EVALUATION OF MILK PRODUCTION AND CONSTITUENTS IN RANGE BEEF COWS WITH DIVERGENT GENETIC MERIT FOR MILK PRODUCTION

By

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NOMENCLATURE

d	days
EPD	Expected Progeny Difference
h	hours
kg	kilograms
MM	Mechanical milk method
WSW	Weigh-suckle-weigh method
WW	adjusted 205-d weaning weight
yr	years

CHAPTER I

INTRODUCTION

Calf weaning weight is an important factor in determining the overall profitability of a cow-calf enterprise. Weaning weight of the calf is a result of its own genetic merit for growth, the genetic merit for maternal ability in the cow, and other environmental effects. Naturally, selection for increased weaning weight is a priority of many cow-calf producers. The calves need not only the genes for growth, but also a desirable environment to support expression of those genes. At least a large part of this environment is supplied by the cow in terms of her milk production that is made available to the calf. It is this genetic merit for maternal ability (milk) that can be evaluated using Milk Expected Progeny Differences (EPD). The use of milk EPDs provides a method of comparing sires based on the maternal performance of their daughters. The milk EPD is expressed in pounds of calf produced by these daughters, not pounds of milk. Thus, by using milk EPDs to compare bulls, effective selection pressure can be placed on calf weaning weight.

EPDs need to be experimentally tested in order to evaluate the effectiveness of them when used in a selection program and subsequent improvements in performance. In addition to comparing parents by pounds of calf weaned, evaluation of milk components needs to be considered to determine if differences exist between cows bred for divergent milk producing ability.

Milk constituent analysis has been performed by many with notable differences in percentages and yields based on breed, age of dam, and stage of lactation. Butson and Berg (1984) found that no significant differences existed in butterfat % between breeds, but Herefords tended to be higher. Protein percent was found to be significantly higher in 2 yr olds and no age differences existed for lactose percent. In a similar study, several groups of crossbred cows representing 5 different breeds were evaluated for milk production and constituent analysis and no significant crossbred group differences existed for percentage or production of butterfat (Chenette and Frahm, 1981). However protein and total solids percentages were significantly influenced by crossbred cow group. Constituent percentages are not significantly influenced by breed-age group or month of test (Gleddie and Berg, 1968).

Several factors may contribute to the environment provided by the cow. Nutritional needs must be met that allow that cow to realize her production efficiency potential and thus pass that along in the form of milk to her calf. Time of year or season of calving and lactation influences not only the nutrition available to both the cow and calf, but also the efficiency by which the cow is able to maintain herself, grow if necessary, condition, and produce milk. This in turn has a direct impact on the amount of energy available for milk production.

Estimates of daily milk production were generated using the calf weigh-suckle-weigh and mechanical milk collection methods. Totusek et al. (1973) compared two methods of milk production evaluation and determined that hand milking could produce satisfactory results in estimating differences in milk yield. In a study comparing milk production based on breed, Hereford milk production declined the most over 87 days when compared to crossbreds of traditional beef and dairy breeds (Butson and Berg, 1984). Cows wintered on a lower nutritional level tended to express a greater increase in milk production in the spring (Furr and Nelson, 1964).

The purpose of this study was to evaluate differences in milk producing ability of spring and fall calving mature cows bred for divergent milk production based on milk EPDs of their sires. In addition, milk constituent differences were analyzed to determine the effect of level of milk production on quality of milk. Finally, the correlation between methods of estimating milk producing ability (calf weigh-suckle-weigh, mechanical) was estimated to compare the effectiveness of the methods.

CHAPTER II

REVIEW OF LITERATURE

Milk production of beef cows plays a major role on the economic efficiency of any cow-calf producer. Calves sold at weaning are still predominantly marketed on a weight basis, therefore, it is essential to understand methods by which weaning weight can be managed to allow producers to maximize profitability. Preweaning gain is influenced by the milk production of the cow, expressed as maternal ability, and the genetic merit for growth expressed in the calf. The use of expected progeny differences (EPD) to evaluate genetic merit for milk production has allowed producers to optimize the maternal ability of their cows for their environment.

Milk EPDs

Expected Progeny Differences (EPDs) are used to describe the genetic merit of an individual for a specific trait of economic importance. This genetic merit is estimated by using performance records from the individual itself, its relatives, and its progeny. We use these EPDs to compare animals and rank them as potential parents. The reliability of EPDs can be determined by regressing the performance of an individual on its own EPD or the EPD of parents and comparing the expected value to that of the calculated regression coefficient (Mallinckrodt et al., 1993). In most cases, the actual difference in weaning weight is larger than that of the expected value based on the EPD. Marshall and

Long (1993) found that differences in milk yield of daughters and differences in sire milk EPD were positively related. The authors determined that a 1 kg change in sire EPD for maternal weaning weight accounted for a 1.18 kg change in calf weaning weight of the daughters. Removal of records from daughters of unproven sires (cleanup sires) resulted in similar results as when all records were kept in the analysis. Also, the relationship between sire milk EPD and actual performance of the daughters was not different when comparing high-accuracy and low-accuracy sires.

The use of milk and total maternal EPDs to predict differences in calf 205-d adjusted weights have been used extensively for selection purposes. It is important to understand the mechanisms and factors that have an impact on this relationship. Variables describing the genetic merit and/or environment of the cow and calf may be responsible for the relationship between milk EPDs and calf weaning weight.

It has been determined that milk and total maternal EPD interactions with sex of calf and year do not have significant influence on 205-d adjusted weights of the calves (Mallinckrodt et al., 1990). Miller and Wilton (1999) found a high genetic correlation between maternal weaning gain and milk yield. Maternal weaning gain is a combination of genetic merit for growth in the calf and environment provided by the cow. This describes that maternal weaning gain is a good indication of milk yield.

Milk Production

Total milk production and its influence on calf weaning weight has been studied extensively in beef cows (Lamond et al., 1969; Totusek et al., 1973; Belcher and Frahm, 1979; Chenette and Frahm, 1981; Butson and Berg, 1984; Jenkins and Ferrell, 1984;

Bourdon and Brinks, 1987; Mallinckrodt et al., 1993; Marshall and Long, 1993). It is important to understand peak lactation and duration and shape of lactation curves in order to ensure that nutritional needs are being met so that maximum performance can be achieved. This will allow for efficient production of calves, thus increasing net returns. When estimating milk production of cows and deriving corresponding milk production curves, it is essential to remember that curve extrapolation is limited by the earliest and latest times at which estimates were made. Kress and Anderson (1974) developed lactation curves estimated by the quadratic regression of milk production on day of lactation in Hereford cows. Maximum production was recorded at d 20 which was the time of their first estimate. Thus, it is impossible to determine if peak actually occurred at an earlier time. By using a dam intraclass correlation, a repeatability of milk production based on different stages of lactation was $0.32 \pm .06$. Jenkins and Ferrell (1984) regressed the natural log of milk/day of lactation on days to define the shape of the lactation curve and found a range of 49 to 64 days at which peak lactation occurred.

Mallinckrodt et al. (1993) determined that peak yield occurred at about d 60 of lactation in both Simmental and Polled Hereford cows and of those, higher milking cows showed more rapid declines in production after the peak. They also determined a positive correlation ($r=.24$) between calf birth weight and milk yield in Polled Hereford cows; however, these results were not significant.

Clutter and Nielsen (1987) found that in a group of cows bred for high, medium, and low milk production based on genetic potential of their breed of sire, high milk cows achieved peak milk production on average at d 58. Medium and low groups peaked about one week earlier on average. The high group tended to maintain that level for a longer period of time when compared with the other two groups. They also noted that differences between the groups got larger as the cows got older.

Neville (1962) evaluated milk production using the weigh-suckle-weigh method and determined that nutrition coupled with genetic milk producing ability of the cow can have an effect on growth of the calf. Also, nutrition available to the calf other than that supplied by milk may make it difficult to determine how much of the calf performance can be explained by cow milk production. Ultimately, they discovered a range of 400 to 4200 lbs of milk produced by the Hereford cows during the eight month lactation. It was concluded that the first 60 d of lactation contributed more to differences in calf weight gains compared to later stages of lactation.

Gifford (1949) concluded that calf weight gain and milk production of Hereford cows were significantly correlated only during the first four months of lactation. He also found indications that milk production during the first six months was a direct result of consumption capacity of the calves. Higher producing cows that supply an amount above that which is consumed by the calves would level off, thus the increased advantage of high producing cows is lost.

Jenkins and Ferrell (1992) determined that Herefords reached peak milk production earlier than Angus, Braunvieh, and Red Poll. However, Charolais, Gelbvieh, Limousin, Pinzgauer, and Simmental cows did not differ from Herefords in time at which peak milk production was achieved. They also noted that cows fed 210 vs. 170 kcal of metabolizable energy per unit of metabolic body weight achieved peak lactation later at which time peak yield was found to be higher. This is consistent with findings of Broster and Broster (1984) who determined that, in dairy cattle, peak was delayed and yield at that time was increased as energy allowance increased. However, in beef cows metabolizable energy was converted to milk less efficiently than in dairy cows.

Gleddie and Berg (1968) found no sex of calf or calf birth weight effect on milk production of the dam. However, breed of dam did explain 82.5% of the variation in average milk yield, and 71.3% of the variation in calf average daily gain was attributed to milk yield. In comparing crossbred and purebred Hereford cows, heterosis accounts for an increase in milk production of 21% (Anderson et al., 1986).

Furr and Nelson (1964) determined that milk production was lowest during the winter months for fall calving range beef cows in north central Oklahoma. Availability of spring grass supported a recovery in milk production and cows that were on a lower level of feed through the winter showed the most dramatic increase in milk production.

No significant differences existed between younger (3 and 4 yr) and older (≥ 9 yr) Polled Hereford cows when comparing them based on total milk production (Boggs et al., 1980). Butson and Berg (1984a) compared lactation performance in purebred Herefords, a beef-synthetic population, a dairy-beef cross group, and a dairy-synthetic line. They found that dams ranging in age from 3 yr to maturity produced 25 to 39% more milk than 2 yr olds, respectively. The effect of age of cow on milk yield was confounded with year effects so the direct effect of age was not determined (Chenette and Frahm, 1981).

Most published results agree that males tend to hold dam's milk production at higher levels due to increased suckling frequency because of their larger size. However, Rutledge et al. (1971) found results inconsistent with reports by others and noted a 56 kg higher 205 d lactation yield by cows nursing female calves. Significant year effects on milk yield existed, however, calf sire and herd effects were nonsignificant. A quadratic response of age on milk production was also noted, with the peak occurring at 8.4 years in Hereford cows. Also, no significant correlations existed between levels of milk constituents and calf weaning weight.

Sheldon (1983) determined that heavier fetuses could stimulate an increase in milk production due to an increase in placental lactogen secretion. It was also shown that the affect of environment on production is quite large and that a sufficient environment must exist to support the genetic potential for milk production. This was justified by the fact that in mature cows in good years the calf birthweight effect had a more positive relationship with milk production. The confounding effects between birthweight and age and breed of dam probably negates any direct impact of birthweight on milk or constituent yields (Butson and Berg, 1984b).

Milk Constituents

The composition of milk would be interesting to understand based on this type of study. Differences in components between breeds and EPD levels as well as the effect of other variables on these constituents could help to explain some of the variation in milk production. The correlation between total calf gain and percent butterfat, solids-not-fat, and total solids was determined to be near zero (Melton et al., 1967). However, total calf gain was moderately correlated (.30-.45) to yields of these constituents. Butson and Berg (1984b) found similar results. Totusek et al. (1973) found similar results and determined that correcting milk for fat yield produced no increase in the correlation between calf weight and milk yield. Chenette and Frahm (1981), and Hardt et al. (1988) also found results in agreement with these. Rutledge et al. (1971) found nonsignificant correlations

(-.20 to .05) between levels of milk components and calf weaning weight which supports the theory that milk yield is more influential than milk quality on weaning weight. This is in agreement with findings of Gleddie and Berg (1968).

Melton et al. (1967) discovered that breed and age of dam variables had significant effects on total milk yield and total solids in Charolais, Angus, and Hereford cows. In this study, Hereford cows had the lowest overall milk yield but ranked the highest in percent total solids and solids-not-fat.

No significant breed differences were found to exist for butterfat percent or protein percent (Butson and Berg, 1984a), however results suggested that method of milk removal may affect butterfat content, and protein percentages were higher in 2 yr olds when compared to older cows. Higher percentages of milk constituents existed later in lactation (September vs. June). No age differences existed for lactose percent, but lactose yields increased with age of dam and there were significant breed differences also. They also determined that the heritability of constituent percentages is generally high, thus they will respond to selection pressure. However, variation in constituent percentages for beef cattle on range does not seem to follow any consistent trend. Ultimately, total energy consumed by calves is determined more by milk yield than by constituent percentages.

In a follow up study, (Butson and Berg, 1984b) found a significant age x breed of dam interaction for milk yield, percent protein, and yields of butterfat and lactose with stage of lactation contributing to differences in all milk variables more than any other main effect. In an earlier report (Butson et al., 1980) they concluded that milk or constituent yields were responsible for 40% of variation in weaning weight. When all main effects were removed, variation in weaning weight explained by milk variables ranged from 6.2 to 10.4%. Ultimately, a 7.7 kg increase in weaning weight was attributed to a 1 kg increase in daily milk yield.

Mondragon et al. (1983) noted higher milk fat percent early in lactation and increasing protein percent as lactation progressed. Little change in lactose percent was noted throughout the lactation. Little difference in milk components, as a percentage, were observed between cows in parity groups of one, two or three. They also concluded that estimates of milk yield were higher when sampled using the calf nursing method vs. machine milking. It is believed that calves can more effectively remove the majority of milk from the udder than a milking machine (Mondragon et al., 1983). Repeatabilities were found for milk production (.40), milk fat percent (.36), milk protein percent (.58), and milk lactose percent (.52).

In a trial of eight crossbred cow groups (Hereford x Angus, Angus x Hereford, Simmental x Angus, Simmental x Hereford, Brown Swiss x Angus, Brown Swiss x Hereford, Jersey x Angus, and Jersey x Hereford), Chenette and Frahm (1981) found no significant differences in butterfat production or percentage between crossbred cow group. However, protein and total solids percentages were significantly different between cow groups. Time of separation had a significant impact on butterfat and total solids. In this study, cows achieved maximum milk production in the months of May and June. Butterfat yield and percentages were lower for two year olds when compared to four year olds which could have been due to higher fiber content of the diet (Bianca, 1965), or higher temperatures (Foley et al. 1973) the year the four year olds were evaluated. Rankings were the same among cow groups when compared based on total solids content and daily protein content. Daily yield correlations with production of butterfat, protein, and total solids were .93, .98, and .96 respectively. However correlations to percentage butterfat, proteins, and total solids were low (.23, .22, and .30 respectively).

Gleddie and Berg (1968) found little effect of breed age group or month of lactation on milk component percentages. Correlations of yield to constituents were variable but not significant in any case; a low positive correlation (.19) was noted for percent butterfat, a negative correlation (-.30) to percent protein, a near zero correlation (.02) to percent solids-not-fat, and low correlation (.14) to total solids. Likewise, correlations between month of lactation and milk composition estimates were low and variable (-.34 - .28). Milk protein percent was negatively correlated (Hereford x Holstein, -.54; Hereford x Jersey, -.51; Hereford x Hereford, -.35) with calf growth but yield of milk protein was positively correlated (.71) to growth of the calf in Hereford and Hereford x Jersey cows at d 36 of lactation (Hardt et al., 1988).

Marston et al. (1992) performed mechanical milk evaluation on Angus and Simmental cow-calf pairs and evaluated milk constituents. They determined that as lactation persisted, percent fat decreased, which agrees with findings by Lamond et al. (1969). From mid to late lactation, protein percent increased, and lactose increased throughout lactation. These results were consistent in both breeds, however, throughout lactation, total solids decreased only in the Angus cows. Also, in Angus cows, somatic cell count decreased as lactation progressed but in Simmental cows it only decreased between early and mid-lactation. These milk component percentages were not related to calf weaning weight of either breed.

Energy levels (115% vs 85%) of feed intake as a percent of NRC requirements were found to have no significant impact on fat, protein, or energy values of the milk (Wilson et al., 1969). Solids-not-fat were found to be in greater percentage in the 115% diet, however.

Wistrand and Riggs (1966) reported constant percent solids-not-fat throughout lactation in a group of Santa Gertrudis cows. Percent butterfat was found to be the most variable component.

Daley et al. (1987) found differences in milk yield, lactose and solids-not-fat at 60 d postpartum between Angus x Hereford cross cows and Hereford, Brahman x Hereford, and Brahman x Angus cows. Brahman x Hereford produced the highest percentages of protein and solids-not-fat. They also determined that mastitis did not have an effect on 24 h milk yield.

Howes et al. (1958) found that ration protein level affected milk yield and corresponding calf growth. They evaluated milk components and yield and found that for milk yield, calf growth, milk protein, solids-not-fat, fat, and total solids, Brahman cows were superior to Herefords. This relationship held true for the first three months of lactation, after which only milk yield and calf growth were different between the two breeds.

Lactose is typically not amenable to manipulation because it plays a major role in osmotic pressure regulation in the mammary gland. It is affected by blood flow to the mammary gland, increasing blood flow allows mammary cells to extract larger amounts of glucose which is then converted to lactose (Van Horn and Wilcox, 1992).

Means of Measurement

Lam et al. (1970) evaluated three methods of estimating milk production in beef cows. They determined that the method by which the calf nursed then oxytocin was administered to stimulate residual milk removal resulted in the highest estimates of 24 h milk production. In this process, calf weight change was added to the weight of residual milk collected. Lower estimates were obtained when cows were given oxytocin to evacuate the udders and six hours later another injection at which time milk collection was performed using catheters. The lowest estimates of milk production were obtained by the weigh-suckle-weigh method. Calves were allowed to nurse one afternoon then separated from the cows. Weigh-suckle-weigh was performed the following morning and afternoon and the two estimates were combined to estimate 24 h milk production. Results from these three methods were not extremely different. By concurrently testing machine milking and calf nursing methods, Wistrand and Riggs (1966) determined that the two methods predicted similar yields. Totusek et al. (1973) demonstrated that a limited number (2 to 4) of daily estimates of milk yield throughout the lactation could provide a good indication of total milk yield. It is important however, that estimates be obtained carefully and that collections be correctly timed to provide sufficient data to draw inferences about different stages of lactation.

When comparing methods of evaluating milk production, larger measurements are favorable because this supports the idea that the udder is being more completely evacuated. Due to the lack of differences explained by various methods of evaluation practicality and available resources should be the determining factors as to which method should be used.

High correlations between hand milking and weigh-suckle-weigh illustrated that hand milking can provide relative estimates of differences in milk yield. However, Totusek et al. (1973) demonstrated that the hand milking procedure underestimates the quantity of milk produced and misrepresents the amount actually consumed by the calf. Four one-day collections (d 30, 70, 112, 210) produced the highest correlation to estimated 210 production.

Procedures used to evaluate milk production of beef cows using the machine milking method have been described by Anthony et al. (1959). In a trial run of thirty cows where oxytocin was injected to induce milk letdown, a second injection failed to increase milk removal above that collected with one injection when using the teat-tube collection method (Butson and Berg, 1984a).

Chenette and Frahm (1981) milked cows after three different daily separation times at monthly intervals using the machine milking method. Collections followed an intramuscular injection of acepromazine tranquilizer and an intravenous injection of a synthetic oxytocin. They noted higher milk yield estimates than others who have used the calf nursing method or did not inject with oxytocin.

Gleddie and Berg (1968) found that one test milking using the mechanical milk method was sufficient to obtain estimates of milk production but did not give reliable estimates of milk composition. Four milk tests were made in their study corresponding to the first, second, third, and fifth months of lactation. Calves were allowed to suckle the cows the evening prior to test, then separated for a 12 h period overnight. Only one side of the udder was milked, thus the yield was multiplied by 4 to produce a 24 h estimate.

Beal et al. (1990) determined that mechanical milk method of collection expressed higher repeatability than weigh-suckle-weigh. They also determined that time of separation had no effect on estimates of milk production. It was determined that the mechanical milk method was a better indicator of milk production when only one estimate was made. However, when four weigh-suckle-weighs were performed, the ability to estimate milk production was similar to that of mechanical milk.

Lamond et al. (1969) hypothesized that storage capacity of the udder would not likely limit milk yield in the pasture since the calf suckles rather frequently. Thus, when separation from the calf is required in order to get estimates of milk production, true secretion rate could be underestimated in cows with small udders. When emptying the udders with teat cannulas it was concluded that 20 I.U. of oxytocin resulted in complete milk removal. When they studied the effects of different doses it was concluded that oxytocin did not play a role on milk secretion rate.

Belcher and Frahm (1979) milked crossbred cows using the mechanical milk method and determined that average time to milk was ten minutes. The effect of crossbred cow group and month of lactation on milk traits were significant. They attributed an interaction between cow group and month to variation in butterfat analysis due to poor sampling of milk or failing to completely milk-out the cows.

Schwulst et al. (1966) found in several pilot experiments that a 2 ml intramuscular injection of oxytocin would stimulate milk letdown within 4 min. They also found that treating cows with oxytocin did not have an effect on total milk production or milk consumption by the calf.

Cisternal milk, that which is immediately available for removal, comprises less than 20% of the total milk yielded at milking (Bruckmaier et al., 1998). It is essential that stimulation from the milking machine remain continuous throughout the milking session in order to ensure complete milk removal in dairy cattle. This will ensure adequate concentrations of oxytocin release which allows alveolar milk let-down. They also found that in unfamiliar surroundings, oxytocin release occurred more slowly than if the cow was in a familiar environment.

In conclusion, differences in sire Milk EPDs are positively related to differences in milk production of their daughters. Much variation exists between breeds for total milk production, peak milk yield, d of lactation at which peak occurred and the rate at which milk yield declines after peak. Both genetic merit and environmental factors contribute to this variation. Likewise, milk constituent findings vary considerably based on age of dam, breed, method of milk production evaluation and d of lactation, however results are not consistent. Both machine milking and calf weigh-suckle-weigh methods effectively describe differences in milk production and can be used to generate valid comparisons.

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CHAPTER III

ARTICLE

ABSTRACT

Milk production is an important variable affecting calf weaning weight and overall success of any cow-calf enterprise. This study was designed to evaluate the effect of milk EPDs of Angus and Hereford sires on milk production and milk composition of crossbred daughters. Bulls (n=35) were chosen from each breed to represent high or low milk EPDs. Mean EPDs 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 respectively. The daughters were between 5 and 9 years old during this study. Milk production of cows was evaluated via the weigh-suckle-weigh (WSW) method on cows calving in the spring (n=105) and fall (n=122) of 1998. A sample of these cows (n=48) were milked mechanically (MM) during the same lactation. Both techniques were used to generate 24 h milk production estimates. Least squares means were generated for the four Breed x Level interactions and the two Levels for each of seven WSW and four MM observations that were equally spaced throughout the lactation. Least squares means, in kg, from MM for HA, LA, HH, and LH with p values for high versus low were: period 1) 9.16, 5.55, 8.61, and 6.44 ($p<.005$); period 2) 5.62, 4.53, 5.19, and 3.57 ($p<.05$); period 3) 6.46, 4.84, 5.34, and 3.65 ($p<.05$); period 4) 5.34, 3.53, 4.14, and 2.78 ($p<.05$). Likewise, least squares means, in kg, from WSW for HA, LA, HH, and LH with p values for high versus low were: period 1) 7.44, 6.72, 6.23, and 4.57 ($p=.12$); period 2) 5.94, 4.14, 4.15, and

3.81 (p=.18); period 3) 4.31, 3.67, 4.22, and 3.04 (p=.12); period 4) 4.24, 3.27, 3.70, and 2.08 (p<.05); period 5) 2.59, 2.80, 2.81, and 1.41 (p=.38); period 6) 2.09, 1.85, 2.01, and .65 (p=.37); period 7) 2.98, 1.98, 3.55, and 1.97 (p=.11). In addition, WSW and MM totals were moderately correlated (r=.56). These results demonstrate that high milk EPD bulls sired daughters that produced more milk. The correlation between WSW and MM should increase the confidence of that conclusion. Milk EPDs can be used with confidence to influence milk production.

INTRODUCTION

Calf weaning weight is an important factor in determining the overall profitability of a cow-calf enterprise. Weaning weight of the calf is a result of its own genetic merit for growth, the genetic merit for maternal ability in the cow, and other environmental effects. Naturally, selection for increased weaning weight is a priority of many cow-calf producers. The calves need not only the genes for growth, but also a desirable environment to support expression of those genes. At least a large part of this environment is supplied by the cow in terms of her milk production that is made available to the calf. It is this genetic merit for maternal ability (milk) that can be evaluated using Milk Expected Progeny Differences (EPD). The use of milk EPDs provides a method of comparing sires based on the maternal performance of their daughters. The milk EPD is expressed in pounds of calf produced by these daughters not pounds of milk. Thus, by using milk EPDs to compare bulls, effective selection for calf weaning weight can be performed.

The current study focused on determining milk production and constituent differences for spring and fall calving mature cows from sires that differed widely for milk EPD in both the Angus and Hereford breeds. Milk production means were generated using the calf weigh-suckle-weigh and mechanical milk collection methods. Totusek et al. (1973) compared two methods of milk production evaluation and determined that hand milking could produce satisfactory results in estimating differences in milk yield. In a study comparing milk production based on breed, Hereford milk production declined the most over 87 days when compared to crossbreds of traditional beef and dairy breeds (Butson and Berg, 1984). Cows wintered on a lower nutritional level tended to express a greater increase in milk production in the spring (Furr and Nelson, 1964).

Milk constituent analysis has been performed by many with notable differences in percentages and yields based on breed, age of dam, and stage of lactation. Butson and Berg (1984) found that no significant differences existed in butterfat % between breeds, but Herefords tended to be higher. Protein percent was found to be significantly higher in 2 yr olds and no age differences existed for lactose percent. In a similar study, several groups of crossbred cows representing 5 different breeds were evaluated for milk production and constituent analysis and no significant crossbred group differences existed for percentage or production of butterfat (Chenette and Frahm, 1981). However protein and total solids percentages were significantly influenced by crossbred cow group. Constituent percentages are not significantly influenced by breed-age group or month of test (Gleddie and Berg, 1968).

Several factors may contribute to the environment provided by the cow. Nutritional needs must be met that allow that cow to realize her production potential and thus pass that along in the form of milk to her calf. Time of year or season of calving and lactation will influence not only the nutrition available to both the cow and calf, but also the efficiency by which the cow is able to maintain herself, grow if necessary, condition, and produce milk. This in turn has a direct impact on the amount of energy available for milk production.

EPDs need to be experimentally tested in order to evaluate the effectiveness of them when used in a selection program and subsequent improvements in performance. In addition to comparing parents by pounds of calf weaned, evaluation of milk components needs to be considered to determine if differences exist between cows bred for divergent milk producing ability.

The purpose of this study was to evaluate differences in milk producing ability of crossbred cows bred for divergent milk production based on milk EPDs of their sires. In addition, milk constituent differences were analyzed to determine the effect of level of milk production on quality of milk. Finally, the correlation between methods of estimating milk producing ability (calf weigh-suckle-weigh, mechanical) was estimated to compare the effectiveness of the methods.

MATERIALS AND METHODS

Cows were sired by Angus and Hereford bulls that differed in Milk Expected Progeny Difference (Milk EPD). These bulls were mated to Hereford-Angus, ¼ Brahman, ½ Hereford, ¼ Angus, or ¼ Brahman, ½ Angus, ¼ Hereford to produce crossbred females. Bulls (n=35) were chosen to form each of four groups (High Milk EPD Angus n=12, Low Milk EPD Angus n=10, High Milk EPD Hereford n=9, Low Milk EPD Hereford n=9). Milk EPD averages for the four groups differed by 14.8 and 11.3 kg for Angus and Hereford sire groups, respectively (Table 1). Daughters ranging in age from 5 to 9 yr old calved in the spring (n=105) and fall (n=122) of 1998.

Cows were maintained on Cynodon dactylon (Bermudagrass) and native range pastures consisting of Andropogon gerardi (Big bluestem), Schizachyrium scoparium (Little bluestem), Sorghastrum nutans (Indiangrass), Panicum virgatum (Switchgrass), Bromus tectorum (Cheatgrass) at the North Lake Carl Blackwell Research Range, located west of Stillwater, OK. Nutrition was based on constraints from other experimental considerations and consisted of two groups managed separately. High and Low nutrition groups were established by supplementing two different levels of crude protein (CP) intake per day during the winter season. The division into two nutrition level groups was not central to this study, but was done to create differences for other evaluations. Cows from all four sire groups were represented in both nutrition programs during each season. Cows chosen for mechanical milk equally represented the four sire groups in both high and low nutrition treatments.

Winter feeding consisted of prairie hay fed at the rate of 40 cows per 544 kg bale daily. In addition, spring calving cows were supplemented beginning in October and by

November 15 were consuming 3.2 kg of 40% CP range cubes 3 times a week. This was maintained until calving, at which time the high and low nutrition groups received 2.3 and 1.4 kg of 40% CP range cubes daily, respectively. Beginning in April, the CP was reduced to 10% but the cows received the same amount of feed on a weight basis. As spring forage became available and grazing intake began to meet nutritional requirements, the cows were gradually removed from the supplement.

Fall calving cows were also supplemented beginning in October, but since they were already lactating they were immediately divided into two nutrition groups. The feeding protocal for the fall cows follows that of the spring cows, with the same levels of intake and CP levels.

Table 1. Average milk expected progeny differences (EPD)(kg) of Hereford and Angus sires.

Breed	n	Milk EPD level	Milk EPD
Angus	12	High	+8.7
Angus	10	Low	-6.1
Hereford	9	High	+7.4
Hereford	9	Low	-3.9

Milk Production Evaluation. Twenty-four hour milk production of the cows was evaluated via the weigh-suckle-weigh (WSW) and mechanical milk (MM) collection methods. All cows were subjected to monthly (d 40, 66, 94, 126, 151, 179, 207) WSW measurements during the lactation for both seasons. A sample of these cows (n=48) were milked mechanically four times during the same lactation at an average of 66, 112, 157 and 203 d postcalving. This meets a suggested minimum of 2 to 4 correctly timed and carefully obtained daily estimates to provide a good indication of total milk yield per lactation (Totusek et al., 1973).

Cows and calves were gathered from pastures and placed in holding pens the afternoon prior to WSW. Calves were separated from cows at approximately 6:00 p.m. The following morning, calves were placed with dams at 5:45 and allowed to nurse. Groups were randomly separated into smaller pens (approximately 25 cows per pen). Upon completion of nursing (15 to 30 min), calves were separated from dams. This procedure was repeated at 11:45 a.m. with the exception that calves were weighed before and after nursing. Six-hour milk production was estimated as the difference between these two weights. The 11:45 a.m. procedure was repeated at 5:45 p.m. and the two estimates were summed and doubled to provide an estimate of 24-h milk production.

For MM measurements, the two nutrition level groups were evaluated on separate days during the same week in much the same manner used by Anthony et al. (1959) and Belcher and Frahm (1979). Cows and calves were gathered from pastures and placed in holding pens at approximately 4:00 p.m. the afternoon prior to MM and separated at this time. Calves were placed with dams at 8:45 p.m. and allowed to nurse. Upon completion of nursing (15 to 30 min), calves were separated from dams. The following morning, cows were randomly separated into groups of four and milk collection began at 7:00 a.m. A 2 ml injection of oxytocin was administered intramuscularly immediately after the cow entered the chute. A portable DeLaval milking machine was used to evacuate the udder followed by hand stripping to ensure total milk collection. An average of 8 to 15 min was required for total milk-out. Twelve-hour milk production was estimated as the total kg produced. These estimates were doubled to provide an estimate of 24-h milk production. A sample of milk was taken from each cow's production and sent to Heart of America Dairy Herd Improvement Association in Manhattan, Kansas for percent fat, protein, lactose, solids-not-fat, and somatic cell count analysis. Somatic cell counts were adjusted by their natural log before being analyzed.

Statistical Analysis. MM and WSW data were analyzed using least-squares analysis of variance using the GLM procedure of SAS (1990) to determine the affects of season, level of nutrition, breed, EPD group, age of dam, sex of calf, calf sire, sire of dam nested within breed x EPD group, and all two- and three-way interactions on 24-h milk production and constituent data. Interactions were removed from the model if they were confounded or if they failed to represent an important ($p<.30$) source of variation on the dependent variable. Since the sample size was limited to 48 cows, and the model included several independent terms, most interactions were dropped from the model because of confounding. WSW analysis was performed on records from cows (n=48) that were milked mechanically during the same lactation.

Lactation curves for each method of evaluation were derived as explained by Jenkins and Ferrell (1984). The residual sums of squares and cross products of mean lactation curve areas were used to estimate the correlation between the two methods. Likewise, the residual sums of squares and cross products of mean lactation curve areas and adjusted weaning weights were used to correlate the two methods to calf weaning weight.

RESULTS AND DISCUSSION

Weigh-suckle-weigh. Least squares means and standard errors for monthly weigh-suckle-weigh milk production estimates by cow group are shown in Table 2. Least squares means and standard errors for WSW milk measurements of 24-h milk production are shown for main effects in Table 3. Breed exhibited a significant ($p<.05$) effect at d 40 at which time Angus cows had higher levels of daily milk production than Herefords. Breed differences were smaller later in lactation indicating that Angus cows reached a high level of production earlier than Hereford cows.

Although not all differences were significant, cows from high milk EPD bulls tended to produce more milk at all stages of lactation. This effect of milk EPD level has been shown by others as well (Mallinckrodt et al., 1993; Marston et al., 1992). The breed by EPD level interaction was clearly not significant at any period.

Season had a significant impact on production at days 94 and 207 of lactation. Spring cows produced higher amounts of daily milk yield at d 94 ($p<.05$) and at d 207 fall cows were at a significantly higher level of production ($p=.001$). This can be attributed to the quality of forage available to the cows at this time.

Level of nutrition did not have a consistent effect on daily milk production although there was a difference ($p<.05$) at d 66 and 179. During both seasons cows in the low nutrition group had higher daily milk yield estimates.

Age of dam significantly influenced milk production at later stages of lactation. Nine yr old cows produced significantly less milk at d 179 ($p=.01$) and 207 ($p=.02$). This indicates that older cows were not able to maintain expected levels of milk production at later stages of lactation when compared to cows ranging in age from 6 to 8 yr.

Cows nursing male calves produced more daily milk yield at d 179 ($p=.0005$). Daley et al., (1987) concluded that cows nursing male calves maintain greater daily milk production estimates. Male calves tend to be larger and able to consume more milk which may be responsible for holding milk production at higher levels later in lactation. This is supported by the fact that cows nursing male calves tended to produce more daily milk yield during all periods of estimation after d 40. In contrast, findings by Rutledge et al., (1971) suggest that cows nursing females had a 56 kg greater total milk yield than those nursing males. Gleddie and Berg (1968) and Wilson et al., (1969) concluded that sex of calf had no measurable affect on milk production.

Several significant interactions of breed or level with other fixed effects existed although no obvious patterns emerged. There was a significant ($p<.05$) season x EPD level interaction at days 40 and 179 of lactation. At d 207 a significant ($p<.05$) season x breed interaction existed. Breed x age of dam was a significant interaction at d 94 ($p<.0005$), 126, and 207 ($p<.05$). Also at d 94 a significant EPD level x age effect was discovered. A significant nutrition x EPD level interaction existed at d 126 of lactation ($p<.05$). At d 151 of lactation nutrition x breed represented a significant interaction ($p<.05$). Sire of dam nested in breed x EPD level was significant at d 66, 94, 179, and 207.

Mechanical Milk. Least squares means and standard errors for mechanical milk production estimates by cow group are shown in Table 4. Least squares means and standard errors for MM measurements of 24-h milk production are shown by model term in Table 5. No significant breed effects were noted for any of the periods.

Milk EPD level did play a significant role on daily milk yield at d 66 ($p<.005$) and d 112, 157, and 203 ($p<.05$) during all of which cows sired by high milk EPD bulls exhibited a greater daily production than lows. At days 66 and 203, High Milk Angus had significantly higher 24-h milk yield ($p<.05$) than their Angus counterparts. No significant differences existed between High and Low milk EPD Herefords; however, Herefords sired by high milk EPD bulls tended to produce more total daily milk yield. This effect of EPD level on milk production had been shown by others (Marston et al., 1992; Marshall and Long, 1993).

Season had a significant influence ($p<.001$) on production at d 112 of lactation at which time cows calving in the spring produced substantially more milk than fall calving cows at the same stage of lactation.

Plane of nutrition had no significant effect on milk production during any of the periods of evaluation. There is a possibility that there was not a large enough difference in protein intake between the two groups to allow expression of a difference.

Age of dam did not play a significant role in daily milk yield. Cows ranged in age from 6 to 9 yr, thus, level of maturity was not a factor. This is in agreement with Boggs et al. (1980) who found no significant differences between younger and older cows when comparing them based on milk production.

Significant differences in daily milk production by sex of calf did exist at d 112 and 157. During these periods, cows nursing male calves produced more than those with female calves. This can be explained by the fact that male calves tended to be larger on average and thus capable of consuming more milk which in turn may be responsible for holding milk production at a higher level.

Sire of calf had a significant influence on milk production at d 112 and 203. This was in conflict with conclusions by Rutledge et al. (1971) who found no effect of sire of calf on milk yield.

There were several interactions between breed or level and other main effects but little pattern of interactions emerged. No significant breed x EPD level interaction explained variation in daily milk yield at any of these stages of lactation. Nutrition x EPD level, breed x age of dam, and EPD level x age of dam were significant interactions at d 66 ($p<.05$). Sire of dam nested in breed x level had a significant affect on daily milk yield at d 112 ($p<.05$).

Total Milk Production. Total milk production during the lactation by cow group when estimated by the MM procedure is shown in Table 6. EPD level explained some of the variation in total milk production ($p=.0001$). As expected, the high EPD level cows produced substantially more milk. This provides justification for the use of milk EPDs to select for changes in milk production.

Total milk production during the lactation by cow group when estimated by the WSW procedure is shown in Table 6. EPD level explained some variation in lactation curve area ($p=.0006$). High milk EPD level cows produced substantially more milk per lactation. This supports the concept of using sire milk EPDs to select for increased milk production. Several interactions were also influential on milk production. A season x EPD level interaction also existed ($p<.05$).

Figure 1 portrays lactation curves for the cow groups as estimated by both the WSW and MM methods. Early in lactation both methods appear to describe similar amounts of variation between high and low milk EPD groups. As lactation progresses, MM estimates maintain an elevated level of variation. Based on the overall shape of the curves, the WSW method appears to underestimate milk production. This can be supported by the fact that EPD level was significant at all four MM estimates, whereas it was significant only at d 126 when estimated by WSW. Hence, we would expect MM to be a better estimator of the relationship between high and low milk EPDs based on this study, however WSW provides the best estimates of calf milk intake. Peak lactation occurred around d 65 as estimated by WSW. Peak yield has been shown to occur near d 60 in beef cows (Clutter and Nielsen, 1987; Mallinckrodt et al., 1993;) with higher producing cows having a more dramatic decrease in production after peak (Mallinckrodt et al., 1993).

Calf weaning weights by cow group are shown in Table 7. When comparing sire EPDs to observed differences in calf weaning weights we would expect, based on sires used in this study, Angus calves to have an average of 14.8 kg difference in weaning weight between the high and low EPD groups. Likewise, we would expect the Herefords to differ by 11.3 kg. However, Angus calves born in the fall differed by 21.9 kg between the EPD groups and Herefords were on average 29.5 kg different. Spring born Angus were only 6.3 kg different and Herefords were 26.8 kg different. These results agree with findings by Marshall and Long (1993). This suggests that the use of milk EPDs is effective in selecting for maternal ability. Except for the spring Angus calves, greater differences in weaning weight existed than what we would expect based on sire EPDs.

Correlations between total milk production by method and calf weaning weight are shown in Table 8. The correlation between total milk production (MM method) and calf weaning weight was moderate ($r=.56$). EPD level was a significant source of variation in calf weaning weight ($p<.05$) and total milk production ($p<.0005$). These correlations suggest that the mechanical milk collection method may be a better estimator of the relationship between milk producing ability in the cow and performance of the calf measured in weaning weight. The correlation between total milk production per lactation (WSW method) and calf weaning weight was moderate ($r=.47$). This indicates that while milk production of the cow has an impact on weaning weight of the calf and can be useful in increasing calf performance, other factors contribute to growth of the calf (Neville, 1962). Genetic merit for growth must be considered because if the calf does not have the genetic predisposition to grow efficiently, the advantage of high milk production will not be fully realized. Calf weaning weight and total milk was affected by this milk EPD level of the cow ($p<.05$). Breed x sex also explained some variation in calf weaning weight ($p<.05$).

The correlation between methods of estimation is shown in Table 8. The WSW and MM collection methods were moderately correlated ($r=.56$). This shows that both methods are explaining similar relationships of cow group to milk production and provides justification for the use of either method to evaluate milk production.

Constituents. Least squares means for daily constituents as a percentage of milk composition are shown by cow group in Tables 9 through 13. At d 66, breed significantly influenced fat percentage ($p<.01$). Hereford cows were higher in milk fat percentage; however, there was no difference between breeds for daily milk yield at this time of lactation. Hereford cows would typically produce less milk thus allowing fat to comprise a greater percent of milk composition (Melton et al., 1967). Breed of cow did have an effect on protein percent at d 66, 157 ($p<.01$), and d 203 ($p<.05$). Hereford cows had a greater percent of milk comprised of protein than did Angus cows. This agreed with Daley et al. (1987) who found that Brahman x Hereford cows produced a greater percent of protein than Brahman x Angus cows. No breed effect existed when evaluating either lactose concentrations or solids-not-fat in the milk.

EPD level significantly affected fat percent at d 203 ($p<.05$). High EPD level cows displayed greater percentages of fat in addition to producing greater daily milk yields at this time. EPD level had no affect on protein percent at any stage of lactation. No effect of EPD level on percent lactose existed during any of the stages of lactation. This was also true for solids-not-fat.

Season had a significant effect on fat percentage at d 66 ($p<.05$). Fall cows had a greater fat percent than spring calving cows. This may be due to the fact that fall cows were still receiving their nutrition solely from pasture which would provide an adequate amount of roughage relative to fermentable carbohydrates to allow production of fat precursors, namely acetic and butyric acid. Fiber content of the diet has been shown to directly influence milk fat yield (Bianca, 1965). Protein percent was influenced ($p=.0001$) by season at d 203. At this time, spring cows produced more of a percent of milk as protein than did fall cows. Spring cows were receiving a small amount of 40% CP range cubes beginning in October. This supplementation of concentrate could have been responsible for increasing propionic acid levels in the rumen which increases availability of glutamic acid. This increase in amino acid availability will contribute to an increase in protein synthesis. When comparing lactose percentages based on season, fall calving cows displayed a greater percentage of lactose in the milk than spring calving cows (p=.0005) at d 203 of lactation. Solids-not-fat as a percent of milk was affected by season at d 112, 157, and 203 (p<.005). Spring calving cows produced more total solids at these stages of lactation than did fall calving cows. This could be a result of warmer temperatures during the summer when cows typically are not reaching milk production potential, thus allowing solids to show up as a greater percent of composition. Somatic cell count was significantly influenced by season at d 157 (p<.005). At this time, fall calving cows had higher somatic cell counts than spring cows. This is most likely due to the incidence of several of the fall cows having elevated SCC during this period of lactation. No other main effects explain any variation in SCC.

Level of nutrition did not play a significant role on milk fat percentage. This can be attributed to the fact that both nutrition levels were grazing ample forage and were supplemented hay at the same rate per cow in the winter, thus roughage to concentrate ratios were sufficient to allow production of the fat precursors as mentioned above. Milk protein was significantly influenced (p<.05) by nutrition at d 66 and 203. Lactose percent was not significantly influenced by plane of nutrition nor was solids-not-fat.

Age of dam played a significant role on fat percent at d 66 (p<.05). Seven year old cows produced the most fat as a percentage, followed by 8, 6, and 9 year old cows. However, 6 and 8 year old cows were very similar. Milk protein percent was not affected by age of dam. It is important to remember that cows in this study ranged in age from 6 to 9 yr. Age of dam had no effect on percent lactose. Solids-not-fat was not influenced by age of dam.

There were several interactions between breed or EPD level and other main effects. Breed x EPD level served as a significant source of variation in percent fat at d 157 ($p<.01$). Low EPD level Angus and high EPD level Hereford cows produced greater concentrations of fat than did high Angus and low Hereford cows, respectively. Breed x age also significantly influenced fat percentage at d 66 ($p<.05$). EPD level x age significantly influenced fat percent at d 157 of lactation ($p<.05$). Nutrition x breed also had a significant influence on fat percent at d 203 ($p<.05$).

Breed x EPD level served as a significant source of variation in percent protein with high EPD level Angus and low EPD level Hereford cows producing greater concentrations of protein in the milk than low Angus and high Hereford cows, respectively. A significant season x breed effect existed at d 66 ($p<.01$). Nutrition x breed served as a source of variation in protein percent as well ($p<.005$). Nutrition x EPD level and sire of dam nested in breed x level interactions existed at d 157 and 203 ($p<.05$).

A significant breed x EPD level interaction existed at d 157 for lactose percent ($p<.05$). When comparing the Angus cows, those in the low EPD level had higher percentages of lactose than those in the high EPD level. However, within the Hereford breed, high EPD level cows produced more lactose as a percent than those in the low EPD level. Season x EPD level was significant at d 203 ($p<.05$).

Percent solids-not-fat was influenced by a season x EPD level interaction at d 66 ($p<.01$), 157 ($p=.05$), and 203 ($p<.05$). At d 112, a significant breed x age interaction existed ($p<.05$). At d 157 and 203, nutrition x EPD level significantly influenced SNF percent ($p<.05$). Sire of dam nested in breed x level was significant at d 203 ($p<.05$).

Somatic cell count was influenced by a season x breed interaction at d 66 ($p<.05$) and 112 ($p<.005$). Breed x age was a significant interaction at d 66 ($p<.05$) and 112 ($p<.01$). Sire of dam nested in breed x level was a significant source of variation at d 112 ($p<.001$). At d 203, nutrition x EPD level had a significant influence on SCC ($p<.05$).

IMPLICATIONS

These results established that cows sired by high milk EPD bulls tended to produce more milk throughout lactation. The moderate correlation (.56) between WSW and MM should increase the confidence of that conclusion. This is further supported by the correlations between WSW and MM to WW (.47 and .56 respectively). Constituents are influenced by season, breed, and EPD level, all at varying stages of lactation and at different levels of significance. This study also indicates the usefulness of the Milk EPD in selecting for increased calf WW. Differences in WW coincided with expected differences based on the Milk EPD. Sire EPDs can be used with confidence to influence milk production of daughters.

Table 2. Least squares means and standard errors for monthly WSW measurements of 24-h milk production by cow group with tests of significance

	Milk production (kg)						
Cow group	1[a]	2	3	4	5	6	7
High Angus	7.44±.77	5.94±.83	4.31±.60	4.24±.61	2.59±.68	2.09±.85	2.98±.78
Low Angus	6.72±.73	4.14±.75	3.67±.59	3.27±.62	2.80±.66	1.85±.91	1.98±.82
High Hereford	6.23±.76	4.15±.79	4.22±.59	3.70±.65	2.81±.67	2.01±.90	3.55±.89
Low Hereford	4.57±.86	3.81±.80	3.04±.59	2.08±.60	1.41±.65	.65±.90	1.97±.76
P values							
Breed	.02	.16	.54	.15	.38	.44	.73
Level[b]	.12	.18	.12	.04	.38	.37	.11
Breed x Level	.52	.39	.66	.61	.24	.55	.73
Level(Angus)	.48	.11	.44	.25	.82	.85	.35
Level(Hereford)	.12	.76	.18	.08	.15	.32	.19

[a]monthly milk productions were done every 28 d starting on d 40
[b]EPD level

Table 3. Least squares means and standard errors for WSW milk measurements of 24-h milk production

		Milk production (kg)						
		1[1]	2	3	4	5	6	7
Season	Fall	5.49±.44[a]	4.79±.37[a]	3.20±.29[a]	2.97±.38[a]	1.93±.44[a]	1.67±.36[a]	4.00±.45[a]
	Spring	7.01±.71[a]	4.25±.49[a]	4.43±.39[b]	3.68±.45[a]	2.88±.54[a]	1.63±.44[a]	1.23±.51[a]
Nutrition	High	6.35±.47[a]	3.19±.40[a]	3.31±.33[a]	2.95±.39[a]	2.41±.50[a]	.96±.34[a]	3.06±.46[a]
	Low	6.15±.61[a]	5.57±.45[b]	4.33±.34[a]	3.71±.41[a]	2.40±.55[a]	2.31±.40[b]	2.18±.48[a]
Breed	Angus	7.09±.55[a]	5.05±.56[a]	4.00±.42[a]	3.76±.45[a]	2.70±.48[a]	1.97±.64[a]	2.48±.59[a]
	Hereford	5.41±.62[b]	3.98±.55[a]	3.64±.40[a]	2.89±.42[a]	2.11±.45[a]	1.33±.59[a]	2.76±.58[a]
EPD Level	High	6.85±.57[a]	5.06±.58[a]	4.27±.41[a]	3.97±.43[a]	2.70±.48[a]	2.05±.59[a]	3.27±.59[a]
	Low	5.65±.63[a]	3.98±.56[a]	3.36±.41[a]	2.68±.45[a]	2.11±.46[a]	1.25±.67[a]	1.98±.57[a]
Age of Dam	6	5.55±.97[a]	3.52±.79[a]	2.92±.68[a]	2.92±.85[ab]	2.41±.96[a]	1.68±.74[a]	2.11±.95[a]
	7	7.68±1.04[a]	5.20±.82[a]	3.60±.68[a]	1.90±.98[a]	3.73±1.04[a]	3.32±.77[a]	5.90±1.09[b]
	8	6.82±.95[a]	5.35±.73[a]	3.78±.63[a]	4.70±.71[a]	2.67±.88[a]	3.07±.63[a]	1.97±.81[a]
	9	4.96±1.47[a]	4.00±1.14[a]	4.96±.83[a]	3.78±1.01[ab]	.80±1.18[a]	-1.48±.98[b]	.49±1.2[a]
Sex of Calf	Female	6.34±.47[a]	3.95±.40[a]	3.52±.34[a]	2.84±.39[a]	2.29±.47[a]	.60±.35[a]	1.98±.45[a]
	Male	6.16±.58[a]	5.08±.47[a]	4.11±.34[a]	3.81±.42[a]	2.52±.54[a]	2.71±.40[b]	3.26±.53[a]

[1]monthly milk productions were done every 28 d starting on d 40

[ab]means in a column within model term with different superscripts are significantly different ($p<.05$)

Table 4. Least squares means and standard errors for MM measurements of 24-h milk production by cow group with tests of significance

	Milk production (kg)			
Cow group	1[a]	2	3	4
High Angus	9.16±1.22	5.63±.85	6.46±.83	5.34±.86
Low Angus	5.55±1.04	4.53±.70	4.84±.76	3.53±.77
High Hereford	8.61±1.20	5.19±.72	5.34±.75	4.14±.78
Low Hereford	6.44±1.43	3.57±.86	3.65±.83	2.78±.89
P values				
Breed	.86	.28	.11	.14
Level[b]	.002	.04	.01	.02
Breed x Level	.49	.70	.96	.74
Level(Angus)	.005	.23	.08	.04
Level(Hereford)	.15	.09	.08	.17

[a]mechanical milk productions were done every 46 d starting on d 66
[b]EPD level

Table 5. Least squares means and standard errors for MM measurements of 24-h milk production

		Milk production (kg)			
		1[1]	2	3	4
Season	Fall	6.91±1.80 [a]	.66±1.31 [a]	3.09±1.42 [a]	4.66±1.69 [a]
	Spring	7.97±1.33 [a]	8.79±1.00 [b]	7.07±1.14 [a]	3.25±1.19 [a]
Nutrition	High	7.24±.72 [a]	4.32±.48 [a]	5.38±.53 [a]	4.42±.58 [a]
	Low	7.64±.70 [a]	5.14±.54 [a]	4.79±.57 [a]	3.48±.57 [a]
Breed	Angus	7.37±.96 [a]	5.08±.64 [a]	5.66±.65 [a]	4.44±.69 [a]
	Hereford	7.54±1.10 [a]	4.39±.64 [a]	4.50±.70 [a]	3.46±.68 [a]
EPD level	High	8.90±.97 [a]	5.41±.63 [a]	5.90±.63 [a]	4.75±.67 [a]
	Low	6.00±1.05 [b]	4.06±.64 [b]	4.25±.63 [b]	3.16±.69 [b]
Age of dam	6	7.89±.89 [a]	4.14±.60 [a]	5.15±.67 [a]	2.98±.85 [a]
	7	7.35±1.08 [a]	5.65±.76 [ab]	4.05±.79 [a]	5.50±.91 [a]
	8	8.02±.87 [a]	6.08±.66 [b]	5.13±.75 [a]	4.51±.78 [a]
	9	6.49±1.49 [a]	3.07±1.15 [a]	5.98±1.09 [a]	2.81±1.46 [a]
Sex of calf	Female	6.80±.70 [a]	4.03±.46 [a]	4.44±.51 [a]	3.72±.57 [a]
	Male	8.07±.64 [a]	5.44±.47 [b]	5.72±.50 [b]	4.19±.52 [a]

[1]mechanical milk productions were done every 46 d starting on d 66

[ab]means in a column within model term with different superscripts are significantly different ($p<.05$)

Table 6. Least squares means and standard errors for total milk production by cow group with tests of significance by method of estimation

	Total milk production (kg) Method of estimation	
Cow group	**MM**	**WSW**
High Angus	916±95	705±48
Low Angus	695±91	590±55
High Hereford	1015±109	669±56
Low Hereford	612±119	426±58
P values		
Breed	.93	.08
Level[a]	.0001	.0006
Breed x Level	.27	.25
Level(Angus)	.04	.10
Level(Hereford)	.001	.0025

[a]EPD level

Table 7. Least squares means and standard errors for calf weaning weight by cow group with tests of significance by season

	Calf weaning weight (kg)	
	Season	
Cow group	**Spring**	**Fall**
High Angus	228.93±11.25	200.51±7.71
Low Angus	222.63±8.08	178.54±6.45
High Hereford	241.34±9.28	194.97±7.41
Low Hereford	214.58±11.60	165.37±6.98
P values		
Breed	.81	.15
Level[a]	.08	.003
Breed x Level	.34	.22
Level(Angus)	.61	.02
Level(Hereford)	.10	.003

[a]EPD level

Table 8. Correlations between total milk production by method of estimation and adjusted weaning weight

	Correlation	
	Mechanical milk	Weigh-suckle-weigh
Adjusted weaning weight	.56	.47
Mechanical milk		.56
Weigh-suckle-weigh		

Table 9. Least squares means, standard errors for fat percent by cow group

	Fat (%)			
Cow group	1[a]	2	3	4
High Angus	3.14±.35	3.42±.28	2.77±.28	3.25±.25
Low Angus	3.05±.33	3.42±.29	3.06±.28	3.06±.24
High Hereford	4.54±.34	4.05±.28	3.68±.26	3.68±.25
Low Hereford	3.45±.35	3.07±.29	2.32±.31	2.69±.28
P values				
Breed	.0095	.61	.71	.88
Level[b]	.09	.09	.07	.02
Breed x Level	.16	.12	.0098	.13
Level(Angus)	.85	.99	.46	.56
Level(Hereford)	.03	.03	.004	.01

[a]mechanical milk productions were done every 46 d starting on d 66
[b]EPD level

Table 10. Least squares means, standard errors for protein percent by cow group

	Protein (%)			
Cow group	1[a]	2	3	4
High Angus	3.12±.08	3.42±.28	3.22±.06	3.59±.08
Low Angus	3.13±.08	3.42±.29	3.21±.06	3.49±.08
High Hereford	3.31±.09	4.05±.28	3.34±.06	3.59±.08
Low Hereford	3.35±.09	3.07±.29	3.45±.06	3.84±.08
P values				
Breed	.009	.61	.007	.04
Level[b]	.79	.09	.43	.38
Breed x Level	.88	.12	.32	.03
Level(Angus)	.92	.99	.89	.36
Level(Hereford)	.79	.03	.21	.03

[a]mechanical milk productions were done every 46 d starting on d 66
[b]EPD level

Table 11. Least squares means, standard errors for lactose percent by cow group

Cow group	Lactose (%) 1[a]	2	3	4
High Angus	5.02±.05	5.11±.05	4.89±.04	4.89±.05
Low Angus	5.09±.05	5.12±.05	5.02±.04	4.98±.05
High Hereford	5.04±.05	5.07±.05	4.97±.04	4.97±.05
Low Hereford	4.94±.05	5.05±.05	4.88±.05	4.89±.05
P values				
Breed	.19	.25	.42	.96
Level[b]	.83	.95	.65	.88
Breed x Level	.10	.65	.01	.13
Level(Angus)	.26	.78	.03	.22
Level(Hereford)	.21	.71	.15	.36

[a]mechanical milk productions were done every 46 d starting on d 66
[b]EPD level

Table 12. Least squares means, standard errors for solids-not-fat percent by cow group

	SNF (%)			
Cow group	1[a]	2	3	4
High Angus	8.92±.08	9.01±.09	8.89±.09	9.22±.09
Low Angus	8.97±.08	9.12±.10	9.08±.09	9.25±.09
High Hereford	9.06±.08	9.18±.10	9.13±.09	9.28±.09
Low Hereford	9.07±.09	9.16±.09	9.12±.09	9.52±.09
P values				
Breed	.11	.24	.09	.06
Level[b]	.71	.61	.32	.15
Breed x Level	.77	.46	.27	.26
Level(Angus)	.62	.37	.12	.79
Level(Hereford)	.96	.88	.92	.08

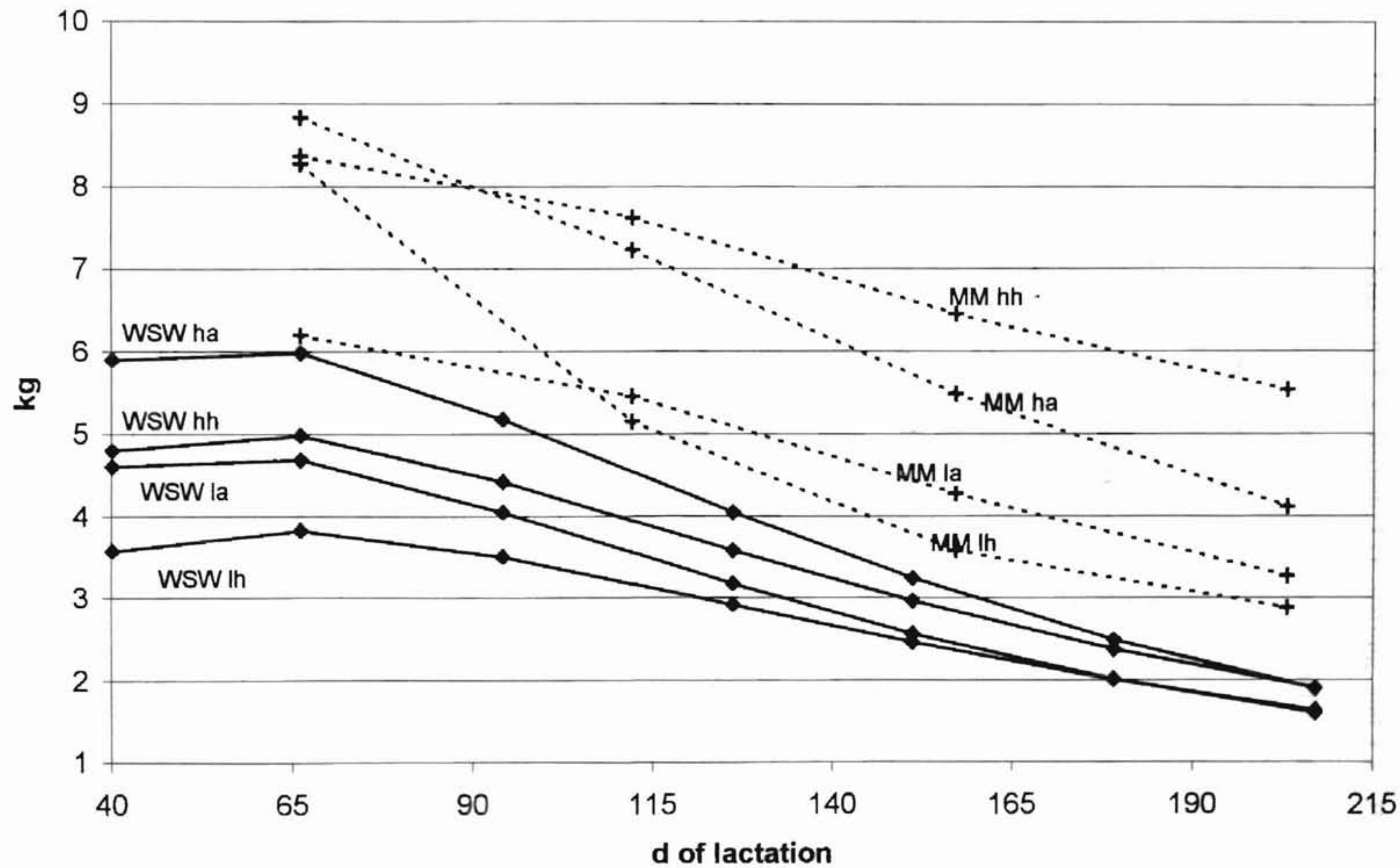
[a]mechanical milk productions were done every 46 d starting on d 66
[b]EPD level

Table 13. Least squares means, standard errors for somatic cell count by cow group

	SCC[a]			
Cow group	1[b]	2	3	4
High Angus	3.81±.47	4.20±.58	4.04±.51	5.02±.44
Low Angus	4.35±.43	3.24±.55	4.17±.55	4.89±.42
High Hereford	3.76±.47	3.34±.56	3.93±.56	5.11±.43
Low Hereford	4.97±.48	5.13±.59	4.75±.51	5.54±.45
P values				
Breed	.83	.48	.57	.13
Level[c]	.10	.80	.33	.76
Breed x Level	.83	.12	.44	.48
Level(Angus)	.18	.18	.88	.76
Level(Hereford)	.35	.34	.24	.49

[a]somatic cell counts were adjusted by their natural log before being analyzed
[b]mechanical milk productions were done every 46 d starting on d 66
[c]EPD level

Figure 1. MM and WSW Lactation Curves



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APPENDIX

Table A. Levels of significance for main effect model terms on 24-h milk yield estimates for MM collection method

	P-values			
	d of lactation			
Model term	1[a]	2	3	4
Season	.7214	.0008	.1098	.6144
Nutrition	.6256	.2082	.4090	.1627
Breed	.8635	.2752	.1076	.1381
EPD level	.0021	.0375	.0149	.0158
Age of dam	.7638	.0766	.5864	.2683
Sex of calf	.0797	.0087	.0323	.3978
Sire of calf	.1691	.0062	.1510	.0344

[a]mechanical milk productions were done every 46 d starting on d 66

Table B. Levels of significance for main effect model terms on 24-h milk yield estimates for WSW collection method

Model term	P-values d of lactation 1	2	3	4	5	6	7
Season	.0979	.4279	.0282	.2879	.2192	.9449	.0010
Nutrition	.8006	.0042	.0597	.2145	.9870	.0236	.2376
Breed	.0207	.1592	.5395	.1475	.3751	.4463	.7286
EPD level	.1201	.1765	.1218	.0406	.3835	.3703	.1115
Age of dam	.5060	.4451	.3064	.1647	.5160	.0100	.0205
Sex of calf	.7980	.0984	.2724	.1370	.7820	.0005	.1109

[a]monthly milk productions were done every 28 d starting on d 40

Table C. Levels of significance for interaction terms on 24-h milk yield estimates for MM collection method

Interaction term	P-values d of lactation 1	2	3	4
Seas x Nut.	ND	ND	ND	.1441
Seas x Breed	ND	ND	ND	ND
Seas x EPD lev.	ND	ND	ND	.1232
Seas x Age	.1095	.2718	ND	.0365
Seas x Sex	.0140	ND	ND	ND
Nut. x Breed	ND	ND	ND	ND
Nut. x EPD lev.	.0021	ND	ND	ND
Nut x Age	.0188	ND	ND	.0893
Nut x Sex	ND	ND	ND	.0567
Breed x EPD lev.	.4858	.7005	.9585	.7434
Breed x Age	.0050	ND	ND	ND
Breed x Sex	ND	ND	ND	.1616
EPD lev. x Age	.0434	ND	ND	ND
EPD lev. x Sex	ND	.0893	ND	ND
Age x Sex	ND	.0684	ND	ND
Sire of dam w/in Breed x EPD lev.	.0101	.0303	.0624	.0857

ND – not discernible

[a]mechanical milk productions were done every 46 d starting on d 66

Table D. Levels of significance for interaction terms on 24-h milk yield estimates for WSW collection method

	P-values						
	d of lactation						
Interaction term	1	2	3	4	5	6	7
Seas x Nut.	.0115	ND	.0028	.0037	ND	ND	.1953
Seas x Breed	ND	ND	.2384	.2559	ND	ND	.0332
Seas x EPD lev.	.0500	ND	ND	.2431	ND	.0069	ND
Seas x Age	.1427	.1127	ND	ND	ND	ND	ND
Seas x Sex	ND	ND	.1130	.0519	ND	.0052	ND
Nut. x Breed	.1733	ND	.2083	.1616	.0151	ND	ND
Nut. x EPD lev.	ND	.0591	ND	.0188	.0646	ND	.1093
Nut x Age	.1863	ND	ND	.0353	ND	.0805	.0793
Nut x Sex	.1903	ND	.1049	ND	ND	.0331	.1214
Breed x EPD lev.	.5222	.3878	.6644	.6114	.2429	.5567	.7263
Breed x Age	ND	.2967	.0003	.0285	.2402	ND	.0201
Breed x Sex	ND	ND	ND	.2906	.3080	ND	.1115
EPD lev. x Age	.1387	ND	.0436	ND	ND	ND	ND
EPD lev. x Sex	.0757	.2171	ND	ND	.2960	ND	ND
Age x Sex	.1338	ND	ND	ND	ND	ND	.0772
Sire of dam w/in Breed x EPD lev.	.1505	.0112	.0258	.1054	.2955	.0002	.0275

ND – not discernible

[a]monthly milk productions were done every 28 d starting on d 40

Table E. Levels of significance for model terms on total lactation curve area as estimated by MM and WSW procedures

	P-values	
	Method of estimation	
Model term	**MM**	**WSW**
Season	.6202	.7341
Nutrition	.5741	.1255
Breed	.9316	.0882
EPD level	.0001	.0006
Age of dam	.6387	.1138
Sex of calf	.3219	.3973
Sire of calf	.0641	
Season x nutrition	ND	.0374
Season x breed	ND	.2254
Season x EPD level	ND	.0238
Season x calf sex	.2118	.1586
Nutrition x EPD level	ND	.2367
Breed x EPD level	.2766	.2480
Breed x age	.1849	.0802
Age x sex	.0203	.0157
Sire of dam nested in breed x level	.0672	.1858

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