INTERRELATIONSHIPS AMONG UDDER CHARACTERISTICS AND MILK YIELD OF BEEF COWS SIRED BY HIGH OR LOW MILK EXPECTED PROGENY DIFFERENCE BULLS

By

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CHAPTER I

INTRODUCTION

The rate of genetic improvement of production efficiency through selective breeding depends on the choice of the most important traits, the heritability, the variability, the generation interval, and the selection differential. The ability to accurately measure the traits of interest is critically important due to the relationship of the accuracy to heritability. In cow-calf production systems weaning weight of calf considerably influences net income. Its improvement is often of high priority and can be achieved effectively by within herd selection. However, an even faster gain will be obtained by introduction of outside replacement animals. In either case sound evaluation approaches are essential. A large body of evidence indicates that while weaning weight is influenced by many factors, supply of maternal milk is the single most important component.

In an effort to study joint and separate influences of breed, age, weight, summer and winter weight changes and milk yield of dam, breed of sire, and birth weight, weaning age and sex of calf on calf preweaning weight, Jeffery et al. (1971) reported that of all variables considered, milk yield had the greatest influence on preweaning weight. They reported correlations of .78 and .76 for two consecutive years between milk yield and average daily gain (ADG) to weaning. Gleddie et al. (1968) found milk yield in any month to be highly predictive of calf ADG from birth to weaning. They reported that milk yield accounted for 71.3% of variation in calf ADG. Milk yield and calf ADG correlations from birth to weaning ranged from .73 to .83 in a four month-period of testing. Brumby et al. (1963) reported that some 50% of variation in weaning weight may be attributed to difference in milk consumption. Clutter et al.(1987) reported that calves suckling high milk group dams had 16.9 kg greater 205-d weaning weight than those suckling low milk group dams, solely because of difference in maternal environment. Robison et al. (1978) stated that estimates of percentage of variation in weaning weight accounted for by milk volume ranged from 20 to 60%. Rutledge et al. (1971), who noted that milk quantity rather than milk quality was more important in its influence on 205-day weight, also reported that on a within herd-sex-year basis approximately 60% of variance in 205-day weight could be attributed to the direct influence of the dam's milk yield. Rollins et al. (1954) reported that the lactating ability of a cow makes a major contribution to the growth of the calf throughout the entire suckling period. Bradford et al. (1941) reported a simple correlation of 0.52 between daily gain and quantity of milk. They further indicated that the superior beef characters of the bull calves retained for breeding were due to the greater quantities of milk consumed during the suckling period.

Because of wide acceptance of the role of maternal milk of beef cows in determining calf growth, genetic improvement of milk production in beef cows is of high priority to the industry. Unfortunately, as indicated by Williams et al. (1979), milk production in beef cattle was difficult and costly to measure. Mallinckrodt et al. (1992) reported that optimizing potential milk yield was difficult because direct measurements of milk production of beef cows is not practical and indirect measurement was inaccurate. In addition, they indicated that calf weaning weight is also a poor measure of dam milk yield due to the confounding influence of the calf's growth potential. Consequently, numerous researchers have studied body, udder, and teat measurements and scores to investigate probable relationships or correlations among various physical characteristics and milk production in beef cattle. Those studies were aimed at developing alternative avenues that can be considered to accurately estimate the genetic potential for milk production to increase net income of beef production operations by producing heavy calves at weaning. Williams (1979) stated that milk production in beef cattle was difficult and costly to measure, thereby making repeatable traits that were highly correlated with milk important tools in practical selection for milk production. Kersey et al. (1987) reported that many breed associations, including the American Hereford Association, have designed a scoring system to evaluate the total mammary system, but little information has been available to evaluate the usefulness of these scoring systems in a beef production system.

In the last two decades considerable progress has been achieved in livestock evaluation procedures. The development of mathematical models and statistical analysis procedures, as well as progress in computer capabilities, lead to the advent of best linear unbiased methods using mixed model equations to make milk Expected Progeny Difference (EPD) available to producers through national beef cattle evaluation programs. This information provides the potential for rapid genetic progress in milk production. In a study of Holsteins, Bertrand et al. (1985) found daughters of sires with high predicted differences for milk produced 16% more milk than daughters of average sires. Mallinckrodt (1993) presented results showing that maternal milk EPD and total maternal EPD are good predictors of genetic differences in milk and weaning weight. Buchanan et al. (1992) reported similar results from a study of performance of calves from heifers sired by high and low milk EPD sires and indicated that producers should be able to use milk EPDs to rank bulls for maternal ability.

While existing literature concerning both udder characteristics and milk EPDs seems to provide evidence that associations can be used to select bulls for maternal ability, little to no information is available about correlations between milk EPD, milk production and udder characteristics. In those places or instances where communication means and technological development are not yet appropriate for application of best linear unbiased procedures, the possibility of reliably associating low or high milk EPD to known and consistently identifiable udder characteristics may constitute a viable alternative strategy for an increased accuracy of selection.

The purposes of this study were 1) to assess the relationships among selected udder characteristics, milk production, and sire milk EPDs in Angus and Polled Hereford breeds, and 2) to examine how those associations could be used to develop criteria for selection of bulls on the basis of measurements during one lactation of their daughters.

CHAPTER II

REVIEW OF LITERATURE

This review will survey the literature relating to 1) estimation of milk production in beef cows, 2) udder characteristics and relationships with milk yield and 3) Best Linear Unbiased Prediction (BLUP) and Expected Progeny Difference (EPD) for milk.

Estimation of Milk Production in Beef Cows

As the ability to accurately measure a trait is critical in choosing a characteristic to improve through selection, and upon acceptance of the reported facts about the importance of milk yield on beef calf weaning weight, the question one has to address is how milk yield in beef cows can be estimated? Numerous approaches have been reported in the literature. In general, methods suggested in the literature include hand milking, machine milking with or without injection of oxytocin, a teat cannulation method following administration of oxytocin, a body water dilution technique (Yates et al., 1971), an isotope dilution method (Nicol et al., 1973), and the calf-weight-change technique also called weigh-suckle-weigh (WSW).

These techniques, while all are different, have been questioned for either their degree of reliability or practicability in production situations. The method most used and considered simplest (Nicol et al., 1973) is the WSW technique that involves weighing a calf before and after suckling to determine, by weight difference, its milk intake. Milk intake is generally equal to milk production of the dam. Totusek et al. (1973) reported that daily milk yield determined by WSW was 29% higher at every stage of lactation than that estimated by hand milking. It is thought that a greater release of oxytocin due to calf nursing stimulus may have caused the advantage of WSW over hand milking. The technique suffers from the major disadvantage of having to determine a small increase in live weight, due to milk consumption, in a relatively large animal. Also this approach requires extreme care to avoid cross-suckling or urination and defecation between suckling and weighing (Nicol et al., 1973). Somerville et al. (1980) reported that calf defecation or urination occurred at 8% of sucklings during the first week of lactation but rarely thereafter. This is contrary to the findings of Schake et al. (1966) who stated that frequency of urination and defecation by calves involved in the calf-weight change technique increased as lactation advanced. Somerville et al. (1980) indicated that this potential source of inaccuracy can be obviated by observing the calves at suckling and disregarding milk intake data when a calf is seen to defecate or urinate between weighing.

Another problem, with the WSW method of estimating milk yield is the choice of an appropriate separation interval (i.e. sampling procedure). Williams et al. (1979) studied 117 Hereford cows during 1975 and 1976 using the WSW method. Separation intervals of 4, 8, and 16 hours were compared to determine their effect on estimates of milk production. Results underscore the dilemma one may experience to set up the sampling procedure. They reported correlations of .25, .46, and .45 between calf average daily gain and 4, 8 and 16 hours production estimates, respectively, and indicated that when production was adjusted to a 24 hour basis, measurement errors were ±1.4, ±0.7 and ± 0.3, respectively. They recommended an 8 hour separation time with the claim that 16 hours was not natural and resulted in a distended condition of the udder; and 4 hours had greater measurement error and lower correlation with ADG. One may have suggested 16 hours for less labor and less animal disturbance in addition to the fact that this alternative presents the least measurement errors. In fact, Neville et al. (1962) considered a 16 hour separation time in their study. They used 4 samples at equal intervals between birth and weaning at 8 months to assess how environmental conditions affected the importance of milk production and the role of persistency of production in increasing weaning weights. They indicated that only two or three milk samplings during the nursing period are needed to determine the relationship of milk consumption to calf gains. Also, they reported that the relationship of milk to calf weight gains was greatest during the first 60-day period of the calf's life and declined slightly by weaning. Lamond et al. (1969) stated that the calf suckles many times each day and storage capacity of the udder is unlikely to limit milk yield in the field. Therefore, any long separation time such as 8 or 16 hours could underestimate the true secretion rate in cows with small mammary glands.

Christian et al. (1965) indicated that frequent nursing may prevent pressure build up in the dams udder and allow a greater amount of milk intake over a 24 hour period. Drewry et al. (1959) indicated that in unpublished data the average number of times suckled per day was 4.6, 4.8 and 3.0 times for the first, third, and sixth month of lactation, respectively. Day et al. (1987) performed two experiments to study whether suckling behavior of calves with similar growth potential varies depending on the dam's estimated milk production level and stage of lactation. They reported that frequency of suckling was associated with milk production level of the cows and the pattern of nursing changes as the lactation period progresses. This was in agreement with the findings of Williams et al. (1977) who studied nursing behavior of Hereford calves during two 48-hour periods at 3 and 7 weeks after calving and reported that as calves got older they tended to nurse less often. They indicated that calves tended to supplement their diet from other sources as their capacity for milk increases.

The WSW technique as it has been used in a number of studies (Bradford et al., 1941; Williams et al., 1979; Lamond et al., 1969; Reynolds et al., 1978; Le Du et al., 1979; Gleddie et al., 1968; Totusek et al., 1973; Robison et al., 1978; Somerville et al., 1980; Neville, Jr. et al., 1962; Rutledge et al., 1971 and 1972) may in some instances not reflect the actual milk producing ability of the cow, rather the milk consumption ability of the calf during one suckling. For example, Somerville et al. (1980) indicated that individual calves were unable to consume all milk that was available to them during the first month of lactation. Drewry et al. (1959) reported that in their study, cows were checked for additional milk after calves finished nursing but none was found except in some heavier producing cows during the first month of lactation.

In a study of 62 Hereford cows to test the reliability and practicability of using teat cannulation following administration of oxytocin, Lamond et al. (1969) confirmed that oxytocin used to evacuate the udder did not influence the rate of secretion. They reported that a dose of 20 IU of oxytocin intravenously for a 6-hour test program can be widely applicable. However, a 9% reduction in yield was observed during one experiment and was attributed to the stress brought about by a combination of frequent handling, fasting and separation from the calves over a long period of time.

Somerville et al. (1980) compared machine milking without oxytocin to WSW as methods of estimating milk yield of 50 Hereford x British Friesian cows and found machine milking without injection of oxytocin to be an unsatisfactory method of measuring milk yield of beef cows. Four of six machine-milked cows dried off within 100 days of calving and of the two which lactated for 150 days, only one had a cumulative yield comparable to the calf-suckling cows. Machine milking presented the lowest lactation yield resulting from failure of pre-milking stimulus to elicit a satisfactory milk-ejection reflex, but also from stress before and during milking.

Le Neindre et al. (1975) contrasted three methods of estimating milk production of nursing cows during the first two months of lactation: WSW with 5-hour intervals, WSW twice per 24 hours and hand milking after injection of 5 IU of oxytocin. They reported the first method was the least reliable. The two others were more advisable despite the fact that they were less accurate at this stage of lactation than at later stages.

Le Du et al. (1979) carried out two experiments consecutively on 8 cows, first housed and then on pasture to compare directly machine milking after intrajugular injection of oxytocin and WSW techniques in both housed and grazing environment situations. Milk yields were obtained on the basis of 6 and 8 hour separation intervals for machine milking and WSW, respectively. They found no significant difference between milk yield estimates recorded by the two techniques and it was concluded that the oxytocin technique can be routinely used to estimate milk yield in housed as well as grazing conditions. This seems to be in agreement with the conclusion of Lamond et al. (1969) generalizing that the oxytocin technique could have a wide application in studies in beef cattle. Again, the technique requires that disturbance be minimized. Le Du et al. (1979) cited work by Sibaja et al. (1975) who reported that some care must be taken in handling the animals, since fright and discomfort experienced during the secretion period may cause release of epinephrine, which induces vasoconstriction, limited blood flow within the udder, and hence reduced milk production.

Yates et al. (1971) reported on the use of a body water dilution technique to measure calf milk consumption over longer periods of time. This prevented from interfering with the normal behavior of grazing animals. Weighing methods that provide only intermittent samples, machine milking that is not adapted to beef cows, and oxytocin administration criticized for its potential to influence subsequent rate of milk secretion were also avoided. By this technique, cows and their calves are undisturbed and a week or fortnight becomes the integrated unit of time to measure milk rather than 4 or 6 hours. However, this method does overestimate milk yield because it does not aacount for water intake from pasture consumption.

Nicol et al. (1973) compared the isotope dilution and oxytocin methods. They concluded that the 6 hour milk yield obtained by the isotope method, while showing good agreement on a group basis, did not agree in all individual cases with the 6 hour milk yield obtained by the oxytocin method. Even though the reasons for these discrepancies were not clear, an inconsistent emptying of the udder by the suckling calf was suggested.

These studies provide substantial evidence supporting that estimating milk production in beef cows is difficult because of those factors that may lower the accuracies of measurement, but also the practicability of the existing methods in production situations. Consequently, considering indirect approaches involving measurement and scoring of the cow mammary system may be appropriate in some situations.

Udder Characteristics and Relationships with Milk Yield

Several studies of dairy cows reported useful relationships among udder measurements and milk yield (Petersen et al., 1985; Brantov et al., 1963; Borodin et al., 1963; Fuhrer et al., 1961; Lin et al., 1987; Batra et al., 1984; Moore et al., 1981). Sharma et al. (1983) stated that the udder of a dairy cow is the most vital part for forecasting milk yield in dairy cattle. Fewer studies on beef cattle have dealt with this subject, but based on results from the few undertaken, one can conclude that this statement is also true for beef cows.

The udder dimensions that are of general interest are teat length, teat distance, udder length, width, depth, and height (Moore et al., 1981; Tomar et al., 1973; Lin et al., 1987; Batra et al., 1984; Ziehe, 1989). Teat length is recorded as the distance from the point of connection to the udder to the distal end of the teat. However, Ziehe (1989) indicated that this measurement may be subjective in that the point of connection of the teat to the udder is not always clear. This problem can be reduced if not eliminated when the measurements are consistently made by the same person each time they are taken. Measurement of the distance between the lateral alignment at the front and rear teats determines teat distance (Batra et al., 1984). Udder height as measured by Moore et al. (1981) is considered to be the distance from the tip of the front teat to the floor.

Tomar et al. (1973) carried out a study involving 89 Hariana cows to investigate the association of various udder measurements with milk yield. Measurements taken 1 to 2 hours before afternoon milking were udder length, udder width, udder depth, fore and rear teat length and milk yield. Udder length, width, and depth were highly associated with milk production as illustrated by correlation coefficients of .455, .481 and .781, respectively. Correlations of milk yield and length of fore and rear teats were .352 and .362, respectively. In this study udder length was measured from the rear attachment of the udder, near the escutcheon, to the front of the udder where it blends smoothly with the body. Udder depth was measured by subtracting the distance separating the barn floor up to the udder floor from the distance recorded from the barn floor to the base of the udder.

Qureshi et al. (1984) studied 201 Gir cows between second and third lactations to analyze teat measurements, the shapes of udder and teats, and their correlations with milk yield. The justification for including all those variables was clearly stated by the authors: "It is not the size of udder alone that is important, but teat measurements and shape are also equally important in judging the productivity of a cow". This can be corroborated by the conclusion made by Doornbos et al. (1983) that indirect selection for milk production by selecting for visual udder score alone would not be efficient. Doornbos studied herds of 76 Hereford dams and 164 Hereford, Angus x Hereford and Simmental x Hereford dams to determine the correlation of 24-hour milk production and udder size score and their relationships with calf average daily gain from birth to weaning. Correlations were .09 between milk yield and udder score when milk test took place at 30 to 50 days of lactation. However, the correlation between milk yield and udder score when tested 130 to 150 days of lactation was .46. The considerable difference in the two correlations does suggest a problem of reliability in making use of udder score alone to select for milk yield improvement.

Qureshi et al. (1984) measured teat length, teat diameter and placement of teat; determined frequency of different shapes of udder and teat; and considered average of yield of 3 days (previous day, day of teat measurement, and the day following). Results of their study showed positively significant correlations among all teat measurement traits and all were correlated with milk yield. The correlations of milk yield with teat length, placement of teat and teat diameter were .315, .295 and .289, respectively. Similar results were reported by Brantov et al. (1965) on Ukrainian Red Streppe cow udders that were evaluated visually and measured 1/2 hour before milking during days 35 to 55 of lactation.

Borodin et al. (1963) evaluated the udders of Simmental cows in the second month of lactation. Measurements were made 1 hour before milking. Correlations of .177, .357 and .392 between milk yield and udder length, udder depth, and udder size, respectively, were observed suggesting that in selection, udder measurements should be used in addition to visual appraisal. This is in agreement with the report of Qureshi et al. (1984).

Tavildarova et al. (1961) studied the shape and size of udder of cows of various breeds in Kazakhstan and indicated that within breeds, milk yield of cows with cup shaped udders exceeded that of females with rounded udders by 6.0 to 18.1%. Compared to cup shaped udders, rounded udders had smaller circumference and relatively greater depth and teats were closer together. The smaller circumference observed on cows with rounded udder may largely be accounted for by differences in milk yield. The findings of Fuhrer et al. (1961) in a study of German Simmental cows also showed significant correlations between milk yield and udder horizontal circumference and udder volume (.599 and .661, respectively).

The implication that longer and larger teats are associated with higher milk yield should not lead one to select for those traits alone to improve milk production, because it is not enough to increase milk yield if it is not available to the growing beef calf. The shape of the teat must be considered as well. On a study involving 892 cows with various proportions of Brahman, Africander, Hereford and Shorthorn, Frisch et al. (1982) reported that bottle teats were the most important single cause of calf mortality from birth to 2 months of age.

Kersey et al. (1987) scored udder capacity and udder shape in 3 to 10 year old cows from a large Hereford herd to assess the relationships among udder characteristics, cows longevity and calf weight. A 5-point scale was used with 1 for small and 5 for large to evaluate udder capacity. Udder shape was scored from 1 (balanced, udder level with ground) to 5 (unbalanced, funnel- shaped udder). Results of the study demonstrated that little of the variation in calf weight (R^2 = .03 to .07) was explained by udder capacity. Heritability estimates of udder capacity and shape for 3 year old cows were low (.12 and .14, respectively) indicating that most of the variation observed was due to environmental effects.

However, Lin et al. (1987) studied intercorrelations among milk production traits and body and udder measurements in Holstein heifers. They found that the genetic correlations between 308 day milk and half yield with teat lengths, teat diameter, and teat distance were all positive; implying that high producing heifers tended to have longer and larger teats and have greater distance between teats than low producing heifers. As one can reasonably expect, large distance between teats is associated with large udder horizontal circumference that is reported by many authors to be significantly correlated with milk yield (Fuhrer et al., 1961 ; Brantov et al., 1965).

Best Linear Unbiased Prediction (BLUP) Procedures and Expected Progeny Difference (EPD) for Milk in Beef Cattle

The concerns for maximizing the expected value of the functions of future records when individuals are selected upon the basis of their prediction, and finding the most accurate " estimate " of functions of future records (Henderson et al., 1976) have led to the finding and applications of many evaluation methods to increase the accuracy of prediction of genetic value in all livestock species. Approaches cited in the literature include Best Prediction (BP), Best Linear Prediction (BLP) or selection index, Least

Squares (LS), Simplified Regressed Least Squares (SRLS), Best Linear Unbiased Prediction (BLUP), Contemporary Comparison (CC), and Individual phenotype (IND) or performance ratio methods (Henderson et al., 1973 and 1976; Garrick et al., 1991; Singh et al., 1992; Tavernier et al., 1988; Wilson et al., 1988; Mallinckradt et al., 1993 ;Wilton et al., 1975; Quaas et al., 1980; Benyshek et al., 1990; Belonsky et al., 1988). Of all procedures it appears that the mixed model method for multiple traits providing best linear unbiased predictions (BLUP) of breeding value is far more accurate than any other practiced technique for genetic predictions.

Garrick et al. (1991) underlined work by Robinson et al. (1989) who carried out a simulation study over 20 generations using multiple-trait within-herd selection of beef cattle and demonstrated that BLUP resulted in almost 19% greater response in net worth than the selection index system. Garrick et al. (1991) also cited Blair (1981) who in a study of pig selection in Denmark determined a 20% improved response using BLUP compared to selection index. It was estimated that about 1/4 of the increased accuracy resulted from the inclusion of all relatives in the BLUP evaluation. The remaining 3/4 of the improvement was caused by bias avoidance with BLUP when selection was across contemporary groups.

Benyshek et al. (1990) pointed out that in 1988, almost all breeds had incorporated a multiple trait analysis into their national evaluation procedures. This presents the advantage of incorporating existing genetic correlations among traits into the system allowing, for example, progeny performance in one trait to provide more information on another related trait especially in those instances where bulls have limited progeny information. Also, multiple-trait analysis is also an avenue for reduction of bias that could result from sequential selection. An example of this is the effect of selection at weaning on post weaning gain test (Benyshek et al., 1990).

Singh et al. (1992) in a study to compare ranking of sires by BLUP, LS, SRLS, and CC methods used data on 90, 180 and 300 day milk yield of 867 purebred progeny of

Hariana bulls in 3 farms, and reported that the BLUP method was considered more appropriate than other methods. Belonsky et al.(1988) using a computer simulation of a closed swine herd composed of 100 sows and 4 boars to compare genetic changes from selection on individual phenotype (IND) versus BLUP found that gain was greater for selection on BLUP than on IND but relative differences narrowed as heritability increased. The authors reported that at year 10 the relative advantage of selection on BLUP was 55%, 25% and 10% for heritabilities of .10, .30 and .60, respectively. This is in agreement with what is generally accepted, as heritability increases the individual's own record becomes more important. Further, genetic variance was reduced more with selection on BLUP, but rate of response was still greater than with selection on IND because of greater accuracy of evaluation. As pointed out by Benyshek et al. (1988), the BLUP procedures incorporate all available information from progeny, relatives in the pedigree particularly the sire and dam, grand progeny and the individual's own performance records into the prediction of an individual's genetic value.

Tavernier et al. (1988) reported on advantages of BLUP for the horse population in France where a stallion can have only a limited number of progeny because artificial insemination is still forbidden in thoroughbreds and seldom used in other breeds. They indicated that relationships other than parent-progeny are important to consider. Also, they underscored the possibility of evaluating mares with or without progeny or with and without records, in order to make adequate assortative matings. Tavernier et al. (1990) stated that the breeding value of French horses for jumping is now estimated by the BLUP method and that the procedure takes into account all records of dam, sire and breeding background, and environmental influence such as maternal inheritance, herd effect, age, sex, year of recording and management condition.

Other developments of mixed-model methodology for beef cattle are the use of the relationship matrix to account for genetic trend and to provide more precise comparisons of younger and older bulls. With the animal model, when progeny information is used the superiority or inferiority of an individual's mates are adjusted for in the analysis resulting in the reduction if not the elimination of bias due to non-random mating of dams to sires. The ability to avoid bias due to non-random mating of dams to sires, to use all available information and make EPDs available for all animals are important features that distinguish the animal model from the sire model. In addition, the animal model rather than the sire model allows avoidance of upward bias for older animal when there is genetic trend.

Genetic value predictions are performed through the National Cattle Evaluation program for all major breeds that publish sire summaries where breeding values are presented in the form of Expected Progeny Difference (EPD). EPD values are extremely valuable for selection purposes and for identifying optimum values for use in varied cattle breeding system (Brinks, 1987). In general, EPD values for birth weight, weaning weight, yearling weight and milk are found in most published sire summaries; however some additionally include carcass and reproduction traits. Furthermore, weaning weight (WWT) is actually defined by the genotypic potential for growth of the calf received from its dam and sire in addition to the genotypic value for milk of the cow.

The segregation of the WWT into growth and milk with an animal model made it possible to provide the producers with the opportunity to make their decisions on WWT and milk EPDs, separately. The milk EPD has become the expected difference in weaning weight of calves out of daugthers by a particular sire, compared with calves from another sire's daughters, due to differences in mothering ability (Buchanan et al. 1989).

Marston et al.(1990) studied the relationship of Milk EPD to total milk production and calf weaning weight in Angus and Simmental cows. Milk EPD ranged from -5.1 to 5.4 kg in Angus and -5.5 to 6.8 kg in Simmental cows. Milk yield was estimated at 60, 120 and 180 days in lactation. They reported that milk EPD was positively associated with milk production and can be used to predict both total milk production and weaning weight. Marston et al. (1992) reported that a 1 kg change in milk EPD resulted in a 4.85$\pm$ 1.14 kg change in weaning weight in Angus and a 3.74$\pm$1.73 kg change in Simmental.

Diaz et al. (1992) conducted research to investigate the relationship between milk EPD of Polled Hereford sires and actual milk production of crossbred daughters. The range of sire milk EPD sampled was -10 to 16 kg. They reported an estimated residual correlation between milk production and sire milk EPD of .26 and indicated that milk EPD can be used as a selection criterion to change milk production in beef herds.

Summary of Literature Review

The importance of beef cow milk yield on calf weaning weight is widely accepted. Milk yield is consequently an attractive trait to choose as a characteristic to improve through selection. It is recognized that within-herd selection is effective to genetically improve a trait or traits. However, faster gain is more probable with across herd selection by greater selection differential. With respect to milk yield improvement, the greatest difficulty that arises seems to be that of accuracy of measurements that although possible are not practical in most production situations.

Traditionally, the routes used to estimate milk yield in beef cows are indirect. They include approaches that provide some estimate of milk yield but also methods of udder measurements and scores. The WSW technique is by far the most widely used method of milk yield estimation. Others are known as hand milking or machine milking with oxytocin injection, body water dilution and isotope dilution methods. The basis for using udder dimensions and scores is the correlation of those measurements with milk yield. In general, udder measurements must supplement visual scores for prediction of milk yield by these methods to be reliable. In some breeds, cows with cup shaped udders are reported to be associated with more milk yield than cows with rounded udders. Longer teats seem to be predictive of high milk yield. However, attention must be brought to the ability of the young calves to adequately suckle the milk contained in the udder. For example, bottle teats are noted to be an important cause of calf mortality from birth to 2 months of age. In evaluating the beef cow mammary system, it is essential to understand that the shape of the teats is critically as important as is the size. Another indirect method used to evaluate beef cows for milk yield was the comparison of calves WW. However, WW is actually determined by the genotypic potential for growth of the calf and the genotypic value for milk of the cow. The confounding influence of the calf growth potential makes the calf WW a poor measure of dam's milk yield.

More recently, the development of mixed-model methodologies made it possible by BLUP to provide producers with EPDs for economically important traits. By incorporating all available information and accounting for environmental differences among herds, BLUP methods are found to be more accurate than any other existing genetic prediction technique for across herd selection. The BLUP procedures make EPDs available for all animals regardless of age and sex and account for genetic trend. The availability of milk EPDs seems to open to the producer the option to rank bulls for mothering ability based on the milk EPDs. Consequently, this leads to the opportunity of investigating the interrelationships among udder characteristics, milk production and sire milk EPDs for the development of an alternative method of evaluation of beef cattle for milk yield.

CHAPTER III

MATERIALS AND METHODS

Animal Population

Cows involved in the present research were part of an ongoing project conducted by Oklahoma State University at Lake Carl Blackwell experimental range under spring and fall calving systems that are typical of commercial beef cattle production systems in the region. The project was designed to study the effects of sires with either high or low milk Expected Progeny Differences (EPD) on the efficiency of the production of their daughters. For the purpose of this thesis, data were collected on 143 lactating cows during the fall of 1992 and spring 1993. Data collected in the fall were from 71 cows that had calved in the preceding spring and those collected in the spring were from 72 cows of the preceding fall calving group. Calving period in the spring extended from early February to late April and that of fall from early September to late November.

The age ranges of the cows were 24 to 36 months and 24 to 42 months for the spring and fall calving groups, respectively. Numbers of cows by age group and calving group are shown in Table 1. Cows were born of Hereford -Angus, 1/4 Brahman - 1/4 Angus - 1/2 Hereford, and 1/4 Brahman - 1/2 Angus - 1/4 Hereford dams that were artificially inseminated with semen from registered Angus or Polled Hereford bulls with either low or high milk EPD.

TABLE 1

NUMBERS OF COWS BY AGE GROUP AND CALVING GROUP

	Age (months)			
Calving group	24	30	36	42
Spring	42	6	23	0
Fall	24	2	20	26
Total	66	8	43	26

For the spring calving group, semen came from 11 and 10 Angus and Polled Hereford sires, respectively. Bulls in each of sire breed were categorized into high and low milk EPD groups. The list of sires by breed with their milk EPD values, EPD groups and number of daughters by calving group is presented in Table 2. Of 11 Angus bulls, five with milk EPDs ranging from -13.61 to -4.54 kg were identified as low EPD sires and six with milk EPD from 6.35 to 12.25 kg were considered high milk EPD sires. Of 10 Polled Hereford sires, 6 were considered to have a low milk EPD (-4.45 to -1.77 kg) and 4 were considered high milk EPD sires (8.39 to 13.11 kg). In the fall calving group, the number of sires used was the same in both sire breeds and for both low and high milk EPD groups. Twelve Polled Hereford sires, of which 6 had a high milk EPD (3.63 to 13.11 kg) and 6 a low milk EPD (-4.45 to -1.77 kg), were used. Likewise, semen from 12 Angus sires, of which 6 had a low milk EPD (-13.11 to -3.18 kg) and 6 a high milk EPD (6.35 to 12.25 kg), were used. For both spring and fall calving groups the number of daughters per sire ranged from 1 to 8 with an average of 4 daughters. The daughters (cows) were either at their first or second parity. A repartition of the cows by parity and calving group is given in Table 3.

TABLE 2

LIST OF SIRES BY BREED WITH THEIR MILK EPD VALUES (KG), GROUPS AND NUMBER OF DAUGHTERS BY CALVING GROUP

		milk EPD		number of daughters	
Breed	sire Id.	value	group	spring	fall
Polled Hereford	6001	-2.04	low	2	5
	6002	-4.45	low	5	6
	6003	-2.13	low	2	5
	6004	-3.54	low	3	2
	6005	-3.76	low	6	2
	6006	-1.77	low	3	1
	6101	9.48	high	-	1
	6102	8.39	high	4	1
	6103	3.63	high	-	5
	6104	9.16	high	3	2
	6105	12.79	high	1	2
	6106	13.11	high	5	1
Angus	7001	-13.61	low	4	8
	7002	-4.08	low	3	3
	7003	-3.18	low	-	2
	7004	-3.63	low	3	4
	7005	-4.08	low	3	3
	7006	-4.54	low	6	2
	7101	6.35	high	3	4
	7102	8.16	high	4	2
	7103	8.16	high	2	4
	7104	12.25	high	4	3
	7105	9.53	high	2	3
	7106	7.71	high	3	1

TABLE 3

NUMBERS OF COWS BY PARITY AND CALVING GROUP

	Parity	
Calving group	1	2
Spring	48	23
Fall	26	46
Total	74	69

Estimation of Daily Milk Yield

Estimates of milk yield were recorded every 28 days starting from the time when the oldest calves of each calving group reached the age of 45 days. At the first stage of lactation, trials were done on all cows with calves older than 15 days. The estimation method used was the WSW technique with 6 hours separation time. A 6 hour separation time was considered adequate; it was expected that the distended condition of the udders would not be observed and milk secreted in that time will be entirely consumed by the suckling calf. Also, underestimation of true secretion rate in cows with small mammary glands would also be avoided. Cows and calves were separated at 6:00 pm the day before the testing day and remained separated overnight. At 6:00 am on the morning of the trial cows were paired with calves to allow each calve to completely suckle its dam. This preliminary 12 hours separation time and subsequent suckling not only began the test on an equal basis for all cows but also minimized possible residual milk in the udders. After the 6:00 am suckling, cows and calves were separated until noon at which time calves were weighed, allowed to suckle and weighed again. Milk yield from that trial was determined by the computation of the difference in weights before and after nursing assuming that all milk that was secreted during the separation time was effectively consumed by the calf. A second trial followed at 6:00 pm after another 6 hour separation time. The sum of yields from the two trials was multiplied by two to obtain an estimate of 24 hour milk yield. Problems of residual milk and defecation or urination between weighings were considered negligible in that they were part of the random error.

Udder Evaluation

Udder characteristics of these lactating cows were repeatedly evaluated by recording pertinent linear measurements and scores on selected udder and teat traits after complete removal of milk from the udder by suckling. Scores and udder dimension data were recorded during periods 6 and 7 corresponding to about days 185 and 213 of lactation, respectively.

Scoring was by a team of two independent scorers; the average of the two scores was used in the final analysis. Selected traits for scoring included udder support, and teat shape. Teat shape and udder support were scored on a scale from one to nine as suggested by Ziehe (1989) and shown in Figure I. Teat shape scoring was rooted in the consideration that a cylindrical shape from top to bottom would be ideal with a score of five. Any deviation from that shape would either move toward a funnel shape, that when extreme was assigned a one, or toward an extremely bulbous shape with a score of nine. Udder support, an extremely important criterion for udder soundness, was scored on how appropriately the udder as a whole was attached to the abdominal cavity. A strong attachment reflected by the way udder is held up into the body cavity was considered ideal and resulted in a score of one. When the attachment was loose in both front and rear it was considered that the udder was broken down and in the worse case a score of nine was assigned. Between those two extremes a score of five was considered for an average strength of attachment. In scoring udder support it was important to distinguish it from udder size despite a close association between the two traits.

Linear measurements of udder dimensions included teat length, distance between front teats, distance between rear teats, and diagonal distance between left front teat and right rear teat. Measurements were made by the same operator each time data were collected. A tape measure was used that read to the nearest 0.25 cm. For teat length, a score of two was assigned when the distance between the point of connection to the udder and the distal extremity was greater than 2 cm, otherwise a score of one was assigned. It was assumed that distances between teats were indicators of udder circumference, size and volume or capacity.

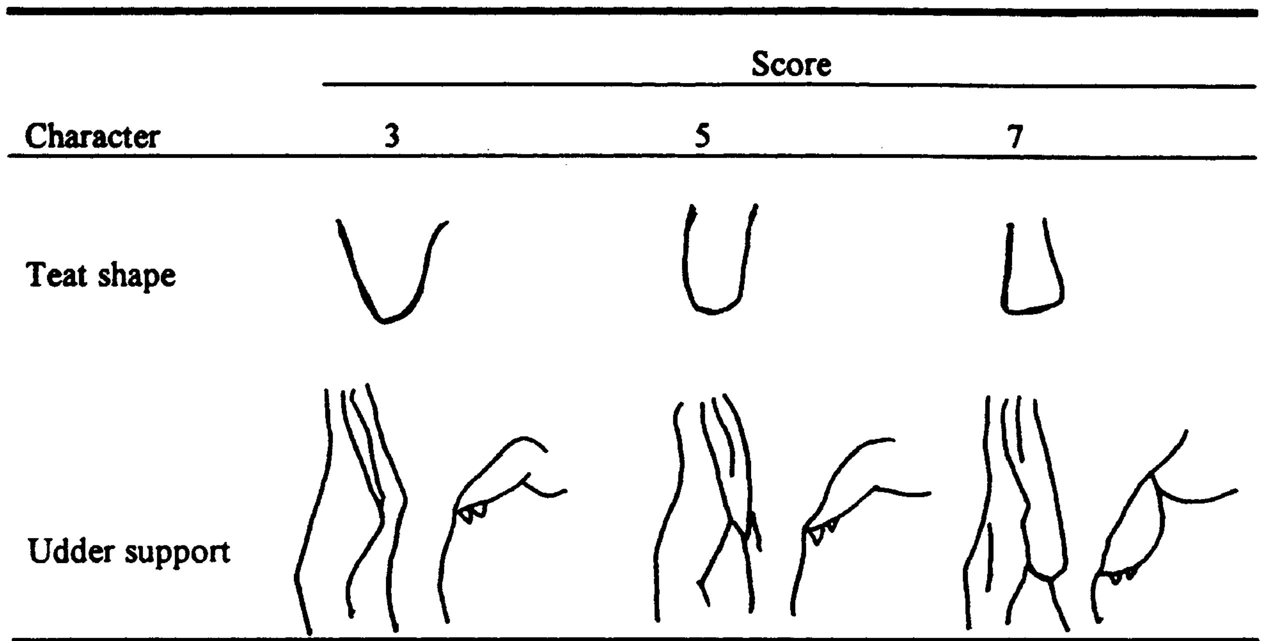

Figure I. Scoring System for Teat Shape and Udder Support adapted from G. K. Ziehe, 1989. MS Thesis Texas A&M University.

Statistical Analysis

Milk yield (MILKY), distance between front teats (DFT), distance between rear teats (DRT), diagonal distance (DIAG), total teat distance (TOTDIST), left front teat shape (LFS), right front teat shape (RFS), left rear teat shape (LRS), right rear teat shape (RRS), average teat shape (AVETS), udder support system (USS), left front teat length (LFL), right front teat length (RFL), left rear teat length (LRL), and right rear teat length (RRL) were analyzed by general linear model (GLM) procedures of SAS (1989). TOTDIST was the sum of DIAG, DFT and DRT. AVETS and AVETL were simple means of teat scores and teat length, respectively. Measurements and scores analyzed were means for period 6 and 7 of lactation. The initial full model included the fixed effects of calving group, parity, breed of sire of dam, milk EPD group within breed of sire of dam

EPD group within breed of sire of dam and all interactions among fixed effects. The model also included the random effect of sire within milk EPD group x breed of sire x parity. The effects of breed of sire, milk EPD group within breed of sire and interactions of parity x breed of sire and parity x milk EPD group within breed of sire were tested using the random sire effect as the error term. For each trait, a reduced model that included all main effects, regardless of their degree of significance in the full model, and interactions with $P<.3$ starting with highest order of interactions was used. Least square means were calculated from reduced models for all main effects and for 2 and 3-ways interactions that were significant ($P<.10$). Associations between MILKY, TOTDIST, AVETS, USS and AVETL were determined using Pearson's correlation (SAS, 1989). Initial phenotypic correlations were calculated within each parity, milk EPD group and breed of sire subclass. Subclass correlations were pooled using procedures described by Snedecor and Cochran (1980). Since repeatabilities of measurements and scores were estimated between periods 6 and 7 only, the correlation procedures (SAS,1989) were used.

CHAPTER IV

RESULTS

Milk Production

Analysis of variance results for milk yield are presented in Table 4. Milk EPD group within breed of sire, parity, calving group, and parity x breed of sire of dam interaction were all significant sources of variation in milk yield. However, for the purpose of this study milk EPD group is of special interest. Milk yield data from cows sired by Angus and Polled Hereford bulls with either high or low milk EPDs are shown in Table 5. Least squares means and associated standard errors for milk yield by milk EPD group indicate different results for Angus and Polled Hereford sired cows. Sire milk EPD group significantly affected milk yield of Angus-sired cows ($P<.03$) but not Polled Hereford-sired cows ($P>.30$). In Angus, high milk EPD sired cows had 22.50% more yield than low milk EPD sired cows (9.47 kg vs 7.34 kg). In Polled Hereford-sired cows, milk yield was not higher for cows sired by high milk EPD bulls than those sired by low milk EPD males. This suggests that sire milk EPD was indicative of the genetic potential for milk yield in Angus sired cows.

Udder and Teat Scores

Analysis of variance results for scores of udder support system (USS), left front teat shape (LFS), right front teat shape (RFS), left rear teat shape (LRS), right rear teat

TABLE 4.

ANALYSIS OF VARIANCE RESULTS FOR MILK YIELD

Source of variance	df	Mean square
cg	1	196.10 **
par	1	43.28 *
bosd	1	55.10 *
grp(bosd)	2	25.00 +
cg*bosd	1	16.05
par*bosd	1	27.81 +
sidd(par*grp*bosd)	24	9.26
residual	111	9.51
coefficient of determination = .40		

List of acronyms : sidd =sire of dam identification, cg = calving group, par = parity, grp = milk EPD group, bosd = breed of sire of dam.
+ = P < .10 ;* = P < .05 ;** = P < .01

TABLE 5. LEAST SQUARES MEANS (kg) WITH ASSOCIATED STANDARD ERRORS FOR MILK YIELD BY MILK EPD GROUP WITHIN BREED OF SIRE

	Polled Hereford		Angus	
Trait	low	high	low	high
Milk Yield	$7.15 \pm .60^{a}$	$6.28 \pm .75^{a}$	$7.34 \pm .64^{a}$	$9.47 \pm .63^{b}$

$^{a, b}$ means with different superscripts within subgroups in a row differ(P <.05).

shape (RRS) and average teat score (AVETS) are presented in appendix Tables 13 to 18. Milk EPD group within breed of sire did not significantly affect any of these traits. However, there was a calving group x parity x milk EPD group within breed of sire interaction on USS (P<.10) and RFS (P <.05). Breed of sire and parity affected USS (P<.05). Calving group affected USS, LFS, RFS, LRS and AVETS (P<.01). The calving group x parity interaction was a source of variation for USS (P<.05) and RRS (P<.10). The calving group x parity x breed of sire interaction affected (P<.10) only USS. The amount of variation explained by various reduced models for all scored traits was generally high. Observed R^2 values were .70, .74, .82, .75, .79 and .81, respectively, for USS, LFS, RFS, LRS, RRS and AVETS and showed that the models used accounted for much of the total variation.

Least squares means with associated standard errors for RFS and USS by calving group, parity, and milk EPD group within breed are presented in Table 6. There was a calving group x parity x milk EPD group within breed of sire interaction (P<.10) for RFS. In the spring calving group at parity one, the high milk EPD group had greater (P<.05) RFS than than the low milk EPD group. Sire milk EPD group affected (P<.05) USS on cows sired by Polled Hereford only at parity one of the spring calving group (3.34 vs 2.83 for low and high milk EPD daugthers, respectively). However, USS on Angus sired cows was affected by sire milk EPD only at parity two in the spring calving group. There was also a calving x parity x milk EPD group within breed of sire interaction (P<.10) for RFS on Angus cows, but least squares means for EPD group within subclasses were not significantly different.

Least squares means for RRS, LFS, LRS and AVETS presented in Table 7 indicate no significant effect of milk EPD group within breed on any of these traits in daughters of Angus sires. However, for cows sired by Polled Hereford the high milk EPD group had greater (P < .05) LRS and AVETS than the low milk EPD group. RRS and LFS means were greater in high milk EPD group but not significantly.

TABLE 6

LEAST SQUARES MEANS WITH ASSOCIATED STANDARD ERRORS FOR RFS AND USS BY CALVING GROUP , PARITY AND MILK EPD GROUP

		Spring				Fall			
		Parity 1		Parity 2		Parity 1		Parity 2	
Traits*	Breed	Low	High	Low	High	Low	High	Low	High
RFS	PH	5.88±.12 ^{a}	6.35±.14^{b}	6.31±.14^{a}	5.84±.32^{a}	5.02±.20^{a}	5.02±.16^{a}	4.75±.09^{a}	4.97±.18^{a}
	Angus	6.15±.12^{a}	6.18±.12^{a}	5.93±.17^{a}	6.11±.15^{a}	4.69±.15^{a}	5.05±.18^{a}	4.97±.11^{a}	4.71±.12^{a}
USS	PH	3.34±.15^{a}	2.83±.17^{b}	3.68±.18^{a}	4.18±.42^{a}	2.54±.25^{a}	2.26±.21^{a}	2.39±.11^{a}	2.30±.23^{a}
	Angus	2.73±.15^{a}	2.91±.15^{a}	2.68±.22^{a}	3.64±.19^{b}	1.89±.20^{a}	2.16±.24^{a}	2.23±.15^{a}	2.37±.15^{a}

List of acronyms: RFS = right front teat shape, USS = udder support system, PH = Polled Hereford.

* Traits for which calving group x parity x milk EPD group within breed of sire of dam was significant ($P < .10$).

$^{a, b}$ means with different superscripts within subgroup in a row are different ($P < .05$) .

TABLE 7.

LEAST SQUARES MEANS WITH ASSOCIATED STANDARD ERRORS FOR UDDER AND TEAT SCORED TRAITS BY MILK EPD GROUP WITHIN BREED OF SIRE

	Breed and Milk EPD Group			
	Hereford		Angus	
Trait	low	high	low	high
RRS	5.39±.08[a]	5.47±.09[a]	5.34±.08[a]	5.47±.08[a]
LFS	5.31±.08[a]	5.47±.09[a]	5.34±.08[a]	5.45±.08[a]
LRS	5.35±.08[a]	5.66±.10[b]	5.44±.09[a]	5.51±.09[a]
AVETS	5.34±.06[a]	5.54±.07[b]	5.41±.06[a]	5.47±.06[a]

a, b means with different superscripts within subgroups in a row differ(P <.05).

List of acronyms: LFS = left front teat shape, LRS = left rear teat shape, RRS = right rear teat shape, AVETS = average teat score.

Linearly Measured Traits

Appendix Tables 19 to 23 present results of analyses of variance for right front teat length (RFL), left front teat length (LFL), left rear teat length (LRL), right rear teat length (RRL) and average teat length (AVETL). The effect of milk EPD was significant (P< .10) only for RRL. Breed of sire had no effect on any of these traits. Parity was not a source of variation for RFL (P>.13), RRL (P>.53), AVETL (P>.22) and LRL (P>.53), but affected LFL (P < .10). Calving group affected LRL and RRL (P<.05) but not LFL (P>.08), RFL (P>.12) and AVETL (P>.44). There was a calving group x parity interaction for RRL, RFL and LRL (P<.05).

Least square means for RFL, LFL, LRL, RRL and AVETL by calving group and parity are shown in Table 8. In the spring calving group, parity did not significantly affect any of these traits. However, in the fall calving group all measurements at parity two were greater ($P<.05$) than those at parity one.

TABLE 8 LEAST SQUARES MEANS (cm) WITH ASSOCIATED STANDARD ERRORS FOR TEAT LENGTH BY CALVING GROUP AND PARITY

	spring		fall	
trait	parity 1	parity 2	parity 1	parity 2
RFL	$1.74 \pm .06^{a}$	$1.69 \pm .09^{a}$	$1.46 \pm .09^{a}$	$1.74 \pm .06^{b}$
LFL	$1.70 \pm .06^{a}$	$1.64 \pm .11^{a}$	$1.42 \pm .09^{a}$	$1.77 \pm .06^{b}$
LRL	$1.47 \pm .07^{a}$	$1.31 \pm .11^{a}$	$1.44 \pm .09^{a}$	$1.71 \pm .07^{b}$
RRL	$1.46 \pm .06^{a}$	$1.34 \pm .11^{a}$	$1.45 \pm .09^{a}$	$1.77 \pm .07^{b}$
AVETL	$1.59 \pm .06^{a}$	$1.48 \pm .10^{a}$	$1.44 \pm .08^{a}$	$1.74 \pm .06^{b}$

* Trait for which interaction of parity and calving group was significant ($P<.1$).

List of acronyms : RFL = right front teat length, LFL = left front teat length, LRL = left rear teat length, RRL = right rear teat length, AVETL = average teat length.

a, b, means with different superscripts within subgroups in row are different ($P < .05$).

Analysis of variance results for diagonal distance (DIAG), distance between rear teats (DRT), distance between front teats (DFT) and total distance (TOTDIST) are shown in appendix Tables 24 and 25. Milk EPD group within breed affected ($P<.05$) all these traits with the exception of DIAG. Breed of sire of dam affected ($P < .10$) DRT. Parity was a source of variation for DIAG, DFT, TOTDIST ($P<.01$) and DRT ($P<.10$). Calving group affected TOTDIST and DIAG ($P<.05$), and DFT ($P<.01$), but not DRT ($P>.28$).

Least squares means for linearly measured traits by milk EPD group within breed of sire of dam are presented in Table 8. Results are different for Angus and Polled Hereford sired cows. In Angus measurements of distances between teats (DIAG, DRT, DFT and TOTDIST) on high milk EPD cows were greater (P<.05) than those on low milk EPD cows. In Polled Hereford-sired cows, milk EPD group did not affect (P>.10) distances between teats. Milk EPD group affected (P<.05) RRL in both breeds but in opposite directions. Cows sired by Angus bulls with high milk EPD had greater (P<.05) RRL than those with low milk EPD. In contrast, RRL of high milk EPD Polled Hereford sired cows was smaller (P<.05) than those of low milk EPD Polled Hereford-sired cows.

TABLE 9. LEAST SQUARES MEANS (cm) WITH ASSOCIATED STANDARD ERRORS FOR UDDER LINEARLY MEASURED TRAITS BY MILK EPD GROUP WITHIN BREED OF SIRE

	Breed and Milk EPD Group			
	Polled Hereford		Angus	
Characters	low	high	low	high
DIAG	5.55±.14[a]	5.51±.18[a]	5.24±.14[a]	5.76±.14[b]
DFT	6.03±.16[a]	5.92±.20[a]	5.66±.16[a]	6.32±.16[b]
DRT	3.77±.14[a]	3.73±.18[a]	3.07±.14[a]	3.74±.14[b]
LRL	1.72±.08[a]	1.43±.11[b]	1.29±.08[a]	1.50±.08[a]
TOTDIST	15.35±.40[a]	15.16±.50[a]	13.98±.40[a]	15.83±.40[b]
RRL	1.72±.08[a]	1.42±.10[b]	1.29±.08[a]	1.53±.08[b]
AVETL	1.74±.07[a]	1.56±.09[a]	1.44±.07a	1.51±.07[a]
LFL	1.76±.08[a]	1.67±.10[a]	1.60±.08[a]	1.50±.08[a]
RFL	1.74±.07[a]	1.72±.09[a]	1.58±.08[a]	1.59±.08[a]

[a, b] means with different superscripts within subgroups in a row differ(P < .05).

List of acronyms: DFT= distance between front teats, TOTDIST= total distances, DRT= distance between rear teats, DIAG= diagonal distance, RRL= right rear teat length, RFL= right front teat length, LRL= left rear teat length, LFL= left front teat length, AVETL= average teat length.

Association Among Milk Production and Udder Characteristics

Estimates of phenotypic correlations are presented in Table 10. Traits included MILKY, TOTDIST, AVETS, AVETL that were derived from various scores and measurements in addition to USS. TOTDIST (indicator of udder circumference, size or volume), AVETS, and USS were positively correlated ($P < .001$) with milk yield. The correlations ranged from .10 to .30. Correlations of TOTDIST/AVETL, AVETL/USS, TOTDIST/AVETS and AVETL/AVETS were not significant. Those of TOTDIST/ USS (.373) and USS/ AVETS (.529) were positive ($P<.001$). Milk yield and AVETL were not correlated ($P>.11$).

TABLE 10. POOLED PHENOTYPIC CORRELATIONS BETWEEN MILK YIELD, TOTAL DISTANCES, AVERAGE TEAT LENGTH, UDDER SUPPORT SYSTEM, AND AVERAGE TEAT SCORE

Characters	TOTDIST	AVETL	USS	AVETS	MILKY
TOTDIST	1.000	.089 NS	.373***	-.033 NS	.223***
AVETL		1.000	.0747NS	-.060NS	.097 NS
USS			1.000	.529***	.299***
AVETS				1.000	.217***

List of acronyms: TOTDIST = total distances, AVETL = average teat length, USS = udder support system, AVETS = average teat score, MLKY = milk yield.

NS = not significant ($P < .05$)
* * * $P < .001$

Repeatability Estimates

The repeatability estimates (Table 11) for linearly measured traits were moderate to high, ranging from .511 to .860. Estimates for the repeatabilities of scores were lower than those of dimensions. They were .217, .289, .343, .198 and .363 for RRS, LRS, FRS, LFS and AVETS, respectively. The repeatability estimate for milk yield between period 6 and 7 was .523.

TABLE 11. REPEATABILTY OF MEASUREMENTS AND SCORES FOR MILK YIELD AND UDDER TRAITS

TRAITS	N	REPEATABILITIES
Milk Yield	138	.523
Diagonal Distance	143	.820
Distance between Front Teats	143	.831
Distance between Rear Teats	143	.810
Total Distances	143	.860
Right Rear Teat Shape	143	.217
Right Rear Teat Length	142	.511
Left Rear Teat Shape	143	.289
Left Rear Teat Length	143	.529
Udder Support System	143	.559
Right Front Teat Shape	143	.343
Right Front Teat Length	143	.555
Left Front Teat Shape	143	.198
Left Front Teat Length	143	.528
Average Teat Score	143	.363
Average Teat Length	142	.576

CHAPTER V

DISCUSSION

Results obtained in Angus, where high milk EPD sired cows had 22.50% more milk yield than low milk EPD sired cows (9.47 kg vs 7.34 kg), are in agreement with previous reports with regard to the positive relationship between sire milk EPD and estimates of genetic potential for actual milk yield. In dairy cattle, Bertrand et al. (1985) investigated the difference between daughters of dairy sires selected for high and breed-average predicted difference milk. They reported that daughters of dairy sires with high predicted difference milk had 16% more milk than those of sires with average predicted difference milk. In beef cattle, reported residual correlations between sire milk EPD and daughters' milk yield range from .14 for Simmental, Angus and Polled Hereford-sired cows (Marshall et al., 1993) to .34 and .44 for Angus and Simmental, respectively (Marston et al., 1992). Diaz et al. (1992) reported a correlation of .26 between Milk EPD of Polled Hereford sires and actual milk yield of their crossbred daughters. Marston et al. (1990) reported that a 1kg increase in sire milk EPD resulted in an increase of 69.9±19.8 and 70.7±16.9 kg of total milk production in Angus and Simmental cows, respectively. Mallinckrodt et al.(1993) in a study that included Polled Hereford and Simmental indicated that milk EPD may be used to predict genetic difference in milk yield and calf weaning weight. Diaz et al. (1992) reported that the residual correlation between weaning weight and milk production was .64 and the corresponding correlation of residual weaning weight and milk EPD was .20. Buchanan et al. (1992), in an earlier report on the herd in the present study, indicated that calves of cows sired by high milk EPD bulls were heavier than their contemporaries born to cows sired by low milk EPD bulls.

Milk yield results (Table 5) obtained in Polled Hereford sired cows were rather unexpected. Contrary to the previously cited literature results and results in our Angus-sired cows, milk yield was not higher for cows sired by high milk EPD bulls than those sired by low milk EPD males. One reason for such a result may be the size of the sample for high milk EPD daughters versus that of low milk EPD daughters. A review of the numbers in Table 12 shows that in both calving groups the numbers of high milk EPD cows were much fewer than those of low milk EPD group. In total, the numbers of high and low milk EPD cows were 25 and 42, respectively. Diaz et al. (1992) conducted their study with equal numbers of sires and numbers of daughters for high and low milk EPD groups. Also, they used a range of sire milk EPD (-10 to 16 kg) that was greater than that used in the present study (-1.77 to 13.11 kg in Table 2) and reported an increase of about 1% more milk per kilogram of milk EPD. Because the present study did not indicate that sire milk EPD was clearly predictor of milk yield in the Hereford groups, results of measurements and scores have to be considered accordingly.

TABLE 12. NUMBER OF DAUGHTERS BY BREED OF SIRE, CALVING GROUP AND MILK EPD GROUP

	Spring		Fall	
Breed	low	high	low	high
Polled Hereford	21	13	21	12
Angus	19	18	22	14

While only a few studies have investigated the association between milk EPD of beef sires and actual milk production of their daughters, no known results of studies have been reported on udder characteristics in relation to sire milk EPDs. Results of the present study demonstrated that there was a calving group x parity x milk EPD group within breed interaction for RFS and USS in daughters of both Angus and Polled Hereford sires. For Angus-sired cows in the spring calving group at parity two, the high EPD group had less udder support than the low EPD group. This is in agreement with a report by Lin et al. (1987) in dairy cattle that multitrait estimates of genetic and phenotypic correlations between udder height and yield were all negative. Udder height was defined as the average distance from the floor to the point of attachment of all teats. Compared to the present study this was a measurement similar to udder support system. The suggestion was that as milk yield was increased, a poorer udder attachment was recorded . However an important difference between those dairy cows and beef cattle seems to be that of rate of growth or development of the mammary gland. In Angus sired cows of the present study, the high milk EPD group had less udder support only at parity 2 of the spring calving group. This may be associated with an incomplete development of mammary tissue of primiparous cows so that differences in potential for milk production were not yet fully expressed. Ziehe (1989) reported a lack of variability in udder support among first calf heifers due to breed of sire. In that study sire breed effect was significant in the second, third and forth parity. The same results could be expected with sire milk EPD effect.

With regard to the difference of effect of milk EPD group on USS or any other score / measurement in the fall and spring calving groups, no study was found to provide the basis for an explanation. However, reduced number of high milk EPD daughters (Table 12) associated with the absence of sire milk EPD effect on USS in the fall calving group (Table 6) should be noted.

For Polled Hereford-sired cows in the spring calving group, daughters of high milk EPD sires had greater udder support than low Milk EPD group. This was consistent with results obtained in Polled Hereford cows with regard to the effect of milk EPD group on milk yield .

Another unexpected result was that sire milk EPD did not influence RRS, LRS, LFS and AVETS (Table 7) in Angus. Moore al. (1981) reported that Holstein cows with cylindrical teats produced more total milk than cows with funnel teats. Frisch et al. (1982) indicated that of calves that survived to weaning, those born to cows with at least one bottle teat had heavier live weights at weaning than those born to cows without bottle teats. They indicated that bottle teats were associated with milk production.

In addition, results of the present study showed that distances between teats were influenced by sire milk EPD. In Angus, measurements greater on high milk EPD cows than low milk EPD cows were in agreement with results of other studies. In dairy cattle, Petersen et al. (1985) reported that daughters of high milk bulls had greater distance between teats, greater perimeter and larger areas of udder floor than daughters of low milk bulls. Tavildorova et al. (1961) reported that milk yield of cows with cup shaped udders exceeded that of cows with rounded udders. Round udders had smaller circumference and teats were closer together.

In the present study, the lack of a significant effect of sire milk EPD on distances between teats in Polled Hereford was not surprising in light of the result stated in regard to sire milk EPD and genetic potential for milk yield. It may have been for the same reason that RRL was influenced by sire milk EPD in both breeds but in opposite directions. Daughters of Angus sires with high milk EPD had greater RRL than those with low milk EPD. In contrast, cows sired by Polled Hereford bulls with high milk EPD had smaller RRL than those by low milk EPD sires.

An additional unexpected result was that sire milk EPD did not affect AVETL, LFL, and RFL in either breeds (Table 9). Frisch et al. (1982), in a study that involved Hereford and Harina cows, suggested lower milk production was associated with short teats. They reported that weaning weight of calves from cows with all teats less than 50 mm long had 5 kg lighter weights than those from cows with at least one teat greater 50 mm long. Tomar et al. (1973) indicated that correlation coefficients of the pooled data (

for parities) were positive and significant. These were 0.352 and 0.362 between fore and rear teat length, respectively, and milk yield of Harina cows. Qureshi et al.(1984) reported a correlation of 0.315 ($P < .05$) between teat length and milk yield when mean measurements for fore teat length and rear teat length were 7.85 cm and 7.15 cm, respectively. One reason for the lack of sire a milk EPD effect on AVETL, LFL and RFL may at priori be the narrow range of measurements considered in the present research. However, finding that RRL was affected by sire milk EPD leads to discarding the speculation about the range of the measurements.

In agreement with previous correlations studies between milk yield and udder characteristics, the present results underscored positive associations among milk production and udder traits. Fuhrer et al. (1961) indicated correlations between milk yield and udder circumference ($r = .599 \pm .096$) and volume ($r = .661 \pm .084$) in German Simmental cows. Brantov et al. (1965) suggested that milk yield on the day on which the udder was measured was correlated with udder circumference, length and width.

The present study included those udder and teat traits that were most descriptive of a beef cow's mammary system. TOTDIST (indicator of udder circumference, size or volume), AVETS, AVETL and USS were positively correlated with milk yield. The significant correlations ranging from .217 to .299 were very close to those presented (.20 to .3) by Petersen et al. (1985) as phenotypic correlations between milk yield and premilking udder dimensions in Holstein cows.

Doornbos et al. (1981) reported a significant positive udder size score/milk yield correlation of .46 at 130 to 150 days in lactation. At an earlier stage (30 to 50 days) the correlation estimate was .26. This indicates some significant effect of days in lactation on correlation estimates. In the present research the data analyzed were those of periods 6 and 7 corresponding to 185 to 213 days in lactation. It may be fair to suggest that different estimates of correlations would be obtained if the data had included earlier periods and the phenotypic correlations based on pooled data from various periods.

Estimate of repeatability for milk yield (.523) obtained in the present study was close to.55 reported by Williams et al. (1979) when milk yield of Hereford cows was estimated after 4 hrs separation time. The relatively high estimates of repeatabilty for linearly measured traits compared to those of scores may mean that the former involved less measurement errors. This coroborates that traits such as TOTDIST (r =.86) that were positively correlated with milk yield (Table 10) may be useful for selection for milk yield improvement.

CHAPTER VI

SUMMARY AND IMPLICATIONS

With the advent of mixed model methodologies, across herd selection has become more efficient than ever before. Best Linear Unbiased Prediction (BLUP) procedures have made it possible to make Expected Progeny Difference (EPD) values available to producers for most important economic traits. Among traits for which EPDs are available, sire milk EPD was the subject of many recent studies to assess its effect on various characters. The present study had two objectives. First, to evaluate the effect of high and low milk EPD sires on milk production, udder measurements and scores of their daughters. Second, to examine associations among milk production and udder characteristics. The usefulness of these associations between milk EPD and udder characteristics for the development of criteria for selection of bulls for milk yield based on measurements and scores on their daughters is relevant in instances were BLUP procedures are not yet applicable.

Data were collected during the fall of 1992 and spring 1993 on 143 lactating crossbred cows sired by high and low milk EPD sires of Angus and Polled Hereford breeds. Milk yield was estimated by the technique of weigh-suckle-weigh with a 6 hr separation time when cows were 185 to 213 days in lactation. Selected traits for scoring included udder support system and teat shape. Those linearly measured were teat length, distance between rear teats and diagonal distance between left front teat and right rear teat. Sire milk EPD effect on milk yield of daughters was different in cows sired by Angus and Polled Hereford bulls. In Angus, daughters of high milk EPD sires had greater milk yield than cows out of sires with low milk EPD. In Polled Hereford, sire milk EPD group was not indicative of milk yield in daughters. Despite a large range of sire milk EPD, milk yields for low and high milk EPD groups were not significantly different. Consequently, the usefullness of associating measurements and scores on Polled Hereford-sired cows with sire milk EPD group is questionable.

Calving group x parity x milk EPD group within breed interaction affected udder support and right front teat shape. In the spring calving group, for Angus-sired cows at parity 2, the high milk EPD group had less udder suport than the low EPD group. It is especially important to underline that if it is only from parity two that milk EPD group becomes a determinant factor in udder support then the value of udder support score as a useful trait in developing genetic prediction strategy could be reduced. Selection decisions would have to be delayed too long and make genetic progress slower. In addition, as results show significantly greater udder support score on daugthers of high milk EPD sires, a concern for developing poor attachment of the udder must be addressed before selection for high milk yield by this mean is considered.

Milk EPD group within breed influenced the right rear teat length, the diagonal distance between right front teat and left rear teat, the distance between rear teats, the distance between front teats and the total distances. Cows sired by high milk EPD Angus bulls had greater right rear teat length, rear teat distance, front teat distance, diagonal distance and total distances than daughters of Angus sires with low milk EPD. This makes these traits attractive in considering characteristics for selection aimed at improving milk production of beef cows. The total distances, a measurement that was highly repeatable, may particularly constitute a powerful indicator for udder circumference, size or volume that are highly correlated with milk yield but more difficult to measure.

Phenotypic correlations between milk yield and total distance, average teat length, average teat score and udder support score were positive. However, the relationship between milk yield and average teat length was not significant. The significantly positve correlations between udder traits and milk yield may imply that when sire milk EPDs are not available to make selection, those traits may be considered as indicator traits for milk production in beef cows. However, as this study did not include estimation of genotypic correlations and heritabilities, these parameters need to be investigated to completely assess the usefulness of udder traits for selection to improve milk yield. Another implication from this study is the confirmation that producers using Angus sires should be able accurately select bulls for maternal ability based on their milk EPD to improve weaning weights of beef calves.

Furthermore, in light of the difference of the effect of milk EPD group on udder dimensions and scores for the spring and fall calving group, more research would be recommended to provide an explanation about the causes of the differences between the calving groups in relation to udder and teat traits.

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Appendix

TABLE 13

ANALYSIS OF VARIANCE RESULTS FOR UDDER SUPPORT SYSTEM (USS)

Source of variance	df	Mean square
cg	1	19.86**
par	1	2.09*
bosd	1	2.58*
grp(bosd)	2	.82
cg*bosd	1	.54
par*bosd	1	.01
cg*par	1	1.05*
cg*grp(bosd)	2	.27
par*grp(bosd)	2	.56
cg*par*bosd	1	.79+
cg*par*grp(bosd)	2	.59+
sidd(par*grp*bosd)	22	.53**
residual	105	.21

coefficient of determination = .70

List of acronyms : sidd = sire of dam identification, cg = calving group, par = parity, grp = milk epd group, bosd = breed of sire of dam.

+=P<.10,*=P<.05,**=P<.01

TABLE 14

ANALYSIS OF VARIANCE RESULTS FOR LEFT FRONT TEAT SHAPE (LFS)

Source of variance	df	Mean square
cg	1	32.27**
par	1	.07
bosd	1	.03
grp(bosd)	2	.14
par*bosd	1	.21
cg*par	1	.31
sidd (par*grp*bosd)	24	.18
residual	111	.14

coefficient of determination = .74

List of acronyms : sidd = sire of dam identification, cg = calving group, par = parity, grp = milk epd group, bosd = breed of sire of dam.

**=P<.01

TABLE 15

ANALYSIS OF VARIANCE RESULTS FOR RIGHT FRONT TEAT SHAPE (RFS)

Source of variance	df	Mean square
cg	1	28.75**
par	1	.16
bosd	1	.03
grp(bosd)	2	.05
cg*par	1	.0002
cg*grp(bosd)	3	.02
par*grp(bosd)	3	.14
cg*par*grp(bosd)	3	.54*
sidd(par*grp*bosd)	22	.14
residual	105	.13

coefficient of determination = .82

List of acronyms : sidd = sire of dam identification, cg = calving group, par = parity, grp = milk epd group, bosd = breed of sire of dam.

*=P<.05,**=P<.01

TABLE 16

ANALYSIS OF VARIANCE RESULTS FOR LEFT REAR TEAT SHAPE (LRS)

Source of variance	df	Mean square
cg	1	30.30**
par	1	.22
bosd	1	.04
grp(bosd)	2	.43
cg*bosd	1	.21
cg*grp(bosd)	2	.42
sidd (par*grp*bosd)	25	.32
residual	109	.18

coefficient of determination = .75

List of acronyms : sidd = sire of dam identification, cg = calving group, par = parity, grp = milk epd group, bosd = breed of sire of dam.

*=P<.05,**=P<.01

TABLE 17

ANALYSIS OF VARIANCE RESULTS FOR RIGHT REAR TEAT SHAPE (RRS)

Source of variance	df	Mean square
cg	1	22.66**
par	1	.22
bosd	2	.003
grp(bosd)	1	.11
cg*bosd	1	.13
par*bosd	1	.77*
cg*par	1	.36+
cg*grp(bosd)	2	.15
par*grp(bosd)	2	.004
cg*par*bosd	1	.06
cg*par*grp(bosd)	2	.06
sidd (par*grp*bosd)	22	.18+
residual	105	.12
coefficient of determination = .79		

List of acronyms : sidd = sire of dam identification, cg = calving group, par = parity, grp = milk epd group, bosd = breed of sire of dam.

+=P<.10,*=P<.05, ** = P<.01

TABLE 18

ANALYSIS OF VARIANCE RESULTS FOR AVERAGE TEAT SCORE (AVETS)

Source of variance	df	Mean square
cg	1	34.36**
par	1	.0000085
bosd	1	.01
grp(bosd)	2	.24
sidd (par*grp*bosd)	25	.14+
residual	112	.09
coefficient of determination = .81		

List of acronyms : avets = average teat score, sidd = sire of dam identification, cg = calving group, par = parity, grp = milk epd group, bosd =breed of sire of dam.

+ = P<.1
* = P<.05
** = P<.01

TABLE 19

ANALYSIS OF VARIANCE RESULTS FOR RIGHT FRONT TEAT LENGTH (RFL)

Source of variance	df	Mean square
cg	1	.35
par	1	.23
bosd	1	.43
grp(bosd)	2	.001
cg*bosd	1	.00000037
par*bosd	1	.38
cg*par	1	.74*
sidd (par*grp*bosd)	24	.20+
residual	110	.14
coefficient of det.(R^2)	.37	

List of acronyms : sidd = sire of dam identification, cg = calving group, par = parity, grp = milk epd group, bosd = breed of sire of dam.

+=P<.10,*=P<.05,**=P<.01

TABLE 20

ANALYSIS OF VARIANCE RESULTS FOR LEFT FRONT TEAT LENGTH (LFL)

Source of variance	df	Mean square
cg	1	.10
par	1	.39+
bosd	1	.51
grp(bosd)	2	.08
cg*bosd	1	.04
par*bosd	1	.11
cg*par	1	.83
cg*grp(bosd)	2	.19
par*grp(bosd)	2	.03
cg*par*bosd	1	.15
cg*par*grp(bosd)	2	.37
sidd (par*grp*bosd)	22	.24*
residual	105	.13
coefficient of determination = .44		

List of acronyms:sidd=sire of dam identification, cg=calving group, par=parity, grp=milk epd group, bosd=breed of sire of dam.

+=P<.10,*=P<.05

TABLE 21

ANALYSIS OF VARIANCE RESULTS FOR LEFT REAR TEAT LENGTH (LRL)

Source of variance	df	Mean square
cg	1	.66*
par	1	.06
bosd	1	.59
grp(bosd)	2	.57
par*bosd	1	.40
cg*par	1	.95*
par*grp(bosd)	2	.0007
cg*par*grp(bosd)	3	.30
sidd (par*grp*bosd)	22	.23+
residual	105	.15
coefficient of determination = .44		

List of acronyms: sidd=sire of dam identification, cg=calving group, par = parity, grp = milk epd group, bosd = breed of sire of dam.

+=P<.10
*=P<.05

TABLE 22

ANALYSIS OF VARIANCE RESULTS FOR RIGHT REAR TEAT LENGTH (RRL)

Source of variance	df	Mean square
cg	1	.65*
par	1	.10
bosd	1	.47
grp(bosd)	2	.66+
par*bosd	1	.37
cg*par	1	.71*
cg*grp(bosd)	1	3.13
par*grp(bosd)	2	.002
cg*par*grp(bosd)	3	.25
sidd (par*grp*bosd)	22	.25*
residual	105	.14
coefficient of determination = .45		

List of acronyms : sidd = sire of dam identification, cg = calving group, par = parity, grp = milk epd group, bosd = breed of sire of dam.

+=P<.10
*=P<.05

TABLE 23

ANALYSIS OF VARIANCE RESULTS FOR AVERAGE TEAT LENGTH (AVETL)

Source of variance	df	Mean square
cg	1	.07
par	1	.17
bosd	1	.56
grp(bosd)	2	.17
par*bosd	1	.29
cg*par	1	.82*
cg*grp(bosd)	3	.10
par*grp(bosd)	2	.007
cg*par*grp(bosd)	3	.25+
sidd (par*grp*bosd)	22	.21*
residual	105	.11
coefficient of determination = .45		

List of acronyms : avetl = average teat length, sidd = sire of dam identification, cg = calving group, par = parity, grp = milk epd group, bosd = breed of sire of dam.

+ = P<.10
*=P<.05

TABLE 24

ANALYSIS OF VARIANCE RESULTS FOR DIAGONAL DISTANCE (DIAG), DISTANCE BETWEEN REAR AND FRONT TEATS (DRT) AND (DFT)

	DIAG		DRT		DFT	
Source of variance	df	MS	df	MS	df	MS
cg	1	2.55*	1	.007	1	6.39**
par	1	8.66**	1	1.33+	1	17.22**
bosd	1	.007	1	2.16+	1	.005
grp(bosd)	2	1.45	2	2.35*	2	2.32*
cg*par	1	.43	1	.61	1	.015
cg*grp(bosd)	3	.27	3	.26	3	.67
par*grp(bosd)	3	.28	3	.47	3	.04
cg*par*grp(bosd)	3	.53	3	.60	3	.71
sidd (par*grp*bosd)	22	.63+	22	.55	22	.71
residual	105	.42	105	.41	105	.52
coefficient of determinations:		.53		.46		.55

List of acronyms: sidd = sire of dam identification, cg = calving group, par = parity, grp = milk epd group, bosd = breed of sire of dam.

+=P<.10
*=P<.05
**=P<.01

TABLE 25

ANALYSIS OF VARIANCE RESULTS FOR TOTAL DISTANCES (TOTDIST)

Source of variance	df	Mean square
cg	1	16.34*
par	1	68.02**
bosd	1	2.19
grp(bosd)	2	18.12*
cg*par	1	2.44
cg*grp(bosd)	3	1.67
par*grp(bosd)	3	1.94
cg*par*grp(bosd)	3	4.66
sidd (par*grp*bosd)	22	4.23
residual	105	3.27
coefficient of determination = .52		

List of acronyms : TOTDIST = total distances, sidd =sire of dam identification, cg = calving group, par = parity, grp = milk EPD group, bosd = breed of sire of dam.

* = $P < .05$
** = $P < .01$

TABLE 26

LEAST SQUARES MEANS WITH ASSOCIATED STANDARD ERRORS FOR MILK YIELD (KG) BY CALVING GROUP , PARITY AND BY BREED OF SIRE OF DAM

	Calving group		Parity		Breed of sire of dam	
Traits	Spring	Fall	One	Two	Polled Hereford	Angus
Milk Yield	$8.92 \pm .44^{a}$	$6.20 \pm .45^{b}$	$6.82 \pm .49^{a}$	$8.30 \pm .47^{b}$	$6.72 \pm .48^{a}$	$8.41 \pm .45^{b}$

$^{a, b}$ means with different superscripts within subgroup in a row are different ($P < .05$) .

TABLE 27. LEAST SQUARES MEANS (kg) WITH ASSOCIATED STANDARD ERRORS FOR MILK YIELD BY PARITY AND BREED OF SIRE OF DAM

	Parity		Angus	
Trait	Polled Hereford	Angus	Polled Hereford	Angus
Milk Yield	6.55±.68[a]	7.10±.69[a]	6.88±.72[a]	9.71±.61[b]

a, b means with different superscripts within subgroups in a row differ(P <.05).

TABLE 28. LEAST SQUARES MEANS WITH ASSOCIATED STANDARD ERRORS FOR TEAT LENGTH AND DISTANCE (cm) BY CALVING GROUP

Characters	Spring	Fall
DIAG	5.69±.11[a]	5.34±.10[b]
DFT	6.27±.12[a]	5.70±.11[b]
DRT	3.57±.11[a]	3.59±.10[a]
LRL	1.39±.07[a]	1.57±.06[b]
TOTDIST	15.53±.31[a]	14.63±.27[b]
RRL	1.40±.06[a]	1.58±.06[b]
AVETL	1.53±.06[a]	1.59±.05[a]
LFL	1.67±.06[a]	1.60±.05[a]
RFL	1.71±.06[a]	1.60±.06[a]

a, b means within a trait not sharing a common superscript are different (P < .05).

List of acronyms: DFT=distance between front teat, TOTDIST=total distances, DRT=distance between rear teats, DIAG=diagonal distance, RRL=right rear teat length, RFL=right front teat length, LRL=left rear teat length, LFL=left front teat length, AVETL=average teat length.

TABLE 29. LEAST SQUARES MEANS WITH ASSOCIATED STANDARD ERRORS FOR TEAT SCORES BY CALVING GROUP

Characters	Spring	Fall
LFS	5.95±.06[a]	4.86±.06[b]
LRS	6.05±.06[a]	4.92±.06[b]
AVETS	6.00±.04[a]	4.88±.04[b]

a, b means within a trait not sharing a common superscript are different ($P < .05$).

List of acronyms: LFS = left front teat shape, LRS = letf rear teat shape, AVETS = average teat acore.

TABLE 30. LEAST SQUARES MEANS WITH ASSOCIATED STANDARD ERRORS FOR TEAT SCORES BY BREED OF SIRE OF DAM

Characters	Polled Hereford	Angus
LFS	5.39±.06[a]	5.42±.06[a]
LRS	5.50±.07[a]	5.48±.06[a]
AVETS	5.44±47[a]	5.44±.44[a]

a, b means with different superscripts within a row are different ($P <.05$).

List of acronyms:LFS=left front teat shape, LRS=left rear teat shape,AVETS=average teat score.

TABLE 31. LEAST SQUARES MEANS WITH ASSOCIATED STANDARD ERRORS FOR TEAT LENGTH AND DISTANCE (cm) BY BREED OF SIRE OF DAM

Characters	Polled Hereford	Angus
DIAG	$5.23 \pm .11^{a}$	$5.51 \pm .10^{a}$
DFT	$5.98 \pm .13^{a}$	$5.99 \pm .11^{a}$
DRT	$3.75 \pm .11^{a}$	$3.41 \pm .10^{b}$
LRL	$1.57 \pm .08^{a}$	$1.39 \pm .06^{b}$
TOTDIST	$15.25 \pm .32^{a}$	$14.90 \pm .28^{a}$
RRL	$1.57 \pm .06^{a}$	$1.41 \pm .06^{a}$
AVETL	$1.65 \pm .06^{a}$	$1.47 \pm .05^{b}$

a, b means within a trait not sharing a common superscript are different ($P < .05$).

Linearly measured traits: DFT=distance between front teat, TOTDIST=total distances, DRT=distance between rear teats, DIAG=diagonal distance, RRL=right rear teat length, LRL=left rear teat length, AVETL=average teat length.

TABLE 32. LEAST SQUARES MEANS WITH ASSOCIATED STANDARD ERRORS FOR TEAT LENGTH AND DISTANCE (cm)AND FOR TEAT SCORES BY PARITY

Characters	Parity1	Parity2
DIAG	$5.17 \pm .11^{a}$	$5.86 \pm .11^{b}$
DFT	$5.50 \pm .12^{a}$	$6.47 \pm .12^{b}$
DRT	$3.44 \pm .11^{a}$	$3.71 \pm .11^{a}$
TOTDIST	$14.12 \pm .30^{a}$	$16.04 \pm .30^{b}$
LRS	$5.54 \pm .07^{a}$	$5.44 \pm .07^{a}$
AVETS	$5.44 \pm .05^{a}$	$5.44 \pm .05^{a}$

$^{a, b}$ means within a trait not sharing a common superscript are different (P<.05).

List of acronyms: DFT=distance between front teat, TOTDIST=total distances, DRT=distance between rear teats, DIAG=diagonal distance, LFL=left front teat length, LRS=left rear teat shape, AVETS = average teat score.

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