and 2). Significant interactions for milk production were: breed x milk level in months four and six; breed x year in month three; breed x season in month seven; breed x cow age (year) in month seven; milk level x sex in month six and overall; year x season in months one, two, three, four, five, seven and overall; year x sex in months three, four, five, six and overall; season x sex in months four and seven; milk level x year x season in month five; milk level x year x sex in months two and four; milk level x season x sex in month one and year x season x sex in months three, four, five, seven and overall ($P < .05$) (Appendix Tables 1 and 2).

For each month and overall, high milk cows produced more milk than low milk cows. This was similar to what was expected from the sires' milk EPD and agreed with the results reported by Marston et al. (1992) and Marshall and Long (1993), but disagreed with Marshall and

TABLE 3. LEAST SQUARES MEANS BY BREED AND MILK LEVEL FOR THE SEVEN MONTHLY MEASUREMENTS OF 24-H MILK PRODUCTION (KG), TOTAL MILK PRODUCTION (KG), YIELD AT PEAK LACTATION (KG) AND TIME OF PEAK LACTATION (DAYS)

	Angus		Hereford		P-value ^a	Avg. std. error
	High milk	Low milk	High milk	Low milk		
Month 1 ^b	6.88	5.87	7.05	5.70	.0007	.520
Month 2	7.20	6.12	6.92	5.74	.0017	.574
Month 3	6.12	5.11	5.07	4.25	.0006	.463
Month 4	6.07	4.92	4.87	4.78	.0120	.444
Month 5	4.80	3.97	4.15	3.75	.0145	.426
Month 6	4.70	3.36	3.18	2.96	.0013	.447
Month 7	3.72	2.53	3.02	2.97	.0465	.614
Total milk	911.44	729.58	757.97	664.15	.0001	48.86
Peak yield	6.98	5.74	6.07	5.24	.0001	.432
Peak time	56.84	81.83	67.70	70.84	.4310	33.16

^a P-value for differences between levels within breed.

^b 28-d intervals beginning approximately one month after average calving date

TABLE 4. LEAST SQUARES MEANS BY CALF SEX FOR THE SEVEN MONTHLY MEASUREMENTS OF 24-H MILK PRODUCTION (KG), TOTAL MILK PRODUCTION (KG), YIELD AT PEAK LACTATION (KG) AND TIME OF PEAK LACTATION (DAYS)

	Steers	Heifers	P-value	Avg. std. error
Month 1 ^a	6.45	6.07	.1137	.519
Month 2	6.49	6.51	.9281	.426
Month 3	5.43	4.85	.0122	.420
Month 4	5.16	5.17	.9519	.384
Month 5	4.14	4.19	.7825	.371
Month 6	3.91	3.19	.0004	.402
Month 7	2.85	3.27	.1176	.489
Total milk	781.37	750.37	.1349	35.92
Peak yield	6.12	5.89	.2363	.343
Peak time	66.42	72.19	.6918	27.35

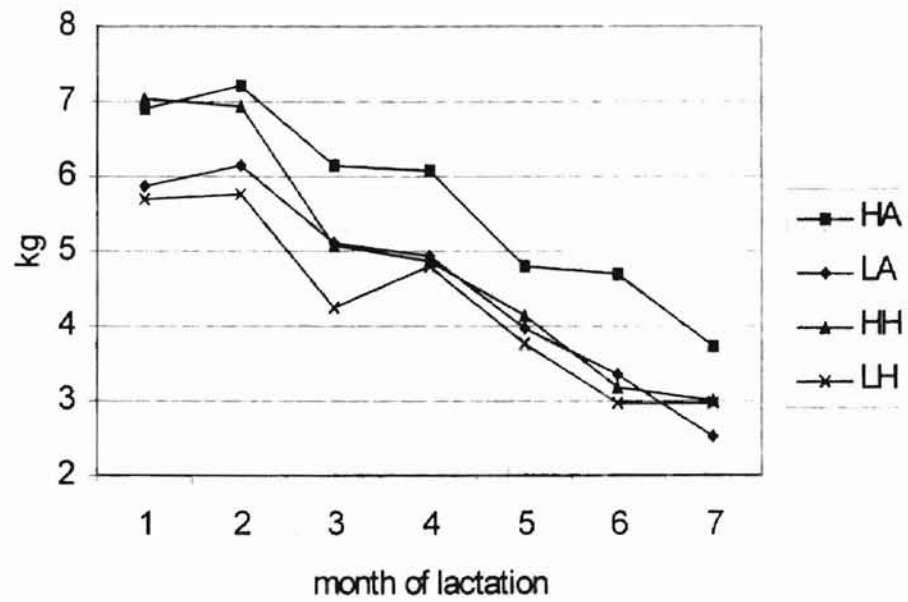
^a 28-d intervals beginning approximately one month after average calving date

TABLE 5. LEAST SQUARES MEANS BY SEASON FOR THE SEVEN MONTHLY MEASUREMENTS OF 24-H MILK PRODUCTION (KG), TOTAL MILK PRODUCTION (KG), YIELD AT PEAK LACTATION (KG) AND TIME OF PEAK LACTATION (DAYS)

	Spring	Fall	P value	Avg. std. error
Month 1 ^a	6.55	5.97	.2063	.554
Month 2	6.72	6.27	.2334	.450
Month 3	5.23	5.04	.5857	.440
Month 4	5.32	5.00	.3259	.403
Month 5	4.26	4.07	.5418	.389
Month 6	4.05	3.06	.0001	.407
Month 7	2.92	3.20	.4788	.512
Total milk	799.72	731.85	.0310	37.75
Peak yield	6.31	5.70	.0407	.360
Peak time	73.91	64.69	.6100	27.87

^a 28-d intervals beginning approximately one month after average calving date

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



Freking (1988), who found that daughters of high and low milk EPD sires didn't produce significantly different amounts of milk.

In the months three, four and six, and overall, Angus cows produced more milk than Hereford cows. This agreed with the results of Jenkins and Ferrell (1992), who found that Angus produced more milk than Herefords. Melton et al. (1967b) also reported that Angus produced more average daily milk than Herefords.

Season affected milk production in month six, and affected total milk production. Spring-calving cows produced more milk than fall calving cows. This is probably because they spend a greater part of their lactation on summer pasture; whereas, fall-calving cows spend most of their lactation on winter feed.

In months three and six, steers received more milk than heifers. This agreed with results reported by Daley et al. (1987), Jeffery et al. (year 1) (1971a), Pope et al. (1963) and Wingert et al. (1984). However, several other studies, including Jeffery et al. (year 2) (1971a) and Rutledge et al. (1971), found that heifers received more milk. The majority of studies, including Lawson et al. (1981), Butson and Berg (1984), Williams et al. (1979), Robison et al. (1978), Marshall et al. (1976), Christian et al. (1965), Reynolds et al. (1978), Todd et al. (1968), Gleddie and Berg (1968), Melton et al. (1967b) and Neville, Jr. et al. (1974), have reported no difference in the amount of milk received between steers and heifers. Our results for months one, two, four, five, seven, and the prediction of total milk agreed with these findings. Steers may have received more milk simply because they were larger than heifers and were able to consume more.

In this study, cow age had little effect on milk production. This disagreed with results found by Williams et al. (1979), Robison et al. (1978), Jeffery et al. (1971a), Rutledge et al. (1970a), Christian et al. (1965), Drewry et al. (1959), Sprivulis et al. (1980), Reynolds et al. (1978), Nemis et al. (1978), Melton et al. (1967a), Gifford (1953), Neville, Jr. et al. (1974) and Todd et al. (1969). However, these results are from three-, four- and five-year-old cows only. This limitation in age range may not have allowed differences in milk production due to age to be expressed.

Using the Jenkins and Ferrell lactation equation, the shape of the curves differed between breed milk level group and between seasons (Figures 2 and 3, Appendix Table 3). Interactions were detected between the regression coefficient and breed x milk level, and the regression coefficient and breed x season (Appendix Table 3).

The Jenkins and Ferrell equation was able to predict time of peak lactation and yield at peak lactation. At peak, high milk cows produced more milk than low milk cows, and Angus produced more milk than Herefords ($P < .05$) (Table 3, Appendix Table 2). Season and days in lactation were also significant ($P < .05$) (Appendix Table 2). Cows that calved in the spring had a higher yield at peak than cows that calved in the fall ($P < .05$). Significant interactions were year x season and year x sex ($P < .05$) (Appendix Table 2). No significant differences existed between breed or milk level in the time of peak lactation (Table 3, Appendix Table 2). Additionally, no sources of variation in the model were significant (Appendix Table 2). Peak lactation for these cows occurred later than the 50 to 65 days reported by Mallinckrodt et al. (1993), Jenkins and Ferrell (1984), Dawson et al. (1960), Chenette and Frahm (1981), Williams et al. (1979) and Gifford (1949). This may be because of different nutritional or environmental conditions.

Figure 2. Lactation curves (Jenkins and Ferrell, 1982, 1984)
for high and low (H, L) milk Angus and Hereford (A, H) cows

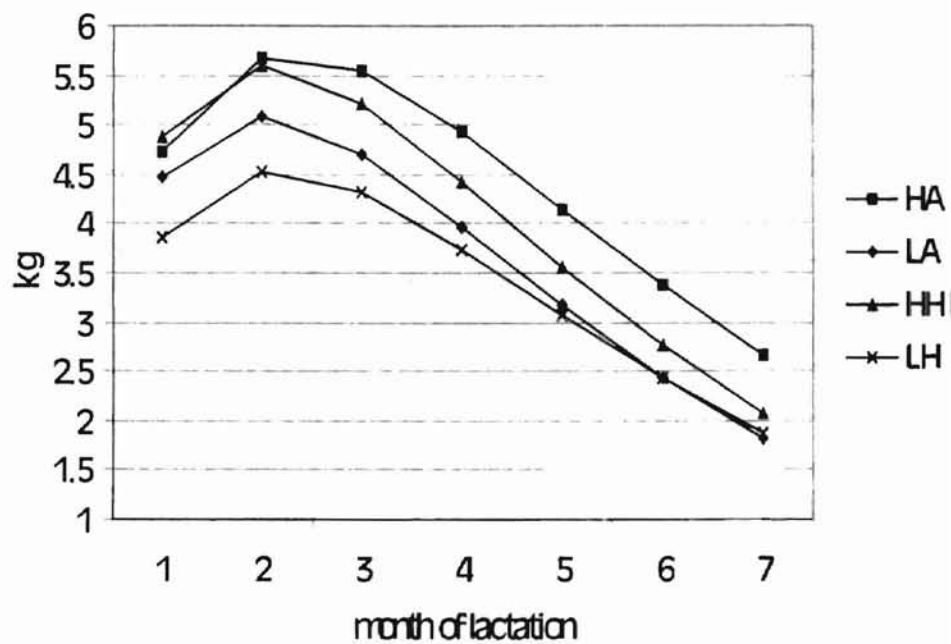
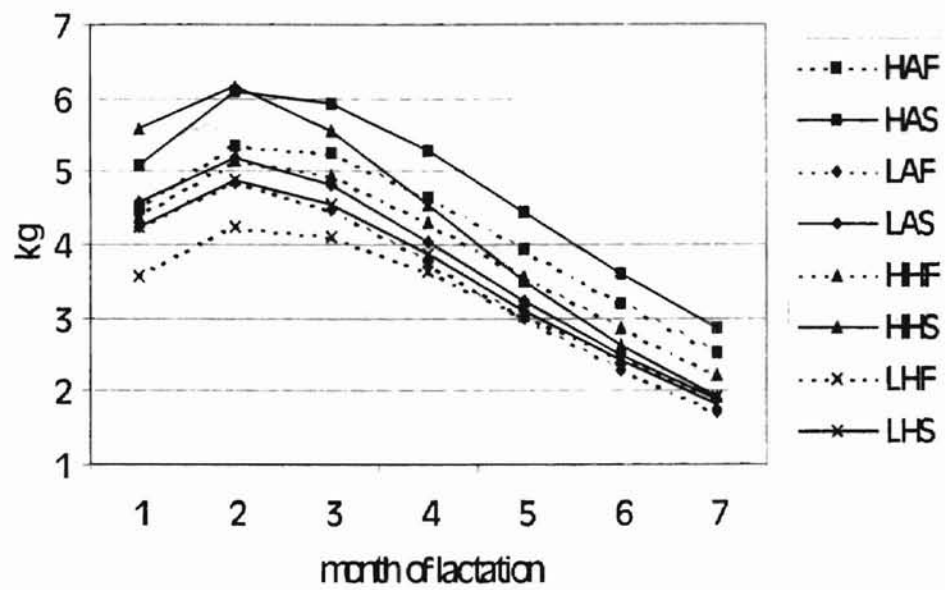


Figure 3. Lactation curves (Jenkins and Ferrell, 1982, 1984) by season (F=fall, S=spring) for high and low (H, L) milk Angus and Hereford (A, H) cows



Calf weight

High milk cows had calves that were heavier than low milk cows in all months ($P < .05$) (Table 6, Appendix Table 4). Angus cows had heavier calves than Hereford cows only in month seven ($P < .05$) (Table 6, Appendix Table 4). Figure 4 shows the growth curves of calves from the four breed milk level groups of cows. Cow sire, year, sex of calf and age of calf were significant for all months ($P < .05$) (Appendix Table 4). Steer calves were heavier than heifers in all months (Table 7). Season was significant in all months except the second ($P < .05$) (Table 8, Appendix Table 4). In month one, fall-born calves were heavier than spring-born calves, but in months three through seven, spring-born calves were heavier than fall-born calves. Cow age within year affected calf weights in months two, three and four ($P < .05$) (Table 9, Appendix Table 4). Calf sire was not significant in any month ($P > .05$) (Appendix Table 4). Significant interactions were: breed x cow age (year) in month two; year x season in all months; season x cow age (year) in months two, three and four and milk level x season x sex in months two, three, four and five ($P < .05$) (Appendix Table 4).

In all months, calves out of high milk level EPD cows were heavier than calves out of low milk level EPD cows. This was expected and agreed with the finding of Klett et al. (1965), Kress and Anderson (1974), Gifford (1953), Melton et al. (1967a), Butson and Berg (1984), Neville, Jr. et al. (1962), Todd et al. (1968), Chenette and Frahm (1981), Carpenter, Jr. et al. (1972), Wilson et al. (1969), Reynolds et al. (1978), Clutter and Nielsen (1987), Butson et al. (1980), Holmes et al. (1968) and Gleddie and Berg (1968) that milk production of the cow has a significant positive effect on gain of the calf.

Breed of dam affected calf weight only at the end of lactation. Wingert et al. (1984) found that the breed of cow had no effect on the gain of the calf. However, most studies, including Freetly and Cundiff (1998), Lawson (1976), Jeffery et al. (1971b), Brown et al. (1970), and Nelson et al. (1985) reported that cow breed had an effect on calf gain.

Season of birth affected calf weight at all measurements except month two. Fall-born

TABLE 6. LEAST SQUARES MEANS BY BREED AND MILK LEVEL FOR THE SEVEN MONTHLY MEASUREMENTS OF CALF WEIGHT (KG)

	Angus		Hereford		P-value ^a	Avg. std. error
	High milk	Low milk	High milk	Low milk		
Month 1 ^b	84.00	78.27	81.38	78.86	.0020	2.861
Month 2	105.01	97.90	101.63	98.80	.0058	3.239
Month 3	129.84	119.65	123.94	120.51	.0026	4.286
Month 4	154.63	142.68	147.76	142.36	.0013	5.083
Month 5	182.86	167.82	175.15	168.50	.0007	6.114
Month 6	207.10	190.32	196.44	189.43	.0006	6.455
Month 7	230.45	211.40	215.03	206.81	.0002	6.564

^a P-value for differences between levels within breed.

^b 28-d intervals beginning approximately one month after average calving date

TABLE 7. LEAST SQUARES MEANS BY CALF SEX FOR THE SEVEN MONTHLY MEASUREMENTS OF CALF WEIGHT (KG)

	Steers	Heifers	P-value	Avg. std. error
Month 1 ^a	83.08	78.18	.0001	1.855
Month 2	104.08	97.59	.0001	1.897
Month 3	127.14	119.83	.0001	2.432
Month 4	151.40	142.32	.0001	2.870
Month 5	178.72	168.44	.0001	3.444
Month 6	201.33	190.32	.0001	3.711
Month 7	222.06	209.78	.0001	3.950

^a 28-d intervals beginning approximately one month after average calving date

TABLE 8. LEAST SQUARES MEANS BY SEASON FOR THE SEVEN MONTHLY MEASUREMENTS OF CALF WEIGHT (KG)

	Spring	Fall	P-value	Avg. std. error
Month 1 ^a	78.70	82.56	.0179	1.980
Month 2	100.40	101.27	.6326	2.033
Month 3	127.12	119.85	.0006	2.594
Month 4	155.31	138.40	.0001	3.064
Month 5	188.98	158.18	.0001	3.687
Month 6	219.02	172.63	.0001	3.954
Month 7	241.11	190.74	.0001	4.238

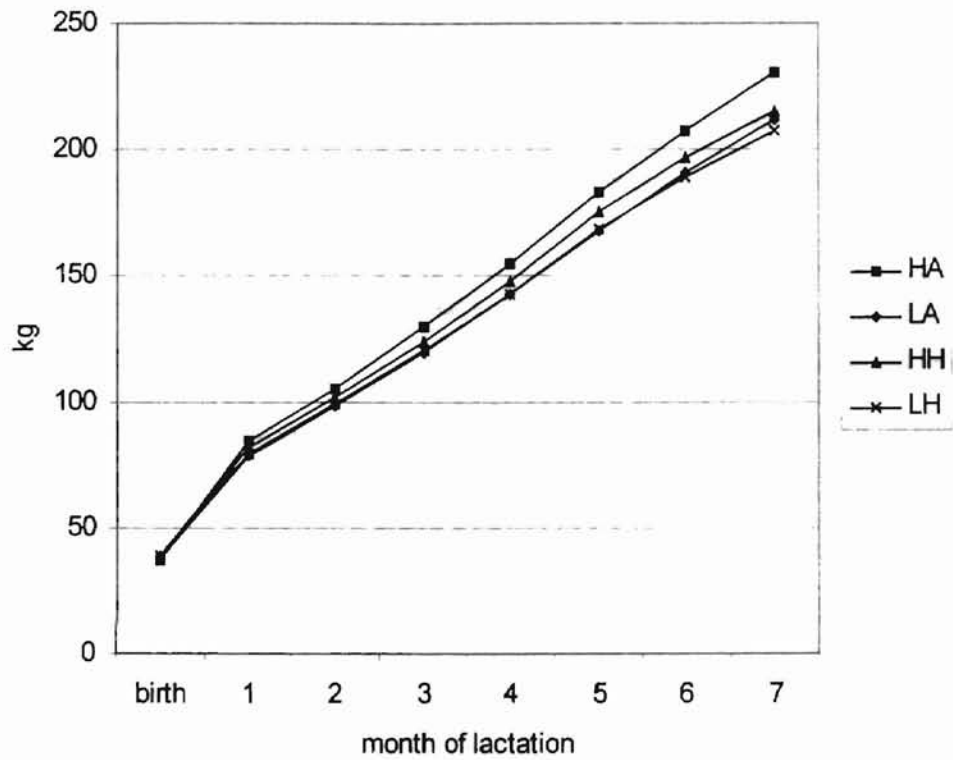
^a 28-d intervals beginning approximately one month after average calving date

TABLE 9. LEAST SQUARES MEANS BY COW AGE WITHIN YEAR FOR THE SEVEN
MONTHLY MEASUREMENTS OF CALF WEIGHT (KG)

Cow age (year)	1 ^a	2	3	4	5	6	7
3 (92)	73.09	84.83	103.54	124.21	147.16	168.75	182.22
3 (93)	62.61	73.67	92.73	116.33	141.60	167.78	189.76
4 (93)	84.33	102.29	123.91	150.87	177.41	203.97	227.13
3 (94)	70.71	82.74	102.67	124.00	144.96	163.78	193.79
4 (94)	89.83	111.80	135.70	160.23	187.89	209.07	237.43
5 (94)	94.18	114.59	140.81	166.84	196.12	219.46	251.05
3 (95)	85.90	108.92	132.50	158.56	187.66	213.01	234.74
4 (95)	83.17	105.81	128.15	153.77	181.92	206.40	227.69
5 (95)	86.60	110.91	134.97	161.35	189.78	212.98	230.84
3 (96)	80.47	110.06	133.78	152.37	182.05	203.85	211.16
4 (96)	81.37	107.61	129.57	150.81	176.96	203.77	226.82
5 (96)	82.90	107.63	129.43	149.30	174.93	201.12	223.93
4 (97)	85.76	115.19	143.74	167.19	197.15	209.97	219.33
5 (97)	85.26	109.17	135.97	161.30	190.98	208.35	232.11
P-value	.0567	.0051	.0112	.0325	.0716	.1172	.0573
Avg. std. error	5.085	5.141	6.399	7.551	9.011	9.784	10.370

^a 28-d intervals beginning approximately one month after average calving date

Figure 4. Average calf weights over the lactation for high and low (H, L) milk Angus and Hereford (A, H) cows



calves weighed more in month one than spring-born calves. This was probably because there was better grass for fall calves in month one (October) than for spring calves (April). Spring calves weighed more at months three through seven. Again, this is probably because the grass was better in these months for spring calves (June through October) than for fall calves (December through April). These results agreed with Brown (1960) and Marlowe and Gaines (1958). At all measurements, steer calves were heavier than heifer calves. This was expected and agreed with the findings of Jeffery and Berg (1972), Franke et al. (1975), Jeffery et al. (1971b), Christian et al. (1965), Knapp, Jr. and Black (1941), Wingert et al. (1984), Nelms et al. (1978), Melton et al. (1967b), Neville, Jr. (1962), Marlowe and Gaines (1958), Reynolds et al. (1978) and Rutledge et al. (1971).

Age of dam was significant for calf weight in months two through four. That is somewhat surprising, since age of dam did not affect milk production in any month. This may indicate that older cows are doing something besides producing milk to cause their calves to be heavier. Most studies have reported that age of dam affects calf weight throughout lactation (Singh et al., 1970; Williams et al., 1979; Franke et al., 1975; Reynolds et al., 1978; Marlowe and Gaines, 1958). However, some researchers have found no relationship between cow age and calf gain (Sprivulis et al., 1980; Neville, Jr., 1962). It is important to remember that this study only used three-, four- and five-year-old cows.

Cow weight

No significant differences in cow weight were detected between milk levels in any month ($P > .05$) (Table 10, Appendix Table 5). Angus cows were lighter than Hereford cows in months four and five ($P < .05$) (Table 10, Appendix Table 5). Figure 5 shows the changes in cow weight over the lactation for the four breed milk level groups. Sire of cow, year and cow age within year were significant in all months ($P < .05$) (Appendix Table 5). Cow weight increased with age within year ($P < .05$) (Table 13, Appendix Table 5). Season affected cow weight in months one, two, three, five, six and seven ($P < .05$) (Table 11, Appendix Table 5). In the first three months, fall-

TABLE 10. LEAST SQUARES MEANS BY BREED AND MILK LEVEL FOR THE SEVEN MONTHLY MEASUREMENTS OF COW WEIGHT (KG)

	Angus		Hereford		P-value ^a	Avg. std. error
	High milk	Low milk	High milk	Low milk		
Month 1 ^b	486.17	501.22	509.61	509.45	.3510	9.635
Month 2	471.26	490.44	491.54	491.31	.2136	8.207
Month 3	481.11	496.35	499.33	498.51	.3527	8.113
Month 4	483.18	505.32	513.99	517.06	.1123	9.494
Month 5	481.49	503.62	511.26	513.65	.1373	9.309
Month 6	480.09	502.05	507.95	511.43	.1246	9.327
Month 7	482.40	505.39	509.49	511.65	.1144	8.967

^a P-value for differences between levels within breed.

^b 28-d intervals beginning approximately one month after average calving date

TABLE 11. LEAST SQUARES MEANS BY SEASON FOR THE SEVEN MONTHLY MEASUREMENTS OF COW WEIGHT (KG)

	Spring	Fall	P-value	Avg. std. error
Month 1 ^a	472.96	530.27	.0001	4.933
Month 2	465.62	506.65	.0001	4.196
Month 3	483.41	504.24	.0001	3.524
Month 4	507.91	501.96	.2524	4.361
Month 5	514.83	490.17	.0001	3.939
Month 6	526.13	474.63	.0001	3.922
Month 7	536.99	467.47	.0001	3.862

^a 28-d intervals beginning approximately one month after average calving date

TABLE 12. LEAST SQUARES MEANS BY BREED, MILK LEVEL AND SEASON FOR THE SEVEN MONTHLY MEASUREMENTS OF COW WEIGHT (KG)

Breed Level Season	1 ^a	2	3	4	5	6	7
Angus High Fall	511.86	489.37	490.84	478.03	466.07	452.99	446.39
Angus High Spring	460.49	453.14	471.37	489.73	496.91	507.19	518.41
Angus Low Fall	524.77	507.93	503.82	501.25	489.11	475.05	468.72
Angus Low Spring	477.68	472.94	488.88	507.95	518.13	529.05	542.05
Hereford High Fall	527.47	502.49	499.74	502.10	489.24	470.18	463.35
Hereford High Spring	491.74	480.59	498.92	528.24	533.27	545.71	555.62
Hereford Low Fall	556.98	526.80	522.56	526.90	516.29	500.29	491.42
Hereford Low Spring	461.92	455.83	474.45	504.88	511.01	522.56	531.88
P-value	.0016	.0052	.0033	.0239	.0082	.0030	.0026
Avg. std. error	8.086	7.086	6.488	7.300	7.063	7.032	6.924

^a 28-d intervals beginning approximately one month after average calving date

TABLE 13. LEAST SQUARES MEANS 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
3 (92)	500.07	490.88	493.83	504.83	499.45	488.92	487.23
3 (93)	449.58	430.89	432.66	454.37	461.35	473.92	457.65
4 (93)	518.51	498.27	500.91	520.23	514.26	525.14	510.61
3 (94)	473.04	466.14	477.32	470.14	467.82	456.37	478.84
4 (94)	532.97	517.42	520.23	526.71	516.63	505.11	526.54
5 (94)	566.99	556.77	552.87	560.25	542.08	532.00	555.47
3 (95)	453.43	450.14	315.87	460.03	445.79	445.86	446.77
4 (95)	496.55	490.47	495.24	491.96	496.97	493.42	497.56
5 (95)	542.48	529.20	527.25	544.31	537.98	538.20	535.48
3 (96)	431.15	391.95	442.93	440.71	479.10	480.86	484.91
4 (96)	478.34	470.94	468.59	477.62	461.16	468.75	484.34
5 (96)	504.93	503.95	515.51	510.22	506.13	514.37	528.91
4 (97)	545.25	498.95	516.54	564.48	560.76	555.13	542.34
5 (97)	519.28	505.77	528.36	522.52	525.65	515.88	515.84
P-value	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Avg. std. error	12.715	10.738	9.209	11.620	10.572	10.526	10.365

^a 28-d intervals beginning approximately one month after average calving date

Figure 5. Average cow weights over the lactation for high and low (H, L) milk Angus and Hereford (A, H) cows

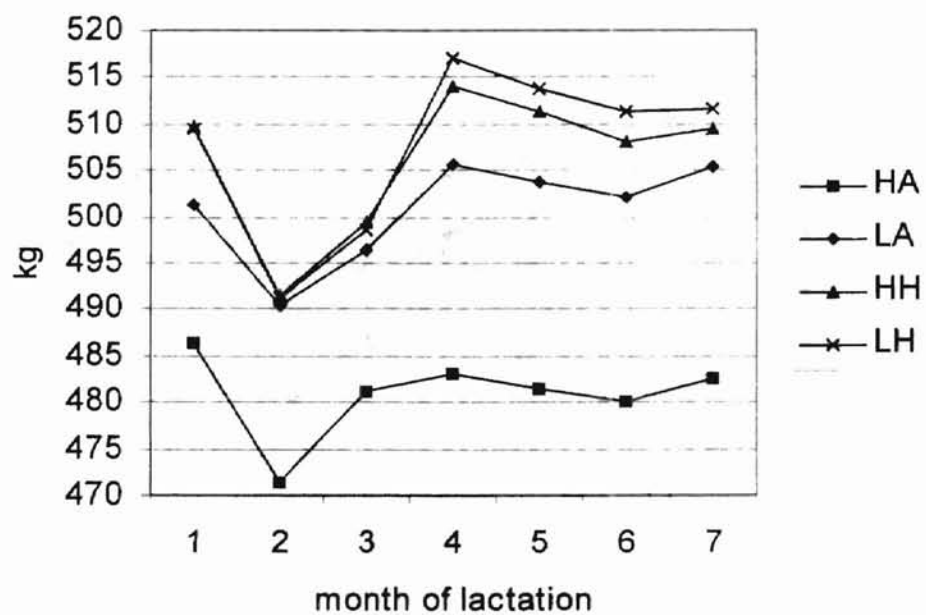
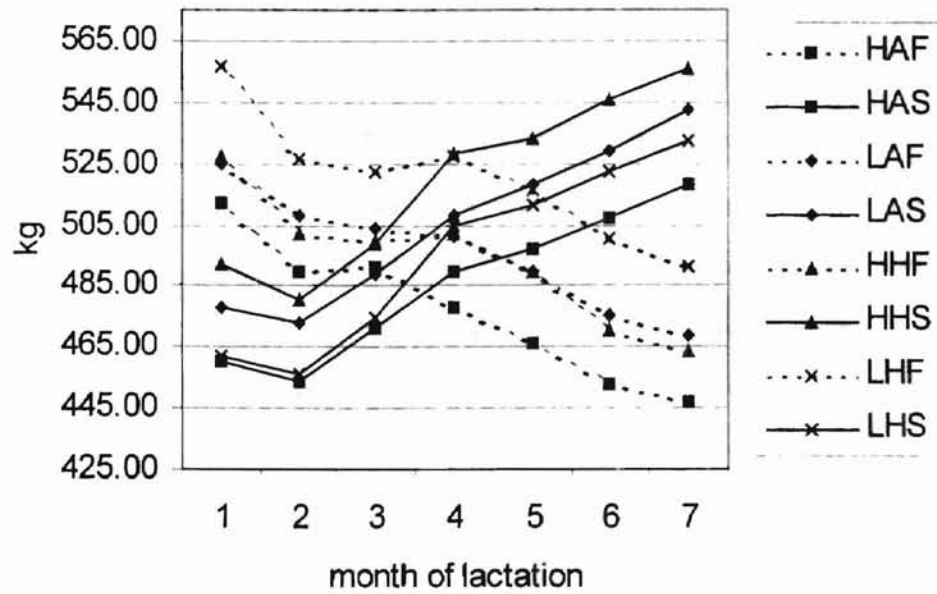


Figure 6. Average cow weight over the lactation by season (F = fall, S = spring) for high and low (H, L) milk Angus and Hereford (A, H) cows



calving cows were heavier than spring-calving cows, and in the last three months, spring-calving cows were heavier than fall-calving cows. Significant interactions were: breed x cow age (year) in months four, five, six and seven; milk level x season in all months (Table 12) (Figure 6); year x season in all months (Table 12) (Figure 6), season x cow age (year) in month four and breed x milk level x season in months one, two, three, five, six and seven ($P < .05$) (Appendix Table 5).

In general, there was little significant effect of milk level on cow weight. Breed had an effect in the fourth month and later. Angus cows may have been lighter because they tended to produce more milk at these times. This increased milk production may have caused them to lose weight more than the Herefords during the lactation. As expected, cow weight increased with age. The effect of season on cow weight varied depending on the season. In months one through three, fall-calving cows were heavier. These cows were coming off of a summer at grass in the first three months. In the first three months of lactation, spring-calving cows were coming off of winter feed. In months five through seven, spring-calving cows were heavier. In these months, spring-calving cows were on summer grass, and fall-calving cows were on winter feed.

Cows that were on summer grass weighed more than cows on winter feed, regardless of their month in lactation.

Cow BCS

High milk cows had lower BCS than low milk cows at months one, two, three, five, six and seven ($P < .05$) (Table 14, Appendix Table 6). Breed had little effect on BCS throughout the lactation ($P > .05$) (Table 14, Appendix Table 6). Figure 7 shows the changes in cow BCS over the lactation for the four breed milk level groups. Year and cow age within year were significant at calving and in all months ($P < .05$) (Appendix Table 6). Sire of cow affect BCS at calving and in months three, four, five, six and seven ($P < .05$) (Appendix Table 6). Season was significant at calving and in months one, two, four, five, six and seven ($P < .05$) (Table 15, Appendix Table 6). Within year, cow BCS increased with age (Table 17, Appendix Table 6). Significant interactions were: breed x season in months two, three and six (Table 16) (Figure 8); milk level x season at

TABLE 14. LEAST SQUARES MEANS BY BREED AND MILK LEVEL FOR CALVING BCS AND THE SEVEN MONTHLY MEASUREMENTS OF COW BCS (1-9 SCALE)

	Angus		Hereford		P-value ^a	Avg. std. error
	High milk	Low milk	High milk	Low milk		
Calving	5.85	5.92	5.79	5.79	.4013	.052
Month 1 ^b	5.09	5.25	5.12	5.18	.0443	.059
Month 2	4.95	5.17	5.07	5.09	.0255	.059
Month 3	5.00	5.22	5.16	5.24	.0253	.069
Month 4	4.96	5.17	5.12	5.12	.0720	.065
Month 5	4.86	5.15	5.02	5.13	.0025	.065
Month 6	4.94	5.17	5.03	5.21	.0019	.069
Month 7	4.90	5.25	5.09	5.20	.0026	.078

^a P-value for differences between levels within breed.

^b 28-d intervals beginning approximately one month after average calving date

TABLE 15. LEAST SQUARES MEANS BY SEASON FOR CALVING BCS AND THE SEVEN MONTHLY MEASUREMENTS OF COW BCS (1-9 SCALE)

	Spring	Fall	P-value	Avg. std. error
Calving	5.40	6.28	.0001	.033
Month 1 ^a	4.98	5.34	.0001	.039
Month 2	5.00	5.14	.0085	.040
Month 3	5.19	5.12	.3842	.038
Month 4	5.16	5.03	.0052	.033
Month 5	5.25	4.84	.0001	.038
Month 6	5.47	4.71	.0001	.037
Month 7	5.43	4.79	.0001	.041

^a 28-d intervals beginning approximately one month after average calving date

TABLE 16. LEAST SQUARES MEANS BY BREED, LEVEL AND SEASON FOR CALVING BCS AND THE SEVEN MONTHLY MEASUREMENTS OF COW BCS (1-9 SCALE)

Breed Level Season	Calving	1 ^a	2	3	4	5	6	7
Angus High Fall	6.29	5.33	5.11	5.05	4.95	4.75	4.64	4.61
Angus High Spring	5.41	4.85	4.78	4.96	4.96	4.97	5.24	5.19
Angus Low Fall	6.40	5.43	5.28	5.20	5.13	4.93	4.86	4.99
Angus Low Spring	5.45	5.07	5.06	5.23	5.22	5.38	5.49	5.52
Hereford High Fall	6.13	5.15	4.96	4.94	4.90	4.68	4.46	4.63
Hereford High Spring	5.44	5.09	5.19	5.38	5.34	5.35	5.60	5.56
Hereford Low Fall	6.29	5.46	5.22	5.30	5.14	4.98	4.90	4.95
Hereford Low Spring	5.29	4.90	4.96	5.18	5.11	5.28	5.53	5.44
P-value	.1010	.0015	.0005	.0001	.0010	.0004	.0009	.0337
Avg. std. error	.058	.069	.067	.065	.063	.062	.063	.071

^a 28-d intervals beginning approximately one month after average calving date

TABLE 17. LEAST SQUARES MEANS BY COW AGE WITHIN YEAR FOR CALVING BCS AND THE SEVEN MONTHLY MEASUREMENTS OF COW BCS (1-9 SCALE)

Cow age (year)	Calving	1 ^a	2	3	4	5	6	7
3 (92)	6.03	5.68	5.47	5.76	5.41	5.58	5.58	5.59
3 (93)	5.62	4.84	4.76	4.77	4.98	4.82	4.91	4.76
4 (93)	5.96	5.36	5.28	5.14	5.30	5.13	5.35	5.24
3 (94)	5.82	5.14	5.00	5.10	5.21	5.10	5.02	5.05
4 (94)	5.96	5.23	5.16	5.24	5.28	5.07	5.19	5.20
5 (94)	6.27	5.67	5.52	5.56	5.40	5.28	5.58	5.59
3 (95)	5.67	5.00	4.91	5.00	4.78	4.65	4.71	4.79
4 (95)	5.95	5.19	5.05	5.13	4.98	4.93	4.84	4.92
5 (95)	6.01	5.34	5.39	5.43	5.26	5.14	5.12	5.15
3 (96)	5.17	4.80	4.51	4.40	4.63	4.51	4.28	4.16
4 (96)	5.47	4.66	4.89	4.87	4.71	4.59	4.77	4.73
5 (96)	5.50	4.75	4.84	4.91	4.76	4.75	4.73	4.88
4 (97)	5.99	4.86	4.85	5.03	5.03	5.02	5.08	5.28
5 (97)	5.89	4.94	4.84	5.02	4.98	5.01	5.06	5.20
P-value	.0001	.0001	.0085	.0001	.0002	.0001	.0001	.0001
Avg. std. error	.086	.099	.102	.100	.088	.088	.098	.108

^a 28-d intervals beginning approximately one month after average calving date

Figure 7. Average cow body condition scores (BCS) over the lactation for high and low (H, L) milk Angus and Hereford (A, H) cows

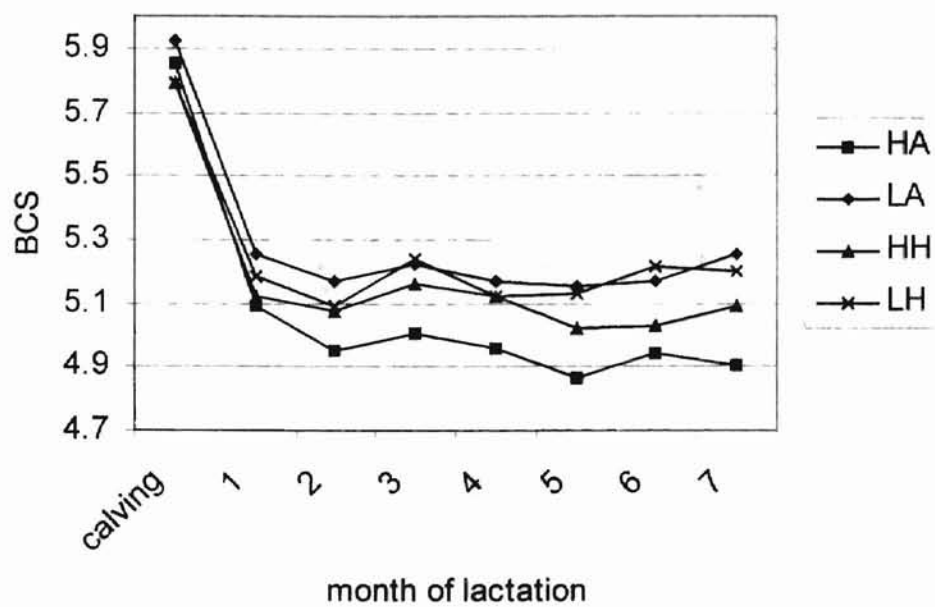
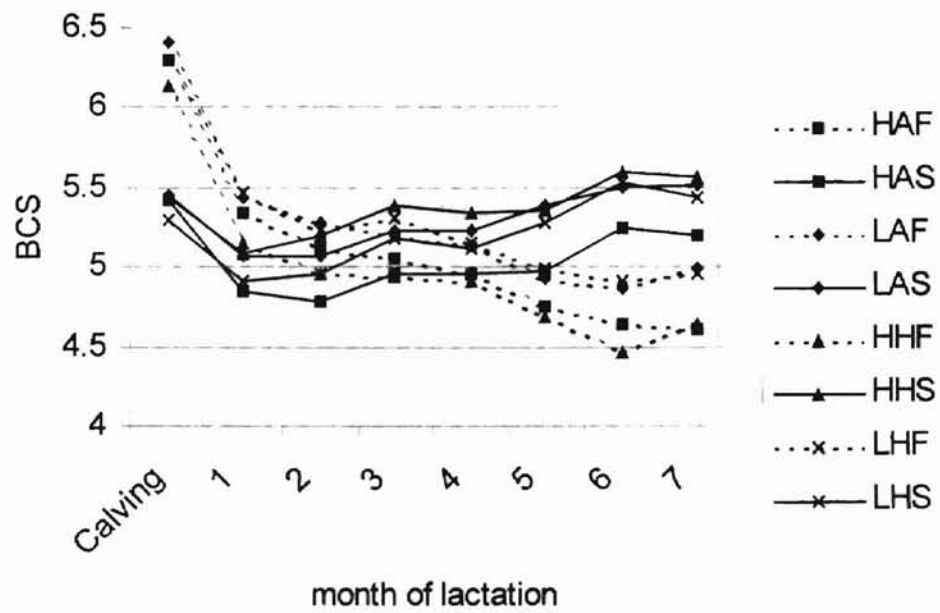


Figure 8. Average cow BCS over the lactation by season (F = fall, S = spring) for high and low (H, L) milk Angus and Hereford (A, H) cows



calving and in months one, two, three, four, six and seven (Table 16) (Figure 8); year x season in all months; season x cow age (year) in months two, three, six and seven and breed x milk level x season in months one through seven ($P < .05$) (Appendix Table 6).

In general, high milk level cows had lower body condition scores throughout lactation as compared with low milk level cows. This was expected because these cows partitioned available body stores to milk rather than fat. These results agree with those reported by Belcher and Frahm (1979), Montaño-Bermudez and Nielsen (1990) and Mondragon et al. (1983). Breed did not significantly affect condition throughout the lactation. This was somewhat surprising, because in the latter part of lactation, the Angus cows were producing more milk than the Hereford cows. This increase in milk production could be expected to cause a decrease in body condition. One reason that this was not observed could have been because the Angus cows began their lactation in slightly better condition. Cow body condition increased with cow age. As the cows matured, they had less of their own growth to support and could use that energy to increase condition. The effect of season on body condition was the same as its effect on cow weight. Cows that were on summer pasture were in higher condition than cows on winter feed, regardless of stage in lactation.

Birth and weaning data

There was no significant difference between milk levels or breeds for birth weight ($P > .05$) (Table 18, Appendix Table 7). Terms in the model that were significant were sire of cow, sire of calf and sex of calf ($P < .05$) (Appendix Table 7). As expected, bull calves were heavier at birth than heifer calves ($P < .0001$) (Table 19). Significant interactions were breed x year, year x season and year x sex ($P < .05$) (Appendix Table 7).

Unadjusted weaning weight was affected by both milk level and breed ($P < .05$) (Table 18, Appendix Table 7). High milk cows had calves with a higher weaning weight than low milk cows ($P < .0001$) (Table 18). Angus cows had calves with a higher weaning weight than Hereford cows ($P = .0099$) (Table 18). Other terms that were significant were sire of cow, year, season,

age of cow, sex of calf and age of calf at weaning ($P < .05$) (Appendix Table 7). Steer calves were heavier at weaning than heifer calves ($P < .0001$) (Table 19). Spring-calving cows weaned heavier calves than fall-calving cows ($P < .0001$) (Table 20). The spring-calving cows spent most of their lactation on summer grass, and the fall-calving cows spent most of their lactation on winter feed. In most years, four- and five-year-old cows weaned heavier calves than three-year-old cows ($P = .0331$) (Table 21). Calf sire approached significance ($P = .0672$). This may indicate that preweaning growth is more dependent of maternal ability of the dam than on the calf's own genetic ability for growth. Year x season was the only significant interaction ($P < .05$) (Appendix Table 7).

Age-adjusted 205-d weight followed a similar pattern as unadjusted weaning weight. By adjusting, calf age at weaning was taken out of the weaning weight model. The other terms showed the same effects, with slightly different significance levels. Calves out of high milk cows were heavier at 205 days than calves out of low milk cows, calves out of Angus cows were heavier at 205 days than calves from Hereford cows, spring-born calves were heavier at 205 days than fall-born calves, and steers were heavier at 205 days than heifers ($P < .05$) (Tables 18, 19, 20, Appendix Table 7). Also significant were sire of cow and sire of calf ($P < .05$) (Appendix Table 7). Year and cow age approached significance ($P < .1$) (Appendix Table 7). As with weaning weight, year x season was the only significant interaction ($P < .05$) (Appendix Table 7).

Calves from high milk cows were heavier at weaning than calves from low milk cows. This agreed with the results of Marston et al. (1992), Mallinckrodt et al. (1990), Diaz et al. (1992), Diaz and Notter (1991) and Marshall and Long (1993). However, Marshall and Freking (1988) and Mahrt et al. (1990) found no significant difference in weaning weights from calves out of high or low maternal or milk EPD cows.

Angus cows weaned heavier calves than Hereford cows. This is consistent with the breed differences reported by Brown et al. (1970) and Nelson et al. (1967). Spring-born calves were heavier at weaning than fall-born calves. This was similar to results reported by Brown (1960) and Marlowe and Gaines (1958).

TABLE 18. LEAST SQUARES MEANS BY BREED AND MILK LEVEL FOR CALF BIRTH WEIGHT (BW), WEANING WEIGHT (WW), 205-D WEIGHT, HIP HEIGHT (HH), CONFORMATION SCORE (CS) AND BODY CONDITION SCORE (BCS)

	Angus		Hereford		P-value ^a	Avg. std. error
	High milk	Low milk	High milk	Low milk		
BW (kg)	37.07	37.85	38.33	38.78	.3086	1.194
WW (kg)	261.57	240.99	245.87	236.24	.0001	6.755
205-d weight (kg)	237.26	218.23	222.17	214.12	.0002	6.254
HH (m)	1.16	1.14	1.15	1.14	.0154	.011
CS	13.15	12.69	12.83	12.70	.0012	.167
BCS	5.47	5.34	5.40	5.34	.0019	.051

^a P-value for differences between levels within breed.

TABLE 19. LEAST SQUARES MEANS BY CALF SEX FOR CALF BIRTH WEIGHT (BW), WEANING WEIGHT (WW), 205-D WEIGHT, HIP HEIGHT (HH), CONFORMATION SCORE (CS) AND BODY CONDITION SCORE (BCS)

	Steers	Heifers	P-value	Avg. std. error
BW (kg)	39.82	36.20	.0001	.696
WW (kg)	253.90	238.44	.0001	4.17
205-d weight (kg)	230.56	215.33	.0001	3.72
HH (m)	.457	.447	.0001	.002
CS	12.94	12.74	.0065	.135
BCS	5.40	5.37	.5817	.052

TABLE 20. LEAST SQUARES MEANS BY SEASON FOR CALF BIRTH WEIGHT (BW), WEANING WEIGHT (WW), 205-D WEIGHT, HIP HEIGHT (HH), CONFORMATION SCORE (CS) AND BODY CONDITION SCORE (BCS)

	Spring	Fall	P-value	Avg. std. error
BW (kg)	38.11	37.91	.7236	.729
WW (kg)	259.42	232.92	.0001	4.54
205-d weight (kg)	238.45	207.45	.0001	3.91
HH (m)	.456	.447	.0002	.003
CS	12.91	12.77	.3207	.147
BCS	5.56	5.21	.0001	.057

TABLE 21. LEAST SQUARES MEANS BY COW AGE WITHIN YEAR FOR CALF WEANING WEIGHT AND 205-D WEIGHT

Cow age (year)	Weaning weight	205-d weight
3 (92)	215.39	196.72
3 (93)	227.53	205.94
4 (93)	265.62	239.79
3 (94)	229.21	208.56
4 (94)	267.96	240.56
5 (94)	282.45	252.81
3 (95)	260.55	235.92
4 (95)	255.77	231.60
5 (95)	257.78	232.84
3 (96)	238.82	216.47
4 (96)	255.80	230.86
5 (96)	252.20	228.30
4 (97)	239.44	217.81
5 (97)	256.95	233.09
P-value	.0331	.0526
Avg. std. error	10.575	9.481

Steers were heavier at weaning than heifers. Rutledge et al. (1970b), Butson et al. (1980), Lawson (1976), Brown et al. (1970), Linton et al. (1968), Cundiff et al. (1966), Christian et al. (1965), Brown (1960) and Wingert et al. (1984) also found that males had heavier weaning weights than females.

Three-year-old cows weaned lighter calves than four- or five-year-old cows. This agrees with results reported by Singh et al. (1970), Butson et al. (1980), Brown et al. (1970), Cundiff et al. (1966), Minyard and Dinkel (1965), Swiger et al. (1962), Wingert et al. (1984), Neville, Jr. et al. (1974) and Christian et al. (1965). However, Rutledge et al. (1970b) and Neville, Jr. (1962) found no relationship between cow age and calf weaning weight.

The difference in calf 205-d weights between high and low milk Angus cows was 19.02 kg, which was about four kg more than the difference of 14.92 kg predicted by the grandsire milk EPD. The difference between high and low milk Hereford cows was 8.05 kg, which was about four kg less than the difference of 12.38 kg predicted by the grandsire milk EPD. Therefore, the Angus milk EPD seems to underestimate true genetic merit for milk production, and the Hereford milk EPD seems to overestimate it. This agreed with the Angus results reported by Marston et al. (1989), Marston et al. (1990) and Marston et al. (1992). Unlike this study, Buchanan et al. (1995) and Mallinckrodt et al. (1990, 1993) showed that Hereford milk EPD underestimated weaning weight differences as well. However, Diaz and Notter (1991) found that in Angus-Hereford cross cows, grandsire milk EPD overestimated differences in calf weaning weight. The differences from predicted value may be because the predicted values were generated from purebred cows.

High milk cows had calves with greater weaning hip height than low milk cows across breeds ($P = .0154$) (Table 18). No significant difference was found between breeds ($P = .3713$) (Table 18). Other terms that were significant were sire of cow, year, season, sire of calf, sex of calf and age at weaning ($P < .05$) (Appendix Table 7). Spring-born calves were heavier at weaning, and they were taller at weaning as well ($P = .0002$) (Table 20). Similarly, the heavier steers were taller than the heifers at weaning ($P < .0001$) (Table 19). Age of calf at measurement affected hip height ($P < .0001$). Significant interactions were year x season, season x sex and milk level x season x sex ($P < .05$) (Appendix Table 7).

High milk cows had calves with higher weaning conformation, or muscle scores, than low milk cows across breeds ($P = .0012$) (Table 18). There was no significant difference in conformation score between breeds ($P = .1062$) (Table 18). Significant terms in the model included year, calf sex and age of calf at measurement ($P < .05$) (Appendix Table 7). Steers had higher conformation scores than heifers ($P = .0065$) (Table 19). Milk level x sex, year x season, year x sex and season x sex were the significant interactions ($P < .05$) (Appendix Table 7). Brown et al. (1970) also found a non-significant effect of cow breed on calf conformation score.

High milk cows had calves with higher weaning body condition scores than low milk cows across breeds ($P = .0019$) (Table 18). There was no significant difference between breeds ($P = .2085$) (Table 18). Year, season and age at measurement were significant ($P < .05$) (Appendix Table 7). Spring-born calves had higher BCS than fall-born calves ($P < .0001$) (Table 20). This was expected, since the spring-born calves spent most of their lives on summer pasture and the fall-born calves spent most of their lives on winter feed. Year x season was the only significant interaction ($P < .05$) (Appendix Table 7). Cobb et al. (1978a) also reported a positive relationship between cow milk production and calf condition score. Similar to these results, Brown et al. (1970) found that breed of cow had a non-significant effect on calf condition score.

Correlation of total milk production with cow and calf performance

The correlation of total milk production with the monthly measures of milk production tended to be moderate (approximately .5) in the first half of lactation and to decrease in the second half of the lactation (Table 22). These estimates are lower than those reported by Totusek and Arnett (1965) for WSW and by Totusek and Arnett (1965) and Totusek et al. (1973) for hand milking. There was a slightly positive correlation ($r = .12$) ($P < .01$) between birth weight of the calf and total milk production (Table 22). This agreed with the findings of Jeffery et al. (1971a) and Pope et al. (1963). One explanation for this correlation is that larger calves were able to immediately consume more milk than smaller calves.

TABLE 22. CORRELATION OF TOTAL MILK PRODUCTION WITH MONTHLY MILK PRODUCTION ESTIMATES (MONTH 1 THROUGH MONTH 7), BIRTH WEIGHT (BW), WEANING WEIGHT (WW), 205-D WEIGHT, HIP HEIGHT (HH), CALF CONFORMATION SCORE (CS), CALF BCS, COW WEIGHT AT WEANING AND COW BCS AT WEANING

	Total milk
Month 1	.5147**
Month 2	.5608**
Month 3	.5205**
Month 4	.5444**
Month 5	.3469**
Month 6	.3674**
Month 7	.3103**
BW	.1163**
WW	.4312**
205-d weight	.4521**
HH	.4887**
CS	.3160**
Calf BCS	.2657**
Cow weight	-.1154**
Cow BCS	-.2621**

** P < .01

There was a moderate correlation ($r = .4312$ and $.4521$) ($P < .01$) between total milk production and weaning weight and 205-d weight (Table 22). This is similar to the correlations reported by Mallinckrodt et al. (1993), Robison et al. (1978), Diaz et al. (1992), Marston et al. (1989), Marston et al. (1990), Marshall and Long (1993) and Butson et al. (1980). Hip height at weaning was also moderately correlated with total milk production (Table 22). The correlation between total milk and calf weaning conformation score and BCS was low to moderate (Table 22). This was lower than the correlations between conformation score and total milk reported by Cobb et al. (1978). There was a low, negative correlation between total milk and final cow weight and BCS. It was expected that cows that produced more milk over the lactation would be lighter and thinner at the end of lactation. This agrees with the findings of Belcher and Frahm (1979), Montaño-Bermudez and Nielsen (1990), Mondragon et al. (1983), Marston et al. (1992) and Pope et al. (1963).

Implications

Milk production differences affect calf performance and cow condition. High producing cows have heavier calves but are lower in body condition during lactation. Milk EPD accurately predicts these differences in performance and can be used as a part of a selection and culling program in purebred or commercial beef herds.

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APPENDIX

TABLE 1. SIGNIFICANCE LEVELS OF MODEL TERMS FOR 24-H MILK PRODUCTION IN THE SEVEN MONTHS OF LACTATION

Model terms	1	2	3	4	5	6	7
Breed	.3596	.3411	.0010	.0101	.0877	.0022	.9912
Milk level	.0007	.0017	.0006	.0120	.0145	.0013	.0465
Breed x milk level	.7977	.8763	.6916	.0304	.3699	.0189	.0736
Cow sire (breed x milk level) ^a	.6721	.0358	.4383	.2780	.3386	.4376	.1067
Year	.1776	.0001	.0562	.4335	.0001	.0190	.6587
Season	.2063	.2334	.5857	.3259	.5418	.0001	.4788
Cow age (year)	.7557	.2970	.4535	.3821	.6157	.5949	.4521
Calf sire	.9906	.3119	.6254	.2630	.6932	.2558	.2104
Sex	.1137	.9281	.0122	.9519	.7825	.0004	.1176
Calf age	.0203	.0001	.0001	.0001	.0696	.0121	.0698
Breed x year			.0051		.0625	.0604	.1183
Breed x season	.0596						.0054
Breed x cow age (year)						.2269	.0284
Breed x sex						.5070	
Milk level x year	.0880	.5317	.1601	.0872	.0839		
Milk level x season	.9916				.3092		
Milk level x sex	.9750	.5530		.2248		.0002	
Year x season	.0003	.0004	.0001	.0001	.0101		.0263
Year x sex		.6121	.0036	.0042	.0095	.0001	.2698
Season x sex	.4603		.1394	.0113	.7596		.0477
Cow age (year) x sex						.1095	
Breed x milk level x year					.0943		
Breed x year x sex						.1835	
Milk level x year x season					.0065		
Milk level x year x sex		.0107		.0407			
Milk level x season x sex	.0447						
Year x season x sex			.0061	.0076	.0005		.0001
Error mean square	29.19	32.26	27.69	23.44	21.29	24.80	35.87

^a Cow sire (breed x milk level) is used as the error term for breed, milk level and breed x milk level

TABLE 2. SIGNIFICANCE LEVELS OF MODEL TERMS FOR TOTAL MILK PRODUCTION, YIELD AT PEAK LACTATION AND DAY OF PEAK LACTATION

Model term	Total milk	Peak yield	Peak time
Breed	.0007	.0068	.9988
Milk level	.0001	.0001	.4310
Breed x milk level	.1072	.3963	.5495
Cow sire (breed x milk level) ^a	.0268	.0937	.1765
Year	.2044	.4467	.8483
Season	.0310	.0407	.6100
Cow age (year)	.8758	.3340	.2123
Calf sire	.5620	.8691	1.000
Sex	.1349	.2363	.6918
Calf age	.9315	.0001	.0001
Breed x year	.1874		
Breed x season	.0830	.1756	
Milk level x year	.7290	.8243	
Milk level x season	.3880		
Milk level x sex	.0163	.0842	
Year x season	.0001	.0026	
Year x sex	.0032	.0088	
Season x sex	.5911	.4425	
Milk level x year x season	.2802		
Milk level x year x sex	.1164	.1478	
Year x season x sex	.0162	.1686	
Error mean square	218420	20.33	29907.4

^a Cow sire (breed x milk level) is used as the error term for breed, milk level and breed x milk level

TABLE 3. SIGNIFICANCE LEVELS OF MODEL TERMS WITH THE JENKINS AND FERRELL LACTATION CURVE EQUATION

Model term	P value
Breed	.5512
Milk level	.0164
Season	.0004
Breed x milk level	.0121
Breed x season	.1161
Milk level x season	.5128
Breed x milk level x season	.7474
Breed x milk level x year x season x cow	.0001
Regression coefficient	.0001
Regression coefficient x breed	.3017
Regression coefficient x milk level	.1693
Regression coefficient x season	.0222
Regression coefficient x breed x milk level	.0005
Regression coefficient x breed x season	.0183
Regression coefficient x milk level x season	.5021
Regression coefficient x breed x milk level x season x cow	.5627

TABLE 4. SIGNIFICANCE LEVELS OF MODEL TERMS FOR CALF WEIGHT IN THE SEVEN MONTHS OF LACTATION

Model terms	1	2	3	4	5	6	7
Breed	.2951	.3613	.2898	.1502	.3276	.0717	.0085
Milk level	.0020	.0058	.0026	.0013	.0007	.0006	.0002
Breed x milk level	.2072	.2286	.1300	.2128	.1749	.1395	.1193
Cow sire (breed x milk level) ^a	.0004	.0001	.0001	.0001	.0001	.0001	.0001
Year	.0029	.0001	.0001	.0003	.0014	.0428	.0119
Season	.0179	.6326	.0006	.0001	.0001	.0001	.0001
Cow age (year)	.0567	.0051	.0112	.0325	.0716	.1172	.0573
Calf sire	.1738	.0756	.0860	.1302	.1746	.1668	.0755
Sex	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Calf age	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Breed x year			.0636		.1303		
Breed x season	.0519				.6683		
Breed x cow age (year)	.1355	.0467	.0748	.0820	.0861	.2300	
Milk level x season		.6100	.9288	.8638	.8431		
Milk level x sex		.6940	.7411	.6019	.6376		
Year x season	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Season x cow age (year)		.0102	.0259	.0341	.0515	.1196	.1531
Season x sex		.0949	.2226	.2947	.5775		
Breed x year x season					.2428		
Milk level x year x season		.0043	.0060	.0167	.0202		
Error mean square	369.1	577.9	883.1	1231.0	1695.5	2078.3	2546.9

^a Cow sire (breed x milk level) is used as the error term for breed, milk level and breed x milk level

TABLE 5. SIGNIFICANCE LEVELS OF MODEL TERMS FOR COW WEIGHT IN THE SEVEN MONTHS OF LACTATION

Model terms	1	2	3	4	5	6	7
Breed	.1608	.1880	.2189	.0338	.0482	.0646	.0823
Milk level	.3510	.2136	.3527	.1123	.1373	.1246	.1144
Breed x milk level	.3435	.2075	.3074	.2371	.2348	.2662	.1940
Cow sire (breed x milk level) ^a	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Year	.0001	.0001	.0001	.0001	.0001	.0070	.0001
Season	.0001	.0001	.0001	.2524	.0001	.0001	.0001
Cow age (year)	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Breed x year				.1263	.1799	.1357	.2682
Breed x season	.1345	.2298	.4059		.2661	.5820	.4977
Breed x cow age (year)	.1353			.0049	.0048	.0098	.0291
Milk level x season	.0072	.0080	.0149	.0078	.0049	.0031	.0046
Year x season	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Season x cow age (year)	.2138	.0775		.0311			
Breed x milk level x season	.0016	.0052	.0033		.0082	.0030	.0026
Error mean square	12041	11851	11571	11585	11885	11781	11424

^a Cow sire (breed x milk level) is used as the error term for breed, milk level and breed x milk level

TABLE 6. SIGNIFICANCE LEVELS OF MODEL TERMS FOR COW BODY CONDITION SCORE
IN THE SEVEN MONTHS OF LACTATION

Model terms	0	1	2	3	4	5	6	7
Breed	.0706	.7370	.6867	.1820	.3765	.3152	.3333	.3527
Milk level	.4013	.0443	.0255	.0253	.0720	.0025	.0019	.0026
Breed x milk level	.4670	.3916	.0614	.3004	.0997	.1545	.6891	.0996
Cow sire (breed x milk level) ^a	.0222	.0580	.0638	.0001	.0007	.0004	.0001	.0001
Year	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Season	.0001	.0001	.0085	.3842	.0052	.0001	.0001	.0001
Cow age (year)	.0001	.0001	.0001	.0001	.0002	.0001	.0001	.0001
Breed x year	.2884							
Breed x season	.3442	.2185	.0023	.0273	.0833	.0722	.0008	.0848
Milk level x year	.2375							.0799
Milk level x season	.0095	.0469	.0253	.0090	.0294	.4186	.0039	.0135
Milk level x cow age (year)					.2600			.1880
Year x season	.0001	.0016	.0001	.0001	.0001	.0001	.0001	.0001
Season x cow age (year)	.0732		.0054	.0094			.0014	.0007
Breed x milk level x season	.1010	.0015	.0005	.0001	.0010	.0004	.0009	.0337
Breed x year x season	.1024							
Milk level x year x season	.1302							
Error mean square	.1484	.2309	.2187	.2132	.2102	.2189	.2030	.2420

^a Cow sire (breed x milk level) is used as the error term for breed, milk level and breed x milk level

TABLE 7. SIGNIFICANCE LEVELS OF MODEL TERMS FOR CALF BIRTH WEIGHT (BW), WEANING WEIGHT (WW), 205-D WEIGHT, HIP HEIGHT (HH), CONFORMATION SCORE (CS) AND BODY CONDITION SCORE (BCS)

Model terms	BW	WW	205	HH	CS	BCS
Breed	.2369	.0099	.0092	.3713	.1062	.2085
Milk level	.3086	.0001	.0002	.0154	.0012	.0019
Breed x milk level	.7905	.1321	.1045	.7338	.0653	.1877
Cow sire (breed x milk level) ^a	.0001	.0001	.0001	.0001	.1123	.8328
Year	.1782	.0304	.0524	.0003	.0001	.0179
Season	.7236	.0001	.0001	.0002	.3207	.0001
Cow age (year)	.1511	.0331	.0526	.1156	.2246	.9568
Calf sire	.0001	.0672	.0049	.0008	.7242	.0817
Sex	.0001	.0001	.0001	.0001	.0065	.5817
Calf age		.0001		.0001	.0001	.0347
Breed x year	.0439			.7050		
Breed x season	.1303					
Breed x cow age (year)	.1236			.1319		
Breed x sex				.2387		.1920
Milk level x year						.9422
Milk level x season				.7359		.9155
Milk level x cow age (year)						.9935
Milk level x sex			.2419	.1298	.0392	.7039
Year x season	.0064	.0001	.0001	.0002	.0001	.0001
Year x sex	.0365				.0031	
Season x sex				.0331	.0412	
Cow age (year) x sex						.3818
Milk level x year x season						.1936
Milk level x season x sex				.0092		
Milk level x cow age (year) x sex						.1227
Error mean square	76.013	2977.4	2395.7	1.8633	.6230	.0864

^a Cow sire (breed x milk level) is used as the error term for breed, milk level and breed x milk level

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