LIFETIME PRODUCTIVITY OF CROSSBRED COWS SIRED BY HIGH AND LOW MILK EPD ANGUS AND HEREFORD BULLS

By

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BCS	Body Condition Score
BWEPD	Birth Weight Expected Progeny Difference
cm	centimeter
d	day
EPD	Expected Progeny Difference
h	hour
hd	head
kg	kilogram
WWEPD	Weaning Weight Expected Progeny Difference

CHAPTER I

REVIEW OF LITERATURE

Expected Progeny Differences (EPD)

The Expected Progeny Difference (EPD) is a selection tool used to predict the performance differences between offspring of potential parents. For a given trait, the difference between the EPD of two individuals represents the difference that can be expected between the future offspring of these animals. The Milk EPD is unique because it predicts a sire's genetic merit for maternal traits that will be expressed in his daughters. This EPD predicts the differences in weaning weights of calves born to daughters of different bulls. The Milk EPD is measured in units of calf weaning weight; however, it represents the maternal component of weaning weight. Several studies have been conducted to determine the ability of EPD to accurately predict cow and calf performance.

In a study of 37 spring-calving Angus and 28 spring-calving Simmental cattle, Marston et al. (1989) reported the correlation between total milk production and Milk EPD to be 0.41 for Angus and 0.55 for Simmental. The correlation between Milk EPD and weaning weight was 0.30 for Angus and 0.47 for Simmental. In addition, a one kg increase in cow Milk EPD resulted in the production of an additional 56.6 kg of milk in Angus and 70.2 kg of milk in Simmental and an increase in weaning weight of 1.8 ± 0.7 kg in both breeds (Marston et al, 1989). Milk production and calf weaning weight were moderately correlated with Milk EPD.

Marston et al. (1990) studied 37 fall-calving Simmental, 86 spring-calving Angus, and 59 spring-calving Simmental cows. The correlations between dam's milk production and Milk EPD to be 0.37 for Angus and 0.46 for Simmental, indicating the traits were moderately correlated. Moderate correlations between dam's Milk EPD and calf weaning weight were found for Angus (0.23) and Simmental (0.48). A one kg increase in Milk EPD resulted in increased milk production of 69.9 ± 19.8 kg for Angus and 70.7 ± 16.9 kg for Simmental, and an increase in weaning weight of 3.8 ± 1.0 kg for Angus and 2.9 ± 1.1 kg for Simmental.

A further study by Marston et al. (1992) found that total milk yield of Angus (n = 114) and Simmental (n = 82) cows was influenced by Milk EPD ($P < 0.01$). A one kg change in dam's Milk EPD resulted in a 42.1 ± 16.6 kg change in total milk yield for Angus and a 69.3 ± 16 kg change in Simmental total milk yield. A one kg change in dam's Milk EPD, while holding calf weaning weight EPD constant, corresponded to 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. These results were not significantly different from the expected change of two kg of weaning weight for every one kg of Milk EPD change. Milk EPD was found to be conservative in estimating true genetic differences between cows.

Baker (1997) evaluated maternal EPD of 73 purebred first lactation Angus cattle. He found that the average weaning weights of high EPD and low EPD lines differed by 10.19 kg; which was 7.96 kg less than predicted by grandsire EPD.

In a study involving Hereford (n = 90) and Simmental (n = 80) cows, Mallinckrodt et al. (1990) found that Milk EPD of Hereford and Simmental dams and Hereford maternal grandsires underestimated differences in adjusted weaning weights ($P < 0.02$) but Simmental maternal grandsire Milk EPD closely predicted 205-d weight differences ($P > 0.5$). Total maternal EPD of Hereford dams and maternal grandsires underestimated changes in adjusted weaning weights ($P < 0.02$) but total maternal EPD of Simmental dams and grandsires were similar to 205-d weights ($P > 0.38$). Milk and total maternal EPD reasonably predicted genetic differences in milk production and weaning weight.

Further analysis of the study by Mallinckrodt et al. (1990) confirmed that milk and total maternal EPD are reasonably good predictors of milk yield and weaning weight (Mallinckrodt et al., 1993). Differences in adjusted 205-d weaning weights were either underestimated or similar to those predicted by maternal milk and total maternal EPD.

Diaz and Notter (1991) found that using EPD to select purebred sires accurately predicted the performance of their crossbred progeny. They reported that for every one kg change in grandsire Milk EPD there was a 0.69 ± 0.19 kg change in adjusted weaning weight of calves from Hereford x Angus cows ($P < 0.0004$).

Diaz et al. (1992) found that the relationship between sire's Milk EPD and daughter's actual milk production was positive and linear. The correlation between sire's Milk EPD and daughter's milk production was 0.26 ($P < 0.01$) and between grandsire's Milk EPD and calf's weaning weight was 0.20 ($P < 0.05$).

Notter and Mahrt (1991) studied Hereford x Angus calves. They reported that for every one kg increase in weaning weight EPD there was an increase of 0.26 ± 0.16 kg 135-d weight, 0.55 ± 0.16 kg weaning weight, and 0.16 ± 0.03 cm weaning height. A one kg increase in grandsire birth weight EPD increased birth weight by 1.13 ± 0.16 kg and a one kg increase in grandsire yearling weight EPD increased yearling weight by 1.14 ± 0.22 kg.

Mahrt et al. (1990) bred grade Angus cows (n = 157) 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. High yearling weight EPD cows had calves that averaged heavier by 2.1 kg at birth ($P < 0.01$) and 7.5 kg at weaning ($P < 0.01$) than calves from low yearling weight EPD cows. The high yearling weight EPD group exceeded the low yearling weight EPD group in yearling weight and hip height at weaning by 16.4 kg and 1.90 cm, respectively. A one kg increase in birth weight EPD corresponded to a 1.18 kg increase in birth weight, a one kg increase in weaning weight EPD corresponded to a 0.75 kg increase in weaning weight, and a one kg increase in yearling weight EPD was associated with a 1.79 kg increase in yearling weight. Weaning weight, yearling weight, and hip height at weaning did not differ between maternal EPD groups. Correlations between performance in registered herds and performance in crossbred herd were 0.78 for birth weight, 0.61 for weaning weight, and 0.93 for yearling weight, indicating that EPD of purebred sires can be used to predict crossbred progeny performance.

In a study of polled Herefords, Angus, and Tarentaise breeds, Marshall and Freking (1988) showed that daughters of high Milk EPD sires ranked higher than daughters of low Milk EPD sires for milk production and weaning weight, but the differences were not significant. Weaning weight differences between calves of daughters from low and high Milk EPD were greater than predicted by sire Milk EPD. Hereford maternal weaning weight EPD more closely reflected weaning weight differences than Angus and Tarentaise, but performance differences were not significant.

Marshall and Long (1993) reported that differences in daughter's (n = 313) milk yield were positively related to sire (n = 32) Milk EPD differences, but the magnitude was less than expected. A one kg change in sire's Milk EPD was associated with a 13.4 kg change in 214-d milk yield ($P = 0.012$). They also found that a one kg change in grandsire's total maternal weaning weight EPD resulted in a 1.18 kg change in calf weaning weight ($P = 0.004$). The correlations between daughter's 214-d milk yield and sire's milk EPD and sire's total maternal weaning weight EPD were both 0.14 ($P < 0.05$). The correlations between 214-d calf weight and grandsire's Milk EPD and grandsire's total maternal weaning weight EPD were 0.18 ($P < 0.01$) and 0.17 ($P < 0.001$), respectively.

Minick et al. (2001) studied the daughters (n = 273) of high and low Milk EPD Hereford and Angus bulls. High and low Milk EPD Angus-sired cows had calves that differed in 205-d weight by 19.02 kg, which was more than the grandsire EPD prediction of 13.68 kg. The difference in calf 205-d weights between high and low Milk Hereford sired cows was 8.05 kg, which was less than the 11.47 kg difference predicted by the grandsire EPD. The Angus Milk EPD underestimated true genetic merit, while the Hereford Milk EPD overestimated it. The authors attributed this difference to the use of crossbred dams. A one kg increase in sire Milk EPD resulted in a 1.22 kg increase in weaning weight for Angus-sired cows and a 0.93 kg increase for Hereford-sired cows. Across breeds, high Milk EPD cows had calves with greater weaning hip height ($P < 0.02$), higher weaning conformation ($P < 0.01$), and higher weaning BCS ($P < 0.01$) than low EPD cows.

Milk production and weaning weight

Milk production of dams has a major influence on the weaning weights of calves (Gifford, 1953; Neville, Jr., 1962; Butson et al., 1980). The degree to which milk yield influences weaning weight varies greatly between studies. The amount of variability in weaning weight that is explained by milk production has been reported as 40 % (Robinson et al., 1978), 60 % (Rutledge et al., 1971), and 66 % (Neville, Jr., 1962) for Herefords and 42 % to 57 % (Jeffery et al., 1971b) for crossbred cows. Butson et al. (1980) reported that after removing the effects of cow age, cow breed, calf sex, and calf age, milk production explained 6 % to 10 % of variance in weaning weight.

Cows that produced more milk weaned heavier calves (Totusek et al., 1971; McGinty and Frerichs, 1971; Wyatt et al., 1977; Marshall et al., 1976; Butson et al., 1980; Clutter and Nielson, 1987; Minick et al., 2001). Totusek et al. (1971) reported that calves from Holstein x Hereford dams were 30 and 36 kg heavier than Hereford calves at 205- and 270-d, respectively, and calves of Holstein dams were 22 and 32 kg heavier than calves of Holstein x Hereford dams at 205- and 270-d, respectively. McGinty and Frerichs (1971) found calves from Brown Swiss x Hereford cows averaged 25 kg heavier at weaning than calves nursed by Hereford dams ($P < 0.01$). In a reciprocal cross-fostering study, Wyatt et al. (1977) found that at weaning, Angus x Hereford calves on a high level of milk consumption were 20 % heavier on range and 19 % heavier in drylot than Angus x Hereford calves on low milk. Charolais x Freisan calves on high milk were 23 % heavier on range and 22 % heavier in drylot than their low milk counterparts (Wyatt et al., 1977). Marshall et al. (1976) reported that cows producing more milk weaned heavier calves and were more efficient than lower milking cows. Butson et al. (1980) reported that cows with dairy breeding produced more milk and weaned heavier calves than cows from an all-beef background. Clutter and Nielsen (1987) found that calves nursed by high milk dams were 16.9 kg heavier at 205-d than calves of low milk dams.

Correlation estimates between milk yield and weaning weight are highly variable. The correlation for Herefords has been reported as 0.40 (Mallinckrodt et al., 1993) and 0.63 (Robinson et al., 1978). For Simmentals, this correlation has been reported as 0.36 (Mallinckrodt et al., 1993), 0.47 ($P < 0.001$) (Marston et al., 1992), 0.52 (Marston et al., 1990), and 0.62 (Marston et al., 1989). In Angus, the correlation between milk yield and weaning weight was 0.30 ($P < 0.001$) (Marston et al., 1992), 0.39 (Marston et al., 1990), and 0.62 (Marston et al., 1989). In crossbred cows, this correlation was 0.20 ($P < 0.1$) (Chenette and Frahm, 1981), 0.44 (Marshall et al., 1976), 0.52 ($P < 0.001$) (Marshall and Long, 1993), 0.60 ($P < 0.01$) (Butson et al., 1980), 0.62 ($P < 0.01$) (Butson et al., 1980), 0.64 ($P < 0.0001$) (Diaz et al., 1992), 0.69 (Belcher and Frahm, 1979), and 0.94 (Nelson et al., 1985).

The correlation between milk yield and weaning weight has been lower in studies that included creep feeding, possibly due to a lower milk intake of calves. Hohenboken et al. (1973) found a correlation of 0.33 ($P < 0.05$) between milk production and weaning weight in creep fed Hereford calves. Marshall et al. (1976) reported the correlation to be 0.44 ($P < 0.05$) in creep fed crossbreds.

The stage of lactation also affects the correlation between milk production and weaning weight. Rutledge et al. (1970b) reported correlations of 0.49, 0.38, 0.36, 0.38, 0.37, 0.29, and 0.25 between weaning weight and seven monthly milk production estimates in Herefords. In another Hereford study, Robinson et al. (1978) found correlations between bimonthly milk yields during 0-60, 60-120, and 120-180 days of lactation and weaning weight to be 0.48, 0.48, and 0.44, respectively. Correlations between milk production at 45, 100, 150, and 205 days post-calving and weaning weight of Angus calves was 0.37, 0.16, 0.44, and 0.37, respectively (Baker, 1997).

Reports of regression of total milk yield on weaning weight are variable. Marston et al. (1989) found that each one kg increase in weaning weight required an additional 26.8 kg of milk. Marston et al. (1990) reported that each one kg increase in weaning weight required an additional 62 kg of milk for Angus and 40 kg milk for Simmentals. For Herefords, Marston et al. (1992) found that a one kg change in total milk production was associated with a 0.014 ± 0.006 and 0.032 ± 0.009 kg weaning weight for Angus and Simmental, respectively. For Herefords, a one kg increase in daily milk yield resulted in 7.2 kg additional 205-d weight (Boggs et al., 1980). For crossbreds, a one kg increase in daily milk production was associated with a 7.5 kg (Butson et al., 1980), 7.8 kg (Butson et al., 1980), 11.3 to 14.6 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), and 13.7 kg (Beal et al., 1988) increase in weaning weight. Marshall and Long (1993) found that for crossbreds, one kg of additional weaning weight was associated with 20.4 kg of additional milk.

Milk production and calf gain

Beal et al. (1990) reported that dam's milk yield is the greatest factor influencing preweaning gain in similarly bred calves. This seems to vary throughout the literature with reports ranging from no effect (Ansotegui et al., 1991; Martin and Franke, 1982) to a positive effect (Neville, Jr., 1962; Melton et al., 1967a; Butson and Berg, 1984a; Chenette and Frahm, 1981). Comerford et al. (1978) found a linear relationship between unadjusted average daily gain and milk yield. The amount of variation in calf gain that is explained by differences in 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). Pope et al. (1963) reported the amount of variation in calf gain accounted for by milk production at 1-2 months, 2-3 months, 3-4 months, and 5-6 months was 42 % to 64 %, 30 % to 49 %, 9 % to 20 %, and 2 % to 6 %, respectively.

The stage of lactation affects the correlation between milk yield and calf average daily gain. The correlations tended to decrease as lactation progressed (Neville, Jr., 1962; Clutter and Nielsen, 1987) because the calf became less dependent on its mother's milk due to grazing or creep feeding. In Herefords, Christian et al (1965) found correlations between milk production and average daily gain of 0.77 ($P < 0.01$) from 0 to 60 days and 0.64 ($P < 0.01$) from 60 to 240 days. Gifford (1953) reported the correlations between daily milk production of Hereford dams and calf gain to be 0.60 ($P < 0.01$), 0.71 ($P < 0.01$), 0.52 ($P < 0.01$), 0.35 ($P < 0.01$), 0.19 ($P > 0.05$), 0.24 ($P > 0.05$), 0.39 ($P < 0.01$), and 0.57 ($P < 0.01$) for one, two, three, four, five, six, seven, and eight months post-calving, respectively. In an Angus study, Schwulst et al. (1980) reported this correlation to be 0.41 ($P > 0.05$) for birth to two weeks, 0.63 ($P < 0.01$) for birth to three weeks, and 0.58 ($P < 0.01$) for birth to five weeks. Franke et al. (1975) found correlations between milk yield and average daily gain from birth to three months, three to five months, and five to seven months to be 0.26, 0.30, and 0.13 for Herefords and 0.45, 0.32, and 0.17 for Angus. In a study of Angus, Hereford, and Charolais, Melton et al. (1967b) reported correlations of 0.58 ($P < 0.05$), 0.38 ($P > 0.05$), 0.01 ($P > 0.05$), 0.19 ($P > 0.05$), 0.27 ($P > 0.05$), and 0.03 ($P > 0.05$) between daily milk yield and average daily gain during six monthly periods. In a study with crossbred cows, Gleddie and Berg (1968) reported correlations of 0.73, 0.83, 0.81, and 0.82 between average daily gain and milk production in months one, two, three, and five. For crossbred cows, Todd et al. (1969) found the correlation between milk yield and average daily gain to be 0.95 in the first month and 0.25 in the third month, and Daley et al. (1987) found the correlation to be 0.45 ($P < 0.01$) at 60 days, 0.36 ($P < 0.01$) at 105 days, and 0.41 ($P < 0.01$) at 150 days.

There are differences in correlations between milk yield and average daily gain between breeds. This correlation in Angus has been reported as 0.45 ($P < 0.05$) (Franke et al., 1975), 0.46 (Cobb et al., 1978a), 0.50 ($P < 0.01$) (Drewry et al., 1959), and 0.54 ($P < 0.001$) (Reynolds et al., 1978). The correlations for Herefords were 0.36 ($P < 0.05$) (Carpenter, Jr., et al., 1972), 0.38 (Meyer et al., 1994), 0.41 ($P < 0.05$) (Franke et al., 1975), and 0.67 (Cobb et al., 1978a). The correlation between milk production and average daily gain has been reported as 0.33 (Meyer et al., 1994) for Wokalups, 0.36 ($P < 0.05$) (Carpenter, Jr., et al., 1972) for Charolais, 0.51 ($P < 0.01$) (Reynolds et al., 1978) for Brahman, and 0.60 ($P < 0.01$) (Reynolds et al., 1978) for Brangus. For crossbred cows, the correlation was 0.14 ($P < 0.05$) (Todd et al., 1968), 0.29 ($P < 0.05$) (Chenette and Frahm, 1981), 0.36 ($P < 0.05$) (Carpenter, Jr., et al., 1972), 0.46 (Wilson et al., 1968), 0.49 ($P < 0.05$) (Wilson et al., 1969), 0.58 ($P < 0.01$) (Reynolds et al., 1978), 0.60 ($P < 0.01$) (Clutter and Nielsen, 1987) 0.60 to 0.70 (Pope et al., 1963), 0.67 to 0.71 ($P < 0.01$) (Butson et al., 1980), 0.71 (Belcher and Frahm, 1979), 0.76 (Jeffery et al., 1971b), 0.78 (Jeffery et al., 1971b), and 0.84 ($P < 0.01$) (Gleddie and Berg, 1968).

The regression of milk production and calf gain is variable. Melton et al. (1967b) reported that a one kg increase in calf gain required an additional 5.7 kg of milk in Angus and 5.3 kg of milk in Charolais. In Herefords, the amount of milk required to produce one kg of calf gain has been reported as 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). Boggs et al. (1980) found that a one kg increase in daily milk yield was associated with a 0.34 kg/d ($P < 0.001$) increase in average daily gain. For Santa Gertrudis, Wistrand and Riggs (1966) reported a one kg increase in daily milk yield resulted in an increased average daily gain of 0.05 to 0.09 kg/d. Butson and Berg (1984b) reported that a 0.1 kg increase in average daily gain was associated with a 0.48 kg increase in June milk yield and a 0.21 kg increase in September milk yield. For Angus cows, one kg of calf gain in the first, third, and sixth months required 12.5 kg, 10.8 kg, and 6.3 kg of milk, respectively (Drewry et al., 1959).

Calf birth weight

The effect of calf birth weight on milk production of the dam ranged from non-significant (Christian et al., 1965; Gleddie and Berg, 1968) to moderately positive (Rutledge et al., 1970a; Rutledge et al., 1971; Robinson et al., 1978; Martin and Franke, 1982; Butson and Berg, 1984b). Larger calves were able to consume more milk and caused their dams to produce more milk (Drewry et al., 1959; Marston et al., 1992; Hohenboken et al., 1973). Heavier fetuses may have caused an increased secretion of placental lactogen and stimulated increased milk yield (Mallinckrodt et al., 1993). Marston et al. (1992) found that a one kg change in birth weight was associated with a 19.2 ± 8.6 kg change in total milk yield in Angus and a 8.6 ± 6.9 kg change in total milk yield in Simmentals. For crossbred cows, Butson and Berg (1984b) found that a one kg increase in birth weight resulted in a 0.4 kg increase ($P < 0.05$) in daily milk yield.

The correlation between birth weight and milk production was highly variable. For Herefords, this correlation has been reported as 0.11 (Hohenboken et al., 1973), 0.18 (Robison et al., 1978), 0.22 (Kress and Anderson, 1974), and 0.24 (Mallinckrodt et al., 1993). Mallinckrodt et al. (1993) found the correlation of -0.05 for Simmentals. Schwulst et al. (1966) reported a correlation of 0.50 ($P < 0.01$) for Angus. For crossbred cows, the correlations between birth weight and milk yield were 0.11 to 0.18 (Jeffery et al., 1971a), 0.14 (Pope et al., 1963), and 0.45 to 0.46 ($P < 0.01$) (Butson et al., 1980).

As lactation progresses, the correlation between birth weight and milk production tends to decrease. Drewry et al. (1959) reported correlations of 0.43, 0.29, and 0.12 in months one, three, and six, respectively, and Robison et al. (1978) reported the correlation between birth weight and bimonthly milk yield of 0.19 ($P < 0.01$), 0.12 ($P < 0.01$) and 0.09 ($P < 0.01$).

The effect of calf birth weight on average daily gain ranged from non-significant (Gregory et al., 1950) to moderately positive (Neville, Jr., 1962; Brown et al., 1970; Rutledge et al., 1970b; Boggs et al., 1980). For Herefords, the correlation between calf birth weight and average daily gain has been reported as 0.07 ($P > 0.05$) (Gregory et al., 1950), 0.32 ($P < 0.05$) (Christian et al., 1965), and 0.44 ($P < 0.01$) (Gregory et al., 1950). In crossbred cows, the correlation was reported as 0.23 (Jeffery et al., 1971b), 0.32 (Jeffery et al., 1971b), 0.24 to 0.45 (Jeffery and Berg, 1972a) and 0.38 to 0.51 ($P < 0.01$) (Butson et al., 1980).

Gregory et al. reported that the correlation between birth weight and weaning weight for Herefords was 0.27 and 0.60. The correlation between birth weight and weaning weight in crossbred cows was 0.37 (Jeffery et al., 1971b), 0.41 (Jeffery et al., 1971b), and 0.40 to 0.53 (Butson et al., 1980). Marston et al. (1992) found that a one kg change in Angus birth weight resulted in a 1.89 ± 0.58 kg change in adjusted weaning weight and Butson et al. (1980) reported a 1.5 to 1.9 kg increase in weaning weight for each one kg change in crossbred birth weight.

Sex of calf

The effect of calf sex on milk production of the dam ranged from males receiving more milk (Pope et al., 1963; Jeffery et al., 1971a; Wingert et al., 1984; Daley et al., 1987; McCarter et al., 1991) to no effect (Christian et al., 1965; Melton et al., 1967b; Gleddie and Berg, 1968; Todd et al., 1968; Neville, Jr., et al., 1974; Marshall et al., 1976; Robison et al., 1978; Williams et al., 1979a; Lawson, 1981; Butson and Berg, 1984a) to females receiving more milk (Jeffery et al, 1971a; Rutledge et al., 1971).

The effect of sex on calf average daily gain ranged from non-significant (Gregory et al., 1950) to males having significantly faster gains than females (Marlowe and Gaines, 1958; Neville, Jr., 1962; Christian et al., 1965; Melton et al., 1967b; Rutledge et al., 1971; Jeffery et al., 1971b; Jeffery and Berg, 1972b; Franke et al., 1975; Nelms et al., 1978; Reynolds et al., 1978; Wingert et al., 1984). Marlowe and Gaines (1958) reported that bulls gained five percent faster than steers, which gained eight percent faster than heifers.

Males tended to be significantly heavier at weaning than females (Brown, 1960; Christian et al., 1965; Cundiff et al., 1966; Linton et al., 1968; Singh et al., 1970; Brown et al., 1970; Rutledge et al., 1970b; Butson et al., 1980; Wingert et al., 1984), however, Gregory et al. (1950) and Marston et al. (1992) reported that sex did not affect weaning weight. In a crossbred study, Marlowe and Gaines (1958) reported that bulls were 7.3 kg heavier than steers, which were 13.6 kg heavier than heifers. For Simmentals, Marston et al. (1992) found that males were 23.4 ± 3.70 kg ($P < 0.0001$) heavier than females at weaning.

The effect of dam's milk yield on the future milk production of heifer calves ranged from no effect (Meyer et al., 1994) to a negative effect (Pope et al., 1963; Koch, 1972; Christian et al., 1965; Cundiff et al., 1974; Lawson, 1976; Lubritz et al., 1989). High levels of nutrition may cause fatty deposits in the udder and have detrimental effects on future production (Lawson, 1976). Lubritz et al. (1989) found that cows raised by two-year-old dams had above average milk production, those raised by three- and four-year-old cows had average milk production, and cows raised by mature dams had below average production.

Breed of cow

Level of milk production differed between breeds (Melton et al., 1967b; Gleddie and Berg, 1968; Todd et al., 1969; Reynolds et al., 1978; Gaskins and Anderson, 1980; Butson and Berg, 1980; Jenkins and Ferrell, 1984; Butson and Berg, 1984b; Nelson et al., 1985; Jenkins and Ferrell, 1992; Freetly and Cundiff, 1998). Melton et al. (1967b) reported that for average daily milk yield, Charolais exceeded Angus by 120 kg and Angus exceeded Hereford by 83 kg. Klett et al. (1965) found average milk yields of 3.90 kg and 2.92 kg for Angus and Hereford, respectively. Reynolds et al. (1978) reported that Brangus produced 0.5 kg/d more milk than Angus, which produced 0.5 kg/d more milk than Brahman ($P < 0.01$). Nelson et al. (1985) found that for average milk yield, Simmentals were higher than Angus, which were higher than Herefords. Minick et al. (2001) reported that Angus-sired cows produced more milk than Hereford-sired cows at peak lactation ($P < 0.01$) and during months 3, 4, and 6 ($P < 0.02$). In a study of nine breeds, Jenkins and Ferrell (1992) reported that total milk production of the breeds ranged from 1,200 kg to 1,800 kg. At peak lactation, Braunvieh (11.9 ± 0.3 kg), Gelbvieh (11.5 ± 0.3 kg), Pinzgauer (11.1 ± 0.3 kg), and Simmental (10.9 ± 0.3 kg) produced more milk than Charolais (9.8 ± 0.3 kg), Limousin (9.5 ± 0.3 kg), Angus (9.4 ± 0.3 kg), and Hereford (8.5 ± 0.3 kg).

Crossbred cows also showed differences in level of milk production (Gleddie and Berg, 1968; Todd et al., 1968; Jeffery et al., 1971b; McGinty and Frerichs, 1971; Totusek et al., 1971; Cobb et al., 1978b; Belcher and Frahm, 1979; Gaskins and Anderson, 1980; Chenette and Frahm, 1981; Mondragon et al., 1983; Butson and Berg, 1984b; Jenkins and Ferrell, 1984; Daley et al., 1987; Hardt et al., 1988). Jenkins and Ferrell (1984) found that differences between crosses were greatest in early lactation and decreased throughout lactation. Crossbred cows produced more milk than purebred cows (Todd et al., 1969; Cundiff et al., 1974; Mondragon et al., 1983; Wingert et al., 1984) and dairy crosses produced more milk than beef crosses (Butson and Berg, 1984a). Cundiff et al. (1974) reported that crossbred cows produced 0.9 %, 7.5 %, 6.1 %, and 38 % more milk than purebreds at 2 weeks, 6 weeks, 14 weeks, and 29 weeks postpartum, respectively.

Breed of dam also affects calf gain and weaning weight (Melton et al., 1967b; Todd et al., 1968; Turner, 1969; Jeffery et al., 1971b; Brown et al., 1970; Comerford et al., 1978; Cundiff et al., 1974; Nelms et al., 1978; Notter et al., 1978; Lawson, 1976; Belcher and Frahm, 1979; Nelson et al., 1985; Freetly and Cundiff, 1989; Minick et al., 2001). Brown et al. (1970) reported that dairy crosses produced calves that were 4.54 kg heavier at weaning that calves of straightbred dams and Hereford-cross and Angus-cross cows produced calves that were 27.24 kg and 24.97 kg heavier at weaning than purebred Hereford and Angus cows, respectively. Todd et al. (1968) found that calves raised by crossbred cows were 19 % heavier at weaning than calves raised by purebred cows.

Cows raising crossbred calves produced more milk than cows raising straightbred calves (Reynolds et al., 1978). Angus cows produced 20 % ($P < 0.05$) more milk and Africander x Angus cows produced 26 % ($P < 0.01$) more milk when their calves were sired by another breed (Reynolds et al., 1978). Crossbred calves may be able to consume more and therefore stimulate their dams to produce more milk.

Cow Weight

The effects of cow weight on milk production ranged from negative (Pope et al., 1963; Marston et al., 1992) to non-significant (Todd et al., 1968; Wilson et al., 1969; Hohenboken et al., 1973; Kress and Anderson, 1974; Marshall et al., 1976; Mondragon et al., 1983; Butson and Berg, 1984b) to positive (Totusek and Arnett, 1965; Rutledge et al., 1970a; Jeffery et al., 1971a; Rutledge et al., 1971; Mondragon et al., 1983; Rahnefeld et al., 1990). The correlations between cow weight and milk production have been reported as -0.37 to -0.22 (Pope et al., 1963); 0.28 to 0.38 (Jeffery et al., 1971a); and 0.69, 0.80, and 0.88 (Totusek and Arnett, 1965).

The effects of cow weight on calf gain ranged from negative (Gregory et al., 1950; Carpenter, Jr. et al., 1972) to non-significant (Neville, Jr., 1962; Brinks et al., 1962; Vaccaro and Dillard, 1966; Fitzhugh et al., 1967; Melton et al., 1967b; Wilson et al., 1969; Singh et al., 1970) to positive (Miquel et al., 1972; Hohenboken et al., 1973). Jeffery and Berg (1972a) reported correlations between cow weight and calf gain of 0.29 to 0.38. Benyshek and Marlowe (1973) found a positive linear relationship between calf gain and adjusted cow weight. A 100 kg increase in cow weight was associated with a 0.04 kg/d (McDonald and Turner, 1969) and a 0.030 ± 0.004 kg/d to 0.046 ± 0.005 kg/d (Benyshek and Marlowe, 1973) increase in calf gain.

The effect of cow weight on calf weaning weight ranged from negative (Carpenter, Jr. et al., 1972; Gregory et al., 1950) to non-significant (Brinks et al., 1964; Neville, Jr., 1962; Melton et al., 1967b; Godley and Tennant, Jr., 1969; Singh et al., 1970; Carpenter, Jr. et al., 1972) to positive (Smith and Fitzhugh, 1968; Singh et al., 1970; Miquel et al., 1972; Hohenboken et al., 1973). Correlations between cow weight and calf weaning weight have been reported as 0.20 (Gregory et al., 1950), 0.21 (Urick et al., 1971), 0.34 (Tanner et al., 1965), and 0.51 (O'Mary et al., 1959). A one kg change in cow weight was associated with 0.04 kg (Urick et al., 1971), 0.07 kg (Jeffery et al., 1971b; Jeffery and Berg, 1972b), and 0.08 ± 0.02 kg to 0.10 ± 0.02 kg (Benyshek and Marlowe, 1973) of calf weaning weight.

Cow weight change throughout lactation affected milk production (Rahnefeld et al., 1990). In general, weight gain during lactation was at the expense of milk production (Gregory et al., 1950; Pope et al., 1963; Jeffery et al., 1971a; Hohenboken et al., 1973; Butson et al., 1980). Jeffery et al. (1971a) reported that a 10 kg increase in summer cow gain was associated with a 0.1 kg decrease in daily milk yield. Correlations between cow gain during lactation and milk yield have been reported as -0.35 (Hohenboken et al., 1973), -0.21 to -0.12 (Jeffery et al., 1971a), -0.24 to 0.10 (Pope et al., 1963), -0.16 (Wilson et al., 1968), and -0.10 to -0.07 (Butson et al., 1980).

The effects of cow weight gain on calf gain and weaning weight were variable. Butson and Berg (1984b) reported that cow gain was not associated with calf performance, while Spitzer et al. (1995) found that cow weight gain was associated with increased calf weaning weight. Others have reported that cows that lost weight (or made the smallest gains) during lactation produced faster growing calves (Brinks et al., 1962; Vaccaro and Dillard, 1966; Singh et al., 1970; Gregory et al., 1950) that were heavier at weaning (Singh et al., 1970). Singh et al. (1970) found that for every 10 % loss of body weight by the cow, calf gain increased by 0.03 kg/d. For every 1 % of body weight lost by the cow, calf weaning weight increased 0.14 to 1.09 kg (Butson et al., 1980) and 0.9 kg (Sing et al., 1970). Correlations between cow weight gain and calf gain were -0.34 (Gregory et al., 1950), -0.20 to -0.12 (Butson et al., 1980), and -0.12 (Gregory et al., 1950). Correlations between cow gain and calf weaning weight were -0.35 (Todd et al., 1968) and -0.22 to -0.16 (Butson et al., 1980).

Cow Body Condition Score (BCS) and other cow measurements

Cows producing more milk tended to have lower BCS (Mondragon et al., 1983; Belcher and Frahm, 1979; Minick et al., 2001). Marshall et al. (1976) found no significant correlation between body condition and milk production, while Wilson et al. (1968) found a correlation of -0.61 between final BCS and kg of milk produced. Different management practices may partly explain the correlation differences.

Cow BCS also affected calf weight. Spitzer et al. (1995) found that increased cow BCS was associated with an increase in calf birth weight without an increase in dystocia. Hohenboken et al. (1973) reported cow BCS had no significant effect on calf size, while Marshall et al. (1976) found that cow BCS was negatively associated with efficiency and calf weaning weight.

Other measurements of cow size were associated with calf weight. Tanner et al. (1965) reported correlations between calf weight and various cow measurements to be 0.33 for wither girth, 0.36 for hook width, and 0.45 for wither height, back length, and rump length. The multiple correlation coefficient for all measurements was 0.52 (Tanner et al., 1965). O'Mary et al. (1959) reported significant correlations ($P < 0.05$) between calf weight and cow measurements to be 0.46 for foreshank length, 0.48 for forearm circumference, and 0.46 for rump length. The multiple correlation coefficient for these three measurements was 0.91.

Cow age

Cow age had a significant effect on milk production (Gifford, 1953; Drewry et al., 1959; Christian et al., 1965; Pope et al., 1963; Melton et al., 1967b; Todd et al., 1969; Rutledge et al., 1970a; Jeffery et al., 1971a; Reynolds et al., 1978; Neville, Jr., et al., 1974; Nelms et al., 1978; Robinson et al., 1978; Williams et al., 1979a; Lawson, 1981; Butson and Berg, 1984a; Wingert et al., 1984; Lubritz et al., 1989). In general, milk production rose rapidly from two to three years old, then increased more slowly until six to nine years old, after which, milk yield began to decline (Gifford, 1953; Dawson et al., 1960; Pope et al., 1963; Christian et al., 1965; Fitzhugh et al., 1967; Todd et al., 1969; Neville, Jr., et al., 1974; Robinson et al., 1978; Wingert et al., 1984; Lubritz et al., 1989). Gaskins and Anderson (1980) reported a linear increase in daily milk yield from two to four years of age. Rutledge et al. (1970) found a quadratic effect of cow age on milk yield. In Shorthorns, an average of 540.26 kg more milk than was expected due to increased age was produced during the second lactation (Dawson et al., 1960). Todd et al. (1969) found cows of six years of age to be more persistent than younger cows. Christian et al. (1965) reported that two-year-olds were more persistent than three- and four-year-olds. Butson and Berg (1984a) found that three-year-old, four-year-old and mature cows produced 25 %, 35 %, and 39 % more daily milk than two-year-olds. Jeffery et al. (1971a) reported correlations of 0.22 to 0.32 between age of dam and milk production.

The effect of dam age on calf gain ranged from non-significant (Nelms and Bogart, 1956; Neville, Jr., 1962) to significant (Marlowe and Gaines, 1958; Singh et al., 1970; Franke et al., 1975; Reynolds et al., 1978; Williams et al., 1979a). Calf gains increased with cow age until six to nine years and then decreased (Marlowe and Gaines, 1958; Singh et al., 1970; Wingert et al., 1984). Marlowe and Gaines (1958) reported that the most important source of variation in growth rate was dam age. The correlation between cow age and calf gain ranged from 0.31 ($P < 0.05$) (Drewry et al., 1959) to 0.32 (Jeffery et al.; 1971a).

The effect of cow age on calf weaning weight also ranged from no effect (Neville, Jr., 1962; Rutledge et al., 1970b) to a significant effect (Linton et al., 1968; Turner, 1969; Brown et al., 1970; Singh et al., 1970; Neville, Jr., et al., 1974; Lawson, 1976; Butson et al., 1980; Wingert et al., 1984; Lubritz et al., 1989). Calf weaning weight increased with dam age until six to nine years of age, and then decreased (Swiger et al., 1962; Minyard and Dinkel, 1965; Christian et al., 1965; Cundiff et al., 1966; Singh et al., 1970; Brown et al., 1970; Neville, Jr., et al., 1974; Butson et al., 1980; Wingert et al., 1984; Lubritz et al., 1989). Singh et al. (1970) reported that calves raised by five- to seven-year-old cows were 10.19 kg heavier than average. The amount of variation in calf weaning weight accounted for by cow age was 4.8 % ($P < 0.05$) (Brown, 1960) and 5.67 % (Linton et al., 1968) for Herefords, 20.9 % ($P < 0.01$) (Brown, 1960) for Angus, and 7 % for Angus and Herefords (Cundiff et al., 1966).

Parity has also been shown to affect milk production and weaning weight (Neville, Jr., et al., 1974). In a Hereford study, Neville, Jr., et al. (1974) found that lactation number may influence milk yield and weaning weight as much as age in immature cows. Cows that calved first as three-year-olds produced calves that were heavier at weaning than cows that calved first as two-year-olds (Cundiff et al., 1974; Notter et al., 1978). Calves from first parity three-year-olds gained 0.026 kg/d faster ($P < 0.05$) and were 5.7 kg heavier at weaning ($P < 0.05$) than calves from second parity three-year-olds (Notter et al., 1978).

Lactation curves

Lactation curves varied widely across breeds and milk production level. In general, milk production increased rapidly until it reached a peak at 50 to 65 days (Gifford, 1949; Dawson et al., 1960; Chenette and Frahm, 1981; Jenkins and Ferrell, 1984; Williams et al., 1979a; Mallinckrodt et al., 1993). Time of peak production differed between breeds (Jenkins and Ferrell, 1992) and between different crosses (Butson and Berg, 1984a; Butson and Berg, 1984b, Jenkins and Ferrell, 1984). Herefords have been found to peak earlier than other breeds (Kress and Anderson, 1974; Jenkins and Ferrell, 1992). Clutter and Nielson (1987) reported that higher producing cows peaked later than lower producing cows. In beef cattle, the consumption capacity of the calf limits the level of milk production of the dam (Gifford, 1949; Gifford, 1950). Drewry et al. (1959) found an earlier peak for cows producing more milk in early lactation than the calf could consume.

After reaching a peak, the lactation curve steadily decreased (Gifford, 1949; Gifford, 1953; Rutledge et al., 1970a; Kress and Anderson, 1974; Reynolds et al., 1978; Robinson et al., 1978; Chenette and Frahm, 1981; Mondragon et al., 1983). Mallinckrodt et al. (1993)

found that cows with higher peak production declined at a faster rate than lower peak cows. In a Hereford study, Gifford (1949) found daily milk yields of 3.9 kg, 3.5 kg, 2.7 kg, 2.8 kg, 2.1 kg, 2.1 kg, and 1.9 kg for months one through eight of lactation, respectively. Similarly, average daily milk production in Herefords has been reported as 5.8 kg, 5.7 kg, 5.1 kg, 4.8 kg, 4.4 kg, and 4.0 kg (Rutledge et al., 1970a) and 5.82 kg, 5.81 kg, 5.54 kg, 5.14 kg, 4.75 kg, and 4.09 kg (Robinson et al., 1978) for the first six months of lactation. For Angus, Drewry et al. (1959) reported milk yields of 6.4 kg, 7.3 kg, and 4.1 kg for the first, third, and sixth months, respectively. By weaning, cows were producing very little milk (Kress and Anderson, 1974) and most of the breed differences in milk production were gone (Hardt et al., 1988).

The shape of the lactation curve also varied. Gleddie and Berg (1968) reported a linear decrease in milk yield, while Kress and Anderson (1974) reported a quadratic curve. Rutledge et al. (1972) found that cow age did not affect the shape of the lactation curve. Gaskins and Anderson (1980) reported a more convex curve for two-year-old cows than for three- and four-year-old cows. First parity females had flatter lactation curves than second or third parity females (Mondragon et al., 1983).

Season of calving influenced the shape and magnitude of the lactation curve. Minick et al. (2001) reported that spring-calving cows had higher peak yield than fall-calving cows. McCarter et al. (1991) reported the milk yield of spring-calving cows increased sharply until peaking at two months post-calving, after which there was a gradual decline. For fall calving cows, peak production occurred during the first month, after which production declined until month four, remained steady until month six, and then declined sharply (McCarter et al., 1991). Differences between seasons could be due to forage availability and temperature.

Brahman crosses have been found to produce more milk during the summer months than European breeds that are less adapted to hot, dry, climates (Martin and Franke, 1982; Daley et al., 1987).

Mezzadra et al. (1989) estimated milk consumption curves for different breeds of calves and determined that different suckling patterns may influence consumption curves. They reported that zebu-sired calves reduced milk dependency at an earlier age due to different milk consumption strategies.

Repeatability

The repeatability of calf average daily gain and weaning weight from one lactation to another was moderate. Gregory et al. (1950) reported correlations of 0.38 to 0.59 and 0.35 to 0.50 for the repeatability of gain from birth to weaning and weaning weight, respectively. Wingert et al. (1984) reported the repeatability of average daily gain to be 0.16 to 0.50. The repeatability of weaning weight has been reported as 0.16 for Angus (Meade, Jr., et al., 1959), 0.06 to 0.45 for crossbreds (Wingert et al., 1984), and 0.29 ± 0.06 to 0.45 ± 0.06 (Neville, Jr., et al., 1974) and 0.42 (Meade, Jr., et al., 1959) for Herefords.

Milk production estimates within the same lactation were highly repeatable (Williams et al., 1979b), with the highest correlations between adjacent measurements (Kress and Anderson, 1974). Repeatabilities for milk yield within the same lactation have been reported as 0.32 ± 0.06 (Kress and Anderson, 1974), 0.38 (Rutledge et al., 1972), 0.49 to 0.76 (Reynolds et al., 1978), 0.55 (Butson and Berg, 1984a), 0.60 (Pope et al., 1963), and 0.93 to 1.0 (Dillard et al., 1978). Rutledge et al. (1970a) reported correlations between total milk production and monthly milk productions of 0.61, 0.67, 0.72, 0.74, 0.74, 0.72, and 0.63.

Minick et al. (2001), found these correlations to be 0.51, 0.56, 0.52, 0.54, 0.35, 0.37, and 0.31 (all $P < 0.01$). The correlation between individual milk yield estimates and total milk production has also been reported as 0.83 to 0.94 ($P < 0.01$) (Reynolds et al., 1978).

The repeatability of milk yield for different lactations was much more variable, ranging from non-significant (Beal et al., 1990) to highly repeatable (Marston et al., 1992). The repeatabilities of milk yield were 0.53 for Simmental, and 0.48 ± 0.04 to 0.61 ± 0.05 (Neville, Jr., et al., 1974), 0.58 (Dillard et al., 1978), and 0.67 (Mallinckrodt et al., 1993) for Herefords. For crossbred cows, these repeatabilities were 0.21 to 0.67 (Wingert et al., 1984), 0.34 to 0.42 (Mondragon et al., 1983), and 0.85 (Lawson, 1981). In an across breed study, Marston et al. (1992) reported a repeatability of 0.76 ($P < 0.0001$) for milk yield.

In conclusion, milk production is an important factor affecting calf performance and genetic improvement can be made through selection. Differences in sire Milk EPD accurately predict the differences in daughter's milk production. Breed and age at calving greatly influence milk production. In general, milk production increases rapidly until age five, slowly increases from six to nine years old, after which milk production begins to taper off. The general shape of the lactation curve also varies between breeds, milk production levels, seasons of calving, and cow ages.

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CHAPTER II

LIFETIME PRODUCTIVITY OF CROSSBRED COWS SIRED BY HIGH AND LOW MILK EPD ANGUS AND HEREFORD BULLS

Abstract

Milk production is a major factor influencing calf weaning weight and overall profitability of cow-calf operations. The objective of this study was to evaluate lifetime productivity of beef dams sired by high or low Milk EPD bulls, as measured by milk production and calf weaning weight. Mean Milk EPD in kg for high Angus (n = 12), low Angus (n = 11), high Hereford (n = 9), and low Hereford (n = 9) were +8.7, -6.1, +7.4, and -3.9, respectively. Cows (n = 287) ranged in age from two to eleven years old and calved in spring or fall from 1991 -- 2000 for a total of 1,864 records. Milk production data were collected at seven monthly intervals by weigh-suckle-weigh. Monthly milk production, total milk production from 37 to 205 days post-calving, yield at peak lactation, time of peak lactation, birth weight, and weaning weight were analyzed using least squares means. Factors included in the models were breed, Milk EPD level, year, season, sex, cow age, breed x Milk EPD level, breed x Milk EPD level x cow age, and all two- and three-way interactions with $P < 0.20$. Sire of cow within breed and Milk EPD level and sire of calf within year were included as random effects. Age of calf was included as a covariate. Angus cows produced more milk than Hereford cows but the difference was not significant ($P = 0.0580$). Angus

cows weaned heavier calves than Hereford cows ($P = 0.0386$). High Milk EPD cows produced more milk and weaned heavier calves than low Milk EPD cows ($P < 0.0001$). High Milk EPD Angus cows weaned calves that were 14.68 kg heavier than low Milk EPD Angus cows, which was 0.24 kg less than predicted by grandsire Milk EPD. High Milk EPD Hereford cows weaned calves that were 13.41 kg heavier than low Milk EPD Hereford cows, which was 1.03 kg more than predicted by grandsire Milk EPD. As a general trend, milk production and weaning weight increased with cow age until six years of age, remained steady until ten years of age, then declined. These results suggest that age of cow may be useful for producers when making herd culling decisions.

Introduction

Weaning weight is an important factor affecting the profitability of cow-calf operations. An increase in pounds of calf weaning weight results in an increase in the amount of product available to market, and thus, an increase in income. Numerous studies have suggested that milk production of the dam is one of the most important factors influencing weaning weight of the calf (Neville, Jr., 1962; Beal et al., 1990). For these reasons, finding ways to assess genetic merit for the level of milk production in a herd would enhance profitability.

The Milk EPD was developed as a tool for improving weaning weight through maternal ability. The Milk EPD predicts the differences in weaning weights, due to maternal ability, of calves born to daughters of different bulls. This EPD is measured in pounds of weaning weight, not pounds of milk as may be expected.

Age of dam greatly influences milk production and weaning weight (Wingert et al., 1984). In general, milk production and weaning weight increase the first two to four years of production, remain steady the next four to five years, then decline (Neville, Jr., et al., 1974; Lubritz et al., 1989). This makes lifetime productivity of the dam an important characteristic to study. The purpose of the current study was to evaluate lifetime productivity of beef cows sired by high or low Milk EPD Angus or Hereford bulls, as measured by milk production and calf weights.

Materials and Methods

An existing herd of Hereford x Angus, ¼ Brahman x ¼ Hereford x ½ Angus, and ¼ Brahman x ¼ Angus x ½ Hereford cows were bred to high and low Milk EPD Angus or Polled Hereford sires. Forty-one bulls were used: twelve high Milk EPD Angus, eleven low Milk EPD Angus, nine high Milk EPD Hereford, and nine low Milk EPD Hereford. Average EPD values are presented in Table 1. Heifers from these matings were born from 1989 to 1993 and were managed to begin calving in 1991. Heifers and cows (n = 287) were mated to Angus, Charolais, Gelbvieh, Limousin, Maine-Anjou, Polled Hereford, Salers, or crossbred bulls. After artificial insemination, heifers and cows were placed in pasture with crossbred bulls for a 75-d total breeding season. Not all breeds were used within one year. Sires used for spring calving were also used for fall calving. Spring calves were born from February to April and fall calves were born from September to November.

TABLE 1. AVERAGE EXPECTED PROGENY DIFFERENCES (KG) FOR ANGUS AND HEREFORD SIRES

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

At calving, all calves were weighed and males were castrated. Cows and calves were placed on native pasture at North Lake Carl Blackwell Range. Calves did not receive creep feed. Winter dry cows were supplemented with 41 % crude protein cubes three times per week at the rate of 0.45 kg/(hd·d) in October, 0.91 kg/(hd·d) in November and December, and 2.72 kg/(hd·d) from January until calving. Cows nursing fall-born calves were also supplemented with 41% crude protein cubes at the rate of 0.45 kg/(hd·d) in October, 0.91 kg/(hd·d) in November and December, 1.81 kg/(hd·d) in January, and 2.27 kg/(hd·d) in February. Cows were also supplemented with 13.61 kg/(hd·d) of grass hay on days when grass was not available. Spring-born calves were weaned at approximately 205 days and fall-born calves were weaned at approximately 240 days. All weights were adjusted to 205 days.

Milk production data were collected on 1,864 cow-calf pairs by weigh-suckle-weigh approximately 37, 65, 93, 121, 149, 177, and 205 days after calving for spring- and fall-calving cows. Cows and calves were separated at 1800 hours on the day prior to measurement. At 0545 hours the next morning, calves were placed with cows and allowed to nurse until the udder was empty. This ensured that all milk was removed from the udder at the beginning of the separation period. Calves were separated from the cows until 1145 hours, at which time they were weighed and returned to their dams to nurse. Calves were weighed after nursing and the difference between the two weights was the 6-h milk production of the cow. The procedure was repeated at 1745 hours and the two estimates of 6-h milk production were used to calculate a 24-h estimate for each cow.

The seven monthly measurements of milk production, birth weights, and 205-d adjusted weaning weights were analyzed by least squares means using the MIXED procedure of SAS (1990). Terms included in the model were breed of cow sire, Milk EPD level, year, season, sex of calf, age of cow, breed x Milk EPD level, breed x Milk EPD level x age of cow, and all two- and three-way interactions with $P < 0.20$. Cow sire(breed x Milk EPD level) and calf sire(year) were included as random effects. Calf age was included as a covariate. Due to inclement weather data were not collected for milk production two during fall of 2000 and model terms year and season were combined to form the variable Yrs = Year * 10 + season.

Lactation curves were estimated by the equation of Jenkins and Ferrell (1982, 1984):

$$Y(n) = n/ae^{kn}$$

where $Y(n)$ is the amount of milk produced on the nth day post-calving and a and k are lactation curve parameters. Amount of milk produced was divided by days in lactation, and the natural log of that value was regressed on day of lactation to estimate curve parameters, such that $\log_e[Y(n)/n] = (\log_e 1/a) - kn$. The curve was integrated from day 37 to day 205 to estimate the amount of milk produced between those days. This measure of milk production from month one to month seven will be referred to as total milk production. The Jenkins and Ferrell (1982, 1984) curve was also used to find yield at peak lactation = $1/ake$ and time of peak lactation = $1/k$.

Records of cows which failed to wean calves during a given lactation were removed. Records of cows raising twins were also removed. For time of peak lactation, cows with estimates greater than 500 d or less than –500 d for a given lactation were removed.

Results and Discussion

Monthly Milk Production

Tests of significance for model terms are presented in Appendix Table 1. Significant interactions of breed or Milk EPD level and other fixed effects were breed x year in month three; breed x season in month seven; Milk EPD level x year in month five; Milk EPD level x season in months three and four; breed x year x sex in months one and five; Milk EPD level x year x sex in month six; and Milk EPD level x year x season in months five and six.

High Milk EPD cows produced more milk than low Milk EPD cows during all months (Figure 1, Table 2). This agreed with the results of Minick et al. (2001), Marston et al. (1992), and Marshall and Long (1993), but disagreed with Marshall and Freking's (1988) findings that high and low Milk EPD sired cows did not produce significantly different amounts of milk. The magnitude of differences between high and low Milk EPD cows varied from month one to month seven, suggesting different lactation curves for the two groups. High Milk EPD cows declined at a steadier rate then low Milk EPD cows.

Angus sired cows produced more milk than Hereford sired cows during all months but differences were only significant for months one and six (Figure 2, Table 2). These results agreed with Minick et al. (2001), Jenkins and Ferrell (1992), and Melton et al. (1967b) who reported that Angus cows produce more milk than Hereford cows. Breed

TABLE 2. LEAST SQUARE MEANS BY BREED AND MILK EPD LEVEL FOR MONTHLY MEASUREMENTS OF 24-H MILK PRODUCTION (KG)

	Angus		Hereford		P-values		
	High Milk	Low Milk	High Milk	Low Milk	Breed	Level[a]	B x L[b]
Month 1	6.99 ± 0.23	5.92 ± 0.24	6.31 ± 0.28	5.26 ± 0.25	0.0120	0.0002	0.9685
Month 2	5.58 ± 0.23	4.72 ± 0.22	5.68 ± 0.28	4.54 ± 0.25	0.8503	< 0.0001	0.5243
Month 3	5.32 ± 0.21	4.26 ± 0.21	5.11 ± 0.27	3.99 ± 0.22	0.2942	< 0.0001	0.8817
Month 4	5.17 ± 0.21	4.27 ± 0.21	4.72 ± 0.24	4.01 ± 0.21	0.0627	0.0021	0.5898
Month 5	4.32 ± 0.21	3.44 ± 0.21	4.02 ± 0.25	3.38 ± 0.22	0.4426	0.0021	0.4938
Month 6	3.96 ± 0.20	3.01 ± 0.20	3.27 ± 0.22	2.72 ± 0.20	0.0071	0.0023	0.2629
Month 7	3.20 ± 0.21	2.30 ± 0.21	2.61 ± 0.25	2.28 ± 0.22	0.1478	0.0039	0.1615

[a]Milk EPD level

[b]Breed (B) x Milk EPD level (L)

Figure 1. Least squares means by Milk EPD level for monthly 24-h milk production of Angus and Hereford cows.

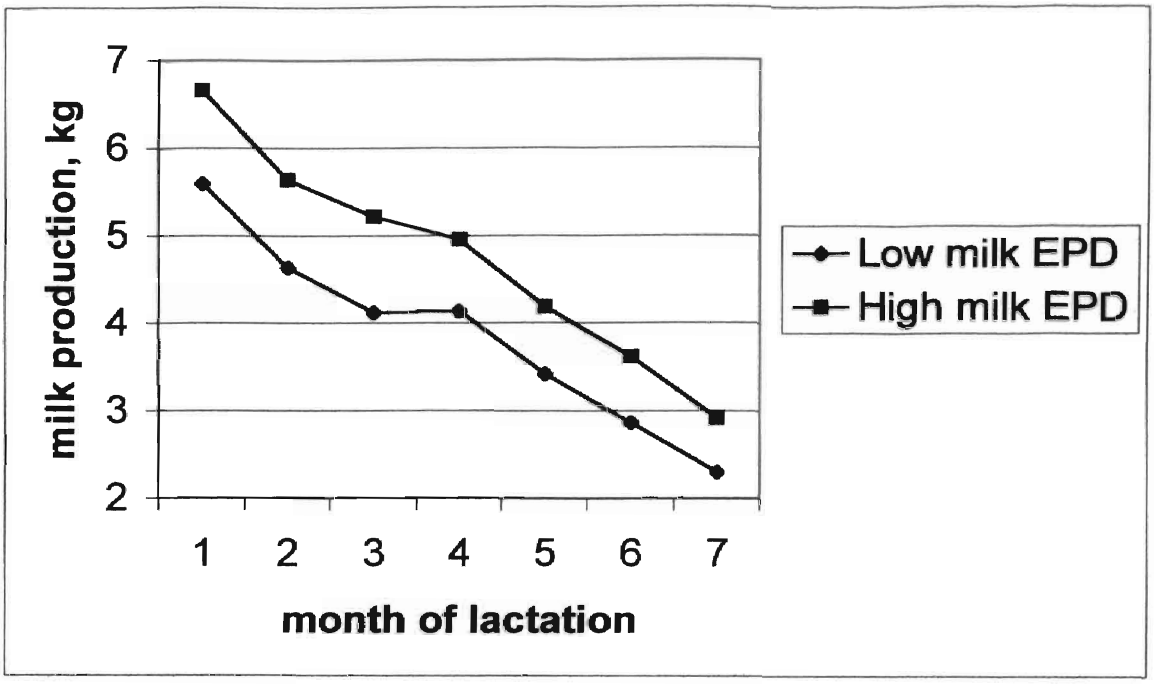


Figure 2. Least squares means by breed for monthly 24-h milk production of Angus and Hereford cows.

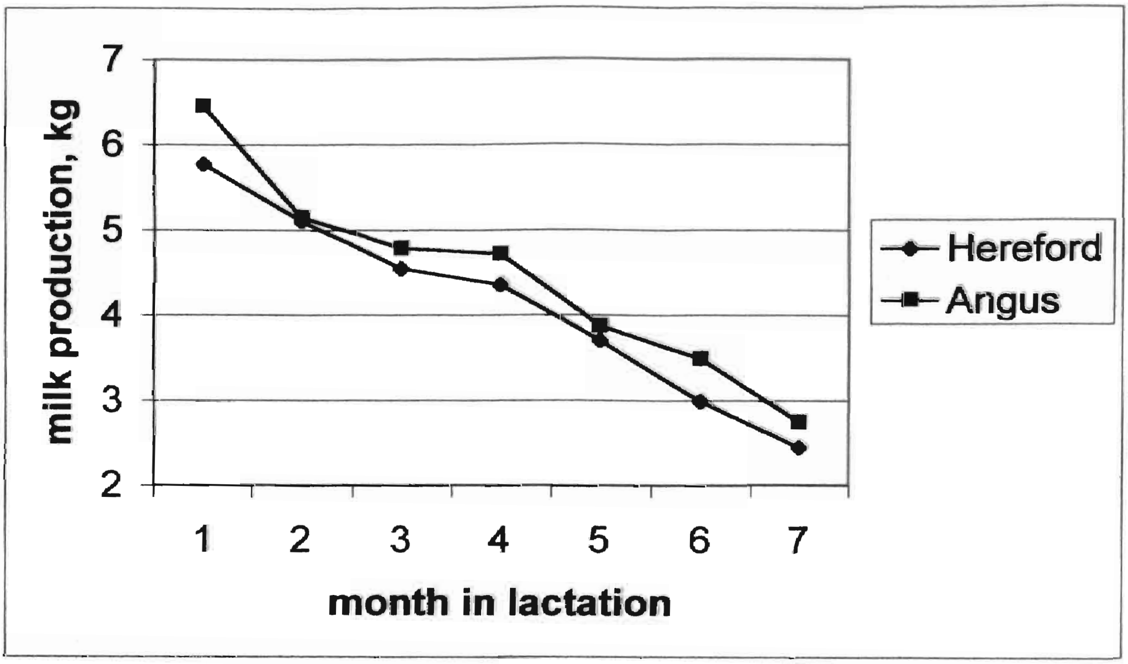
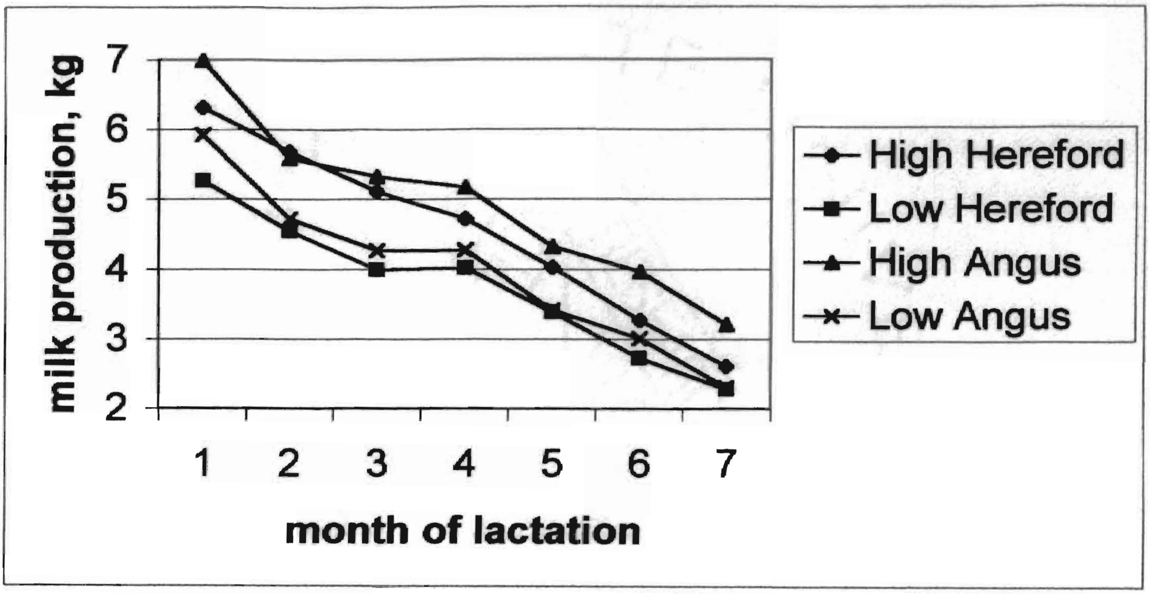


Figure 3. Least squares means by breed and milk level for monthly 24-h milk production of high and low Milk EPD Angus and Hereford cows.



and breed x Milk EPD level differences varied throughout lactation (Figures 2, 3), indicating different lactation curves for Angus and Hereford cows.

Steers received more milk than heifers in months three and six (Table 3) which agreed with results of Pope et al. (1963), Jeffery et al.(year 1) (1971a), Wingert et al. (1984), Daley et al. (1987), and McCarter et al. (1991). No differences were found between steers and heifers for months one, two, four, five, and seven, which agreed with the findings of Christian et al. (1965), Melton et al. (1967b), Gleddie and Berg (1968), Todd et al. (1968), Neville, Jr., et al. (1974), Marshall et al. (1976), Robinson et al. (1978), Williams et al. (1979a), Lawson (1981), and Butson and Berg (1984a). In contrast to these studies, Jeffery et al. (year 2) (1971a) and Rutledge et al. (1971) reported that heifers received more milk than steers. In the current study, steers were generally larger than heifers and may have been able to consume more milk. These differences were only significant during months three and six, however, suggesting differences in the ways steers and heifers responded to the environment during those months.

Season affected milk production in months one, two, three, six, and seven (Table 4). Spring-calving cows produced more milk than fall-calving cows except in month seven. This agreed with the results of Minick et al. (2001) who reported higher milk yield for spring-calving cows. Differences were probably due to the availability of higher quality summer pasture for spring calving cows during the majority of the lactation. By month seven, however, fall calving cows were on spring pasture while spring calving cows were on more mature, lower quality fall forage. Jenkins and Ferrell (1992) reported linear increases in milk production in response to increased energy intake.

TABLE 3. LEAST SQUARES MEANS BY SEX OF CALF FOR MONTHLY MEASUREMENTS OF 24-H MILK PRODUCTION (KG)

	Steers	Heifers	P-value
Month 1	6.20 ± 0.16	6.04 ± 0.15	0.2290
Month 2	5.15 ± 0.18	5.11 ± 0.17	0.7572
Month 3	4.90 ± 0.13	4.44 ± 0.13	0.0003
Month 4	4.56 ± 0.14	4.52 ± 0.13	0.6944
Month 5	3.76 ± 0.14	3.81 ± 0.13	0.6845
Month 6	3.43 ± 0.13	3.05 ± 0.13	0.0012
Month 7	2.48 ± 0.17	2.71 ± 0.16	0.2591

TABLE 4. LEAST SQUARES MEANS BY SEASON FOR MONTHLY MEASUREMENTS OF 24-H MILK PRODUCTION (KG)

	Spring	Fall	P-value
Month 1	6.66 ± 0.16	5.58 ± 0.15	< 0.0001
Month 2	5.53 ± 0.45	4.69 ± 0.44	< 0.0001[a]
Month 3	4.87 ± 0.14	4.47 ± 0.12	0.0021
Month 4	4.61 ± 0.15	4.47 ± 0.13	0.2601
Month 5	3.82 ± 0.14	3.76 ± 0.13	0.6660
Month 6	3.57 ± 0.14	2.91 ± 0.13	< 0.0001
Month 7	2.14 ± 0.18	3.06 ± 0.16	< 0.0001

[a]P-value is for Yrs = Year * 10 + season

Age of dam significantly influenced milk production in months one through six (Table 5). By month seven milk production was relatively low and little difference existed between the age groups. As a general trend, milk production increased rapidly from two to four years old, remained fairly constant from five to ten years old, then began to decline. Similar trends were reported by Gifford (1953), Dawson et al. (1960), Pope et al. (1963), Christian et al. (1965), Fitzhugh et al. (1967), Todd et al. (1969), Neville, Jr., et al. (1974), Robinson et al. (1978), Wingert et al. (1984) and Lubritz et al. (1989). Beef cows reach mature weight after four years of age (NRC, 1996). Younger animals would have to partition energy resources toward both growth and lactation, which could explain why they had lower levels of milk production than mature cows. After ten years of age, the decline in milk production was probably due to the effects of aging on the dam.

TABLE 5. LEAST SQUARES MEANS BY COW AGE FOR MONTHLY MEASUREMENTS OF 24-H MILK PRODUCTION (KG)

Cow age	Month						
	1	2	3	4	5	6	7
2	5.35 ± 0.36	4.40 ± 0.33	3.28 ± 0.32	3.48 ± 0.29	3.11 ± 0.30	2.17 ± 0.28	2.23 ± 0.34
3	5.56 ± 0.27	4.93 ± 0.26	4.56 ± 0.23	4.15 ± 0.22	3.45 ± 0.23	3.08 ± 0.22	3.01 ± 0.26
4	6.44 ± 0.23	6.07 ± 0.23	5.23 ± 0.21	4.96 ± 0.20	4.14 ± 0.20	3.56 ± 0.20	3.10 ± 0.23
5	6.68 ± 0.22	6.06 ± 0.23	5.13 ± 0.20	5.24 ± 0.19	4.25 ± 0.19	4.02 ± 0.19	3.06 ± 0.23
6	6.70 ± 0.23	6.03 ± 0.25	5.28 ± 0.21	5.08 ± 0.21	4.13 ± 0.21	3.88 ± 0.20	3.03 ± 0.24
7	6.79 ± 0.26	5.25 ± 0.28	5.08 ± 0.24	4.80 ± 0.23	3.87 ± 0.24	3.62 ± 0.23	2.93 ± 0.27
8	6.44 ± 0.30	5.03 ± 0.33	5.17 ± 0.28	4.78 ± 0.27	3.86 ± 0.27	3.42 ± 0.26	2.40 ± 0.31
9	6.23 ± 0.34	4.78 ± 0.39	4.90 ± 0.32	4.67 ± 0.31	3.82 ± 0.31	3.47 ± 0.30	2.36 ± 0.36
10	6.26 ± 0.40	5.40 ± 0.47	4.44 ± 0.38	4.64 ± 0.36	4.15 ± 0.37	2.96 ± 0.35	2.07 ± 0.43
11	4.75 ± 0.54	3.38 ± 0.77	3.60 ± 0.51	3.62 ± 0.49	3.09 ± 0.49	2.20 ± 0.47	1.80 ± 0.57
P-value	0.0002	< 0.0001	< 0.0001	< 0.0001	0.0112	< 0.0001	0.0868

Total milk production, yield at peak lactation, and time of peak lactation.

Tests of significance for model terms for total milk production between day 37 and 205, yield at peak lactation, and time of peak lactation are given in Appendix Table 2. Significant interactions of breed or Milk EPD level and other fixed effects were breed x year x sex ($P = 0.0230$) and Milk EPD level x year x season ($P = 0.0144$) for total milk production; breed x sex ($P = 0.0248$), Milk EPD level x season ($P = 0.0248$), Milk EPD level x cow age ($P = 0.0243$), breed x Milk EPD level x season ($P = 0.0441$), breed x sex x cow age ($P = 0.0495$), and Milk EPD level x year x season ($P = 0.0012$) for yield at peak lactation; and breed x year for time of peak lactation.

Least squares means by breed and Milk EPD level for total milk production from 37- to 205-d post-calving are presented in Table 6. Angus sired cows produced more total milk than Hereford sired cows but the differences only approached significance ($P = 0.0580$). Angus cows have been reported to produce more total milk than Hereford cows by Melton et al. (1967b), Jenkins and Ferrell (1992), and Minick et al. (2001).

High Milk EPD cows produced more total milk than low Milk EPD cows ($P < 0.0001$) which agreed with Minick et al. (2001). Marshall and Freking (1988), however, found no difference in total milk yield for high and low Milk EPD cows.

Cows raising steers produced more total milk than cows raising heifers ($P = 0.0040$) (Table 7, Appendix Table 2). This agreed with Pope et al. (1963), Jeffery et al. (1971a), Wingert et al. (1984), and Daley et al. (1987). Studies by Christian et al. (1965), Melton et al. (1967b), Gleddie and Berg (1968), Todd et al. (1968), Neville, Jr., et

TABLE 6. LEAST SQUARES MEANS BY BREED AND MILK EPD LEVEL FOR TOTAL MILK PRODUCTION FROM 37- TO 205-D POST-CALVING (KG), YIELD AT PEAK LACTATION (KG), AND DAY OF PEAK LACTATION

	Total milk	Peak yield	Peak day
High Angus	837.12 ± 22.33	6.62 ± 0.10	85.58 ± 2.58
Low Angus	695.47 ± 23.18	5.41 ± 0.19	83.32 ± 2.31
High Hereford	775.16 ± 26.27	6.18 ± 0.22	85.67 ± 3.41
Low Hereford	660.31 ± 23.97	5.14 ± 0.20	89.77 ± 2.72
P-values			
Breed	0.0580	0.0452	0.2502
Level[a]	< 0.0001	< 0.0001	0.7443
B x L[b]	0.4953	0.6241	0.2507

[a]Milk EPD level
[b]Breed (B) x Milk EPD level (L)

TABLE 7. LEAST SQUARES MEANS BY SEX FOR TOTAL MILK PRODUCTION FROM 37- TO 205-D POST-CALVING (KG), YIELD AT PEAK LACTATION (KG), AND DAY OF PEAK LACTATION

	Steers	Heifers	P-value
Total milk	764.98 ± 15.72	719.05 ± 14.98	0.0040
Peak yield	6.11 ± 0.14	5.55 ± 0.13	0.0004
Peak day	84.68 ± 1.75	87.49 ± 2.15	0.1369

al. (1974), Marshall et al. (1976), Reynolds et al. (1978), Robinson et al. (1978), Williams et al. (1979a), Lawson et al. (1981), Butson and Berg (1984a), and Minick et al. (2001), however, found no significant differences in the amount of milk received by steers and heifers.

Spring-calving cows produced more total milk than fall-calving cows (P = 0.0051) (Table 8, Appendix Table 2). Minick et al. (2001) also reported spring-calving cows produced more total milk. Part of the difference may be because spring cows spent a greater portion of their lactations on summer pasture than fall cows did.

Age of dam influenced total milk production (P < 0.0001) (Tables 9, 10, Appendix Table 2). Total milk production increased quickly from two to four years of age, increased more slowly until six years of age, slowly declined from six to ten years of age, then rapidly decreased. Gifford (1953), Drewry et al. (1959), Melton et al. (1967a), Todd et al. (1969), Rutledge et al. (1970a), Jeffery et al. (1971a), Neville, Jr., (1974), Williams et al (1979a), Wingert et al. (1984), and Lubritz et al. (1989) also reported cow age significantly influenced milk yield. Minick et al. (2001), however, found no effect of cow age on total milk production. Previous studies suggest that younger cows used energy resources to meet both growth and lactation demands (NRC, 1996), which could result in lower milk production in these animals. Older cows were experiencing the effects of aging, including weakened udder attachments and reduced energy intake due to worn teeth, which may explain the rapid decline in milk production of cows over ten years of age.

Least squares means and differences of least squares means by breed, Milk EPD level, and age of cow for total milk production are presented in Tables 11 and 12, respectively. Differences between high and low Angus were fairly consistent but were not significant after nine years of age. High Milk EPD Angus cows reached greatest production

TABLE 8. LEAST SQUARES MEANS BY SEASON FOR TOTAL MILK PRODUCTION FROM 37- TO 205-D POST-CALVING (KG), YIELD AT PEAK LACTATION (KG), AND DAY OF PEAK LACTATION

	Spring	Fall	P-value
Total milk	766.24 ± 16.57	717.78 ± 14.73	0.0051
Peak yield	6.14 ± 0.15	5.53 ± 0.13	0.0002
Peak day	87.39 ± 2.15	84.78 ± 1.76	0.3411

TABLE 9. LEAST SQUARES MEANS BY COW AGE FOR TOTAL MILK PRODUCTION FROM 37- TO 205-D POST-CALVING (KG), YIELD AT PEAK LACTATION (KG), AND DAY OF PEAK LACTATION

Cow age	Total milk	Peak yield	Peak day
2	591.11 ± 29.64	5.05 ± 0.26	86.21 ± 4.31
3	701.21 ± 22.76	5.40 ± 0.20	84.51 ± 3.28
4	808.86 ± 19.82	6.32 ± 0.18	83.62 ± 2.98
5	826.79 ± 19.28	6.21 ± 0.17	80.92 ± 2.88
6	829.07 ± 20.35	6.79 ± 0.18	84.91 ± 3.03
7	797.30 ± 23.36	6.34 ± 0.21	90.11 ± 3.44
8	763.59 ± 26.76	5.95 ± 0.24	88.75 ± 3.86
9	753.57 ± 30.65	5.89 ± 0.28	89.44 ± 4.40
10	747.22 ± 36.63	5.84 ± 0.33	88.56 ± 5.19
11	601.39 ± 48.21	4.55 ± 0.45	83.80 ± 7.16
P-value	< 0.0001	< 0.0001	0.7445

TABLE 10. DIFFERENCES OF LEAST SQUARES MEANS BY COW AGE FOR TOTAL MILK PRODUCTION FROM 37- TO 205-D POST-CALVING (KG), YIELD AT PEAK LACTATION (KG), AND DAY OF PEAK LACTATION

Cow age -Cow age	Total milk	P-value	Peak yield	P-value	Peak day	P-value
2-3	-110.10	< 0.0001	-0.35	0.1687	1.70	0.7015
3-4	-107.65	< 0.0001	-0.92	< 0.0001	0.89	0.8184
4-5	-17.93	0.4171	0.11	0.6172	2.70	0.4640
5-6	-2.28	0.9174	-0.58	0.0062	-4.09	0.2808
6-7	31.77	0.1808	0.45	0.0483	-5.20	0.1991
7-8	33.71	0.1803	0.39	0.1134	1.36	0.7460
8-9	10.02	0.7016	0.06	0.8088	-0.69	0.8746
9-10	6.35	0.8348	0.05	0.8651	0.88	0.8591
10-11	145.83	0.0005	1.29	0.0017	4.76	0.4983

TABLE 11. LEAST SQUARES MEANS BY BREED, MILK EPD LEVEL, AND AGE OF COW FOR TOTAL MILK PRODUCTION FROM 37- TO 205-D POST-CALVING (KG)

Cow age	High Angus	Low Angus	High Hereford	Low Hereford
2	666.59 ± 43.78	543.32 ± 48.24	586.75 ± 62.56	567.76 ± 53.28
3	794.27 ± 34.80	681.77 ± 36.54	699.90 ± 49.28	628.89 ± 41.57
4	923.26 ± 33.02	820.66 ± 32.62	764.34 ± 43.74	727.20 ± 37.85
5	928.61 ± 33.78	827.28 ± 32.30	805.60 ± 41.38	745.69 ± 36.46
6	963.37 ± 34.18	767.98 ± 32.84	859.60 ± 45.12	725.32 ± 39.49
7	906.91 ± 39.22	736.72 ± 37.71	810.07 ± 52.31	735.52 ± 42.45
8	825.90 ± 45.62	700.31 ± 44.34	797.07 ± 57.05	731.08 ± 47.77
9	868.85 ± 49.95	663.05 ± 49.25	832.30 ± 64.35	650.08 ± 58.07
10	769.94 ± 58.38	666.71 ± 59.82	894.63 ± 79.89	630.62 ± 66.23
11	696.44 ± 77.77	546.90 ± 59.82	701.25 ± 103.32	460.95 ± 96.39

TABLE 12. DIFFERENCES OF LEAST SQUARES MEANS BY BREED, MILK EPD LEVEL, AND COW AGE FOR TOTAL MILK PRODUCTION FROM 37- TO 205-D POST-CALVING (KG)

Cow age	High Angus -Low Angus	P-value	High Hereford -Low Hereford	P-value
2	123.27	0.0447	18.99	0.7843
3	112.25	0.0201	71.01	0.2228
4	102.60	0.0234	37.14	0.4919
5	101.33	0.0258	59.91	0.2503
6	195.39	< 0.0001	134.28	0.0180
7	170.19	0.0011	74.55	0.2333
8	125.59	0.0391	65.99	0.3200
9	205.80	0.0020	182.22	0.0161
10	103.23	0.1018	264.01	0.0036
11	149.54	0.1526	240.30	0.0573

later than low Milk EPD Angus cows and were able to maintain high production, whereas, production of low milk Angus cows declined with age at a faster rate. Differences in total milk production in Herefords were only significant for six-, nine-, and ten-year-olds. The magnitude of differences between high and low Herefords were not consistent across the life span, indicating that high and low Hereford cows responded differently to the environment. High Milk EPD Hereford cows reached greatest milk production later in life than low Milk EPD Herefords and produced larger amounts of milk for a longer length of time. Lack of significance for breed and Milk EPD level interactions with age of cow indicate that these differences may not be large.

The Jenkins and Ferrell (1982, 1984) equation was able to predict yield at peak lactation and time of peak lactation. Angus cows produced more milk at peak lactation than Hereford cows ($P = 0.0452$) and high Milk EPD cows produced more at peak than low Milk EPD cows ($P < 0.0001$) (Table 6, Appendix Table 2). Cows raising steers had higher peak yields than cows raising heifers ($P = 0.0004$) (Table 7, Appendix Table 2). Spring-calving cows produced more milk at peak than fall-calving cows ($P = 0.0002$) (Table 8, Appendix Table 2). The effects of cow age on peak yield were similar to those for total milk production ($P < 0.0001$) (Tables 9, 10, Appendix Table 2).

Least squares means and differences of least squares means by breed, Milk EPD level, and age of cow for yield at peak lactation are given in Tables 13 and 14, respectively. Differences between high and low Milk EPD Angus cows were fairly consistent with high Milk EPD cows achieving peak yield at a later age than low Milk EPD Angus cows. High Hereford cows reached peak yield earlier than low Hereford cows but differences varied greatly over the lifetime and were only significant at six, nine, and ten years of age. Yield at peak lactation values for six- and ten-year-old high Milk EPD Herefords may have been

TABLE 13. LEAST SQUARES MEANS BY BREED, MILK EPD LEVEL, AND AGE OF COW FOR YIELD AT PEAK LACTATION (KG)

Cow age	High Angus	Low Angus	High Hereford	Low Hereford
2	6.03 ± 0.40	4.27 ± 0.41	5.08 ± 0.48	4.82 ± 0.43
3	6.02 ± 0.31	5.14 ± 0.33	5.39 ± 0.43	5.03 ± 0.35
4	7.13 ± 0.30	6.20 ± 0.29	6.22 ± 0.39	5.72 ± 0.33
5	7.02 ± 0.31	6.43 ± 0.29	5.62 ± 0.39	5.79 ± 0.32
6	7.32 ± 0.31	6.00 ± 0.29	8.03 ± 0.40	5.82 ± 0.35
7	7.13 ± 0.36	5.85 ± 0.33	6.42 ± 0.47	5.95 ± 0.37
8	6.75 ± 0.41	5.52 ± 0.39	5.97 ± 0.49	5.57 ± 0.40
9	7.11 ± 0.45	5.25 ± 0.42	6.38 ± 0.55	4.82 ± 0.49
10	6.28 ± 0.53	5.10 ± 0.52	7.23 ± 0.69	4.74 ± 0.54
11	5.37 ± 0.72	4.33 ± 0.68	5.42 ± 0.88	3.10 ± 0.84

TABLE 14. DIFFERENCES OF LEAST SQUARES MEANS BY BREED, MILK EPD LEVEL, AND COW AGE FOR YIELD AT PEAK LACTATION (KG)

Cow age	High Angus -Low Angus	P-value	High Hereford -Low Hereford	P-value
2	1.76	0.0021	0.26	0.6944
3	0.88	0.0520	0.36	0.5150
4	0.93	0.0281	0.50	0.3305
5	0.59	0.1753	-0.17	0.7204
6	1.32	0.0020	2.21	< 0.0001
7	1.28	0.0085	0.47	0.4358
8	1.23	0.0313	0.40	0.5302
9	0.73	0.0028	1.56	0.0301
10	1.18	0.1110	2.49	0.0041
11	1.04	0.2932	2.32	0.1687

skewed upward. One six-year-old High Hereford had a peak yield of 37 kg and two ten-year-old High Herefords had peak yields above 11 kg.

Time of peak lactation was not significantly influenced by breed (P = 0.2507) (Table 6), Milk EPD level (P = 0.7443) (Table 6), sex (P = 0.1369) (Table 7), season (P = 0.3411) (Table 8), or cow age (P = 0.7445) (Table 9). Animals in this study reached peak yield between 80 and 90 days post-calving which was similar to results reported by Minick et al. (2001).

Calf Performance

Tests of significance for model terms are presented in Appendix Table 3. Significant interactions of breed or Milk EPD level and other fixed effects were breed x age of cow ($P = 0.0476$) and breed x Milk EPD level x season ($P = 0.0271$) for birth weight and milk EPD level x season ($P = 0.0353$) and breed x year x sex ($P = 0.0449$) for 205-d weight.

Least squares means and standard errors by breed and Milk EPD level for calf birth weights and weaning weights are presented in Table 15. Breed, Milk EPD level, and breed x Milk EPD level did not significantly influence birth weight. Angus cows weaned heavier calves than Hereford cows. This agreed with the results of Brown et al. (1970), and Minick et al. (2001). High Milk EPD cows weaned heavier calves than low Milk EPD cows. This was consistent with reports by Mallinckrodt et al. (1990), Diaz and Notter (1991), Diaz et al. (1992), Marston et al. (1992), Marshall and Long (1993), and Minick et al. (2001). Studies by Marshall and Freking (1988) and Mahrt et al. (1990) reported no significant differences in weaning weights between calves born to high and low milk or maternal EPD cows.

Steers were heavier than heifers at birth and weaning ($P < 0.0001$) (Table 16). Similar results for weaning weight were reported by Brown (1960), Christian et al. (1965), Cundiff et al. (1966), Linton et al. (1968), Singh et al. (1970), Brown et al. (1970), Rutledge et al. (1970b), Butson et al. (1980), Wingert et al. (1984), and Minick et al. (2001). Studies by Gregory et al. (1950) and Marston et al. (1992), however, reported that sex did not affect weaning weight.

TABLE 15. LEAST SQUARES MEANS BY BREED AND MILK EPD LEVEL FOR CALF BIRTH AND 205-D WEANING WEIGHTS (KG)

	Angus		Hereford		P-values		
	High Milk	Low Milk	High Milk	Low Milk	Breed	Level[a]	B x L[b]
BW	37.76 ± 0.55	37.88 ± 0.57	38.83 ± 0.62	38.04 ± 0.58	0.2194	0.5836	0.3620
WW	221.30 ± 3.10	206.62 ± 3.18	213.17 ± 3.66	199.76 ± 3.46	0.0386	< 0.0001	0.8235

[a]Milk EPD level
[b]Breed (B) x Milk EPD level (L)

TABLE 16. LEAST SQUARES MEANS BY SEX FOR CALF BIRTH AND 205-D WEANING WEIGHTS (KG)

	Steers	Heifers	P-value
BW	39.53 ± 0.38	36.72 ± 0.37	< 0.0001
WW	214.61 ± 2.21	205.82 ± 2.16	< 0.0001

Season of calving did not affect birth weight (Table 17). Spring-calving cows weaned heavier calves than fall-calving cows. Minick et al. (2001) reported similar results for birth and weaning weights. Spring-calving cows spent most of their lactations on summer pasture, which may have contributed to the differences in weaning weights between seasons.

Age of dam significantly influenced calf birth weight ($P < 0.0001$) (Tables 18, 19). Birth weight increased quickly from two to four years old, after which, it remained fairly constant. Calves born to three-year-olds were 3.63 kg heavier than calves born to two-year-olds ($P < 0.0001$) but were 2.05 kg lighter than calves born to four-year-olds ($P = 0.0015$). After four years of age, birth weight did not change significantly as dams increased in age.

Age of dam significantly influenced weaning weight ($P < 0.0001$) (Tables 18, 19). Weaning weights increased from two to six years of age, remained constant until nine years of age, after which, weaning weights began to decline. These data agree with reports by Swiger et al. (1962), Minyard and Dinkel (1965), Christian et al. (1965), Cundiff et al. (1966), Singh et al. (1970), Brown et al. (1970), Neville, Jr., et al. (1974), Butson et al. (1980), Wingert et al. (1984), and Lubritz et al. (1989). However, Neville, Jr. et al. (1962), Rutledge et al. (1970b), and Minick et al. (2001) reported that cow age did not have a significant effect on weaning weight.

Although not significant ($P = 0.2019$) three-year-olds weaned calves that were 5.26 kg heavier than calves weaned by two-year-olds. This value was lower than expected, given that three-year-olds produced 110.10 kg more milk than two-year-olds, indicating that there was an environmental component that favored two-year-olds.

TABLE 17. LEAST SQUARES MEANS BY SEASON FOR BIRTH AND 205-D WEANING WEIGHTS (KG)

	Spring	Fall	P-value
BW	38.14 ± 0.40	38.11 ± 0.37	0.9273
WW	237.14 ± 2.49	183.28 ± 2.32	< 0.0001

TABLE 18. LEAST SQUARES MEANS BY COW AGE FOR CALF BIRTH AND 205-D WEANING WEIGHTS (KG)

Cow age	Birth Weight	Weaning Weight
2	31.95 ± 0.71	191.85 ± 4.42
3	35.58 ± 0.57	197.11 ± 3.50
4	37.63 ± 0.49	211.12 ± 2.93
5	38.38 ± 0.48	215.40 ± 2.85
6	39.31 ± 0.50	221.37 ± 2.98
7	39.35 ± 0.56	222.75 ± 3.34
8	40.18 ± 0.63	220.18 ± 3.75
9	39.61 ± 0.72	217.04 ± 4.25
10	39.67 ± 0.84	209.81 ± 4.98
11	39.61 ± 1.08	195.48 ± 6.44
P-value	< 0.0001	< 0.0001

TABLE 19. DIFFERENCES OF LEAST SQUARES MEANS BY COW AGE FOR CALF BIRTH AND 205-D WEANING WEIGHTS (KG)

Cow age -Cow age	Birth Weight	P-value	Weaning Weight	P-value
2-3	-3.63	< 0.0001	-5.26	0.2019
3-4	-2.05	0.0015	-14.01	0.0004
4-5	-0.75	0.1248	-4.28	0.1353
5-6	-0.93	0.0524	-5.97	0.0361
6-7	-0.04	0.9434	-1.38	0.6542
7-8	-0.83	0.1201	2.57	0.4214
8-9	0.57	0.3061	3.14	0.3448
9-10	-0.06	0.9188	7.23	0.0607
10-11	0.06	0.9429	14.33	0.0066

Four-year-olds weaned 14.01 kg more calf than three-year-olds (P = 0.0004). Five-year-old cows weaned calves that were 4.28 kg heavier than calves out of four-year-old cows but the difference was not significant (P = 0.1353). Six-year-old cows weaned 5.97 kg more calf than five-year-olds (P = 0.0361). There were no significant differences in weaning weights between six and nine years of age. Nine-year-olds weaned 7.23 kg more calf than ten-year-olds (P = 0.0607), which was large considering that nine-year-olds only produced 6.35 kg more milk than ten-year-olds. There was some factor, other than milk production, that resulted in a disadvantage for ten-year-olds when compared to nine-year-olds. Ten-year-olds weaned 14.33 kg more calf than eleven-year-olds (P = 0.0066). These data suggest that cows were in their prime from six to nine years of age.

High Milk EPD Angus cows weaned calves that were 14.68 kg heavier than low Milk EPD Angus cows, which was 0.24 kg less than predicted by grandsire Milk EPD. High Milk EPD Hereford cows weaned calves that were 13.41 kg heavier than low Milk EPD Hereford cows, which was 1.03 kg more than predicted by grandsire Milk EPD. This agreed with the Angus results reported by Baker (1997). However, Marston et al. (1989), Marston et al. (1990), Marston et al. (1992), and Minick et al. (2001) found that Milk EPD underestimated weaning weight differences in Angus. In this study, Hereford Milk EPD underestimated differences in calf weaning weight, which agreed with Mallinckrodt et al. (1990) and Mallinckrodt et al. (1993) but disagreed with Minick et al. (2001) who reported that Milk EPD overestimated weaning weight differences.

Least squares means and differences of least squares means by breed, Milk EPD level, and age of cow for 205-d weights are presented in Tables 20 and 21, respectively.

TABLE 20. LEAST SQUARES MEANS BY BREED, MILK EPD LEVEL, AND AGE OF COW FOR CALF 205-D WEANING WEIGHT (KG)

Cow age	High Angus	Low Angus	High Hereford	Low Hereford
2	203.72 ± 5.59	186.72 ± 5.96	193.27 ± 7.70	183.68 ± 7.15
3	209.33 ± 4.68	192.31 ± 4.84	201.02 ± 6.52	185.78 ± 5.71
4	224.34 ± 4.44	206.26 ± 9.48	210.55 ± 5.74	203.17 ± 5.12
5	228.15 ± 4.45	215.11 ± 4.37	214.67 ± 5.48	203.71 ± 4.96
6	230.75 ± 4.50	216.94 ± 4.36	230.28 ± 5.93	207.53 ± 5.37
7	234.65 ± 5.01	216.10 ± 4.82	223.99 ± 6.69	216.24 ± 5.68
8	230.30 ± 5.66	212.45 ± 5.45	223.28 ± 7.12	214.69 ± 6.20
9	226.54 ± 6.11	213.98 ± 5.97	223.21 ± 7.94	204.42 ± 7.44
10	218.96 ± 7.05	209.38 ± 7.15	213.17 ± 9.76	197.73 ± 8.38
11	206.26 ± 9.48	196.79 ± 9.19	198.25 ± 12.73	180.61 ± 11.90

TABLE 21. DIFFERENCES OF LEAST SQUARES MEANS BY BREED, MILK EPD LEVEL, AND COW AGE FOR CALF 205-D WEANING WEIGHTS (KG)

Cow age	High Angus -Low Angus	P-value	High Hereford -Low Hereford	P-value
2	17.00	0.0054	9.59	0.1510
3	17.02	0.0025	15.24	0.0251
4	17.91	0.0015	7.38	0.2669
5	13.04	0.0212	10.96	0.0929
6	13.81	0.0124	22.75	0.0013
7	18.55	0.0015	7.75	0.3004
8	17.85	0.0051	8.59	0.2451
9	12.56	0.0530	18.79	0.0223
10	9.58	0.2156	15.44	0.1124
11	9.52	0.3797	17.64	0.2116

High and low Milk EPD Angus cows followed similar patterns for weaning weights with differences due to Milk EPD level becoming less pronounced after eight years of age. Angus cows weaned the heaviest calves between the ages of five and nine. Differences between high and low Milk EPD Herefords were much less consistent. High Milk EPD Herefords weaned heavier calves earlier than low Milk EPD Herefords and maintained heavier weaning weights longer. High Milk EPD Herefords weaned the heaviest calves from six to nine years of age while low Milk EPD Herefords weaned the heaviest calves as seven- and eight-year-olds. Lack of significance for breed, Milk EPD level, and breed x Milk EPD level interactions with age of cow indicate that these differences may not be very large.

Implications

Increased milk production results in increased weaning weight of calves. The Milk EPD can accurately predict these differences. Age of cow also affects milk production and weaning weight. Knowing the peak production years of cows in a herd would assist producers in culling less productive animals.

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APPENDIX

TABLE 1. LEVELS OF SIGNIFICANCE OF MODEL TERMS FOR SEVEN MONTHLY ESTIMATES OF 24-H MILK PRODUCTION

Model term	1	2	3	4	5	6	7
Breed	0.0120	0.8503	0.2942	0.0627	0.4426	0.0071	0.1479
Level[a]	0.0002	< 0.0001	< 0.0001	0.0021	0.0021	0.0023	0.0039
Breed x level	0.9685	0.5243	0.8817	0.5898	0.4938	0.2629	0.1615
Year	0.0004		< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Season	< 0.0001		0.0021	0.2601	0.6660	< 0.0001	< 0.0001
Yrs[b]		< 0.0001					
Cow age	0.0002	< 0.0001	< 0.0001	< 0.0001	0.0112	< 0.0001	0.0868
Calf age	0.7641	0.5781	0.8128	0.5009	0.6846	0.5276	0.9825
Sex	0.2290	0.7572	0.0003	0.6944	0.6845	0.0012	0.2591
Breed x year	0.3488		0.0143		0.4524		
Breed x season							0.0020
Breed x cow age	0.5465	0.0697	0.4467	0.4246	0.9696	0.3514	0.4859
Breed x sex	0.4200		0.7380		0.4170	0.1795	
Level x year	0.0643		0.3321	0.3887	0.0443	0.8648	
Level x season	0.0824		0.0393	0.0214	0.1299	0.3267	
Level x yrs							
Level x sex						0.0774	0.1594
Level x cow age	0.9261	0.5551	0.6962	0.3991	0.7769	0.8685	0.8697
Year x season	< 0.0001		< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Year x sex	0.0078		< 0.0001	< 0.0001	0.0022	< 0.0001	0.0085
Yrs x sex		0.0083					
Season x sex			0.4707	< 0.0001	0.5234	< 0.0001	0.3770
Season x cow age							0.1951
Cow age x sex							0.0849
Breed x level x year			0.1024				
Breed x level x cow age	0.4861	0.2932	0.6134	0.3071	0.9303	0.6332	0.4063
Breed x year x sex	0.0158		0.0841		0.0051		
Level x year x season	0.0650		0.0712	0.1316	0.0022	0.0198	
Level x year x sex						0.0063	
Year x season x sex			0.0002	< 0.0001	< 0.0001	0.1390	< 0.0001

[a]Milk EPD Level

[b]Yrs = Year * 10 + season

TABLE 2. LEVELS OF SIGNIFICANCE OF MODEL TERMS FOR TOTAL MILK PRODUCTION FROM 37- TO 205-D POST-CALVING, YIELD AT PEAK LACTATION, AND DAY OF PEAK LACTATION

Model term	Total milk	Peak yield	Peak day
Breed	0.0580	0.0452	0.2502
Level[a]	< 0.0001	< 0.0001	0.7443
Breed x level	0.4953	0.6241	0.2507
Year	< 0.0001	< 0.0001	0.0323
Season	0.0051	0.0002	0.3411
Cow age	< 0.0001	< 0.0001	0.7445
Sex	0.0040	0.0004	0.1369
Calf age	0.4391	< 0.0001	< 0.0001
Breed x year	0.3971		0.0321
Breed x season		0.6517	0.2577
Breed x sex	0.6343	0.0248	0.3118
Breed x cow age	0.5426	0.9900	0.1798
Level x year	0.7123	0.3990	0.1201
Level x season	0.1419	0.0256	0.5153
Level x cow age	0.4371	0.0243	0.3543
Level x sex		0.2027	0.0819
Year x season	< 0.0001	< 0.0001	0.1921
Year x sex	< 0.0001	< 0.0001	0.0781
Season x cow age	0.9559	0.5569	0.2788
Season x sex	0.0162	0.1650	0.7966
cow age x sex	0.6312	0.0072	
Breed x level x cowage	0.6507	0.0844	0.1944
Breed x level x season		0.0441	
Breed x level x year			0.0511
Breed x level x sex		0.1327	
Breed x year x sex	0.0230		
Breed x season x cow age		0.1934	
Breed x cowage x sex		0.0495	
Level x year x season	0.0144	0.0012	0.1375
level x season x cow age	0.0587	0.1651	
year x season x sex	0.0465	0.0084	0.0450
season x cow age x sex	0.0020	0.0034	

[a]Milk EPD Level

TABLE 3. LEVELS OF SIGNIFICANCE OF MODEL TERMS FOR BIRTH WEIGHT AND 205-D WEANING WEIGHT

Model term	Birth weight	205-d weight
Breed	0.2194	0.0386
Level[a]	0.5836	$<$ 0.0001
Breed x level	0.3620	0.8235
Year	$<$ 0.0001	0.0032
Season	0.9273	$<$ 0.0001
Cow age	$<$ 0.0001	$<$ 0.0001
Sex	$<$ 0.0001	$<$ 0.0001
Breed x year		0.7093
Breed x season	0.2591	
Breed x cow age	0.0476	0.9282
Breed x sex		0.8943
Level x year	0.5608	
Level x season	0.7870	0.0353
Level x sex	0.2713	
Level x cow age	0.2314	0.9843
Year x season	0.0285	$<$ 0.0001
Year x sex	0.1657	0.0016
Season x sex		0.0140
Season x cow age		0.1467
Breed x level x season	0.0271	
Breed x level x cow age	0.6703	0.6143
Breed x year x sex		0.0449
Level x year x sex	0.0521	
Year x season x sex		0.1203

[a]Milk EPD Level

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