EVALUATION OF UDDER AND TEAT CHARACTERISTICS, CALF GROWTH, AND REPRODUCTION IN YOUNG *Bos indicus – Bos taurus* COWS

A Thesis

by

CODY JACK GLADNEY

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2008

Major Subject: Animal Breeding

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Approved by:

Chair of Committee, Andy D. Herring
Committee Members, Clare A. Gill
James O. Sanders
Head of Department, Gary R. Acuff

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ABSTRACT

Evaluation of Udder and Teat Characteristics, Calf Growth, and Reproduction in Young *Bos indicus* – *Bos taurus* Cows. (August 2008)

Cody Jack Gladney, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Andy D. Herring

Sire and family effects were evaluated for calf growth, udder and teat conformation, and reproduction traits in 2- to 4- yr-old cows from the McGregor Genomics Project. Cows were produced by embryo transfer (ET) and natural service (NS) from the same 4 F_1 Nellore-Angus sires, and were analyzed separately. Sire of cow was significant for calf birth weight (P = 0.014) among ET cows, but not NS cows. Among NS families, calves from cows out of Brahman-Hereford dams were 2.0 kg heavier (P = 0.064) at birth than calves from cows out of Brahman-Angus dams. Sire of cow accounted for variation in weaning weight (P = 0.006) and preweaning ADG (P = 0.005) of calves from ET dams, but not NS dams. Family nested within sire also accounted for variation (P = 0.061) in weaning weights of calves from ET dams. Sire of cow was significant for average teat length in ET (P < 0.001) and NS (P = 0.013) cows. Sire of cow was significant for average teat diameter (P = 0.022) among NS cows. Sire of cow also affected udder support score (P = 0.002), cow disposition at calf birth (P = 0.002), and cow weight at weaning (P = 0.045) in ET cows. Family and cow age also accounted for variation in cow disposition at calf birth (P = 0.015, P = 0.041,

respectively) and cow weight at weaning ($P = 0.001$, $P < .001$, respectively) among ET cows. Calf year of birth also affected ($P < .001$) cow weight at weaning among ET cows. For NS dams, calf year of birth ($P = 0.012$), cow age ($P < .001$), and parity nested within cow age ($P = 0.005$) affected cow weight at weaning. Although reproduction data were not formally analyzed, there appear to be substantial differences for calving rate and average calving date among these cow families. Data from this project will be used for identification of genetic markers for these cow productivity traits.

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INTRODUCTION

Udder conformation and milking ability are essential characteristics in regard to calf survival, growth, and cow longevity. However, not much research about udder conformation differences among families or lines has been reported. Milking ability is essential in maintaining an economically productive cow herd, and the amount of milk a dam is able to produce for her calf affects the preweaning growth of that calf. However, if the dam produces a lot of milk, but has poor conformation of her udder and teats, then she may not be able to stay in the herd for a long period of time. Beef cows in many breeds are recognized to be at the peak level of calf production from the ages of 5 to 10 years. Many producers believe that udder size relates to milk production and therefore weaning weights of calves.

There is evidence of genetic differences for milk production within breeds, and milking ability has been reported to be a moderately heritable trait at around 0.35 (Fuerst-Waltl et al., 1998). There is also evidence for breed differences in udder conformation, and there seems to be a tendency for *Bos indicus* influenced cows to have udder and teat problems (Cartwright, 1980). Cows with Brahman influence tend to have more pendulous udders with larger teats that can affect the calf's ability to nurse (Wythe, 1970).

Calf growth characteristics such as birth weight, weaning weight, and average daily gain are all very important to producers. Producers want to have herds that have

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low birth weight so that the amount of dystocia within the herd can be minimal. However, calves with increased weaning weights are more economically advantageous to the producer. In order to have both desirable birth weight and weaning weight, there has to be a relatively high amount of preweaning growth or a larger average daily gain. This is directly influenced by the cow's milking; however, the calf's growth ability is also a function of its growth potential, which is also related to the size of the cow. Cow weight is important to the producer as larger cows need more supplementation to maintain their body condition. The more that a producer has to supplement his cattle, the more money he is going to have to spend that could be used for other improvements.

Cow disposition is also a factor that influences the worth of the cow to the producer. Cows with more aggressive or flighty dispositions are more difficult to handle and possibly could be a detriment to the producer's or the health of others, and ease of handling may be highly valuable to many producers. However, it is not well understood how cow disposition (temperament) relates to other production traits.

Cow fertility and reproduction are very important to commercial beef herds. Cow fertility and reproduction are typically measured through calf crop born and calf crop weaned percentage. It is economically essential to have cows that can get pregnant, carry the pregnancy to full term, have a live calf, and then raise that calf to weaning. The cow's purpose does not end there as it is just as important that the cow be able to breed back in the time after parturition, while she is still raising a calf. The goal of the producer is to have cows that can give them a calf once a year, every year, for many years.

This research is focused on determining the effect that sire of the cow, breed of the cow's dam, and family has on udder characteristics, calf size and reproduction of young *Bos indicus* – *Bos taurus* crossbred cows produced in the McGregor Genomics Project. The eventual goal of this project is to identify genetic markers for these important cow productivity traits. This research will be useful in evaluating maternal value in regard to cow reproduction, calf growth and longevity characteristics.

The objectives of this project were: (1) investigate differences in udder conformation characteristics within and across cow family lines, (2) study calf growth differences within and across cow family lines, (3) evaluate correlations among udder, cow disposition, and calf growth traits, and (4) conduct a preliminary analysis for female reproduction in young cows within and across family lines.

LITERATURE REVIEW

This literature review will encompass different aspects of beef cow productivity, including udder and teat conformation, cow reproduction, calf growth, and calf survival, with particular emphasis on *Bos indicus* and *Bos indicus*/*Bos taurus* crossbred females.

Riley et al. (2001a) evaluated 116 F_1 cows sired by Angus, Gray Brahman, Gir, Indu-Brazil, Nellore, and Red Brahman bulls and from Hereford dams for reproductive performance and cow weight and height. The authors also evaluated their calves for birth and weaning weight. The heifers were bred as long yearlings to calve in the spring as 2.5 years of age to Charolais bulls. The occurrence of dystocia in 2 yr old first calf heifers for Angus cross heifers was 50.3%, higher ($P < 0.10$) than that of the other sire groups except Gray Brahman crossbred cows (19.7%). Nellore crossbreds had the lowest occurrence of dystocia (4.8%) among all the sire groups. The cows were also evaluated for pregnancy rate, calf crop born, calf survival rate, and calf crop weaned by cow age and sire breed of cow. In comparing the 2, 3, and 4 yr old females, the 3-yr-old Nellore and Red Brahman-sired cows had a 100.0% pregnancy rate and the 3-yr-old Angus-sired cows had the lowest at 79.8%. Over the whole 14-yr period that the cows were evaluated, the Nellore crossbred cows had the highest pregnancy rate at 97.0%, and the lowest belonged to the Angus-sired cows at 87.4%. Among the cows aged 2, 3, and 4 for calf crop born the 3-yr-old, Angus-sired cows had the lowest at 78.6%. Nellore-sired crossbred cows for the ages of 2, 3, and 4 had calf crop born percentages of 95.7, 96.0, and 99.8%, respectively. Throughout the whole study the Nellore-sired cows ranked the highest for calf crop born percentage (97.1%) and the Angus sired cows ranked the lowest (86.7%). For calf survival rate cows 2 yr of age typically had the lowest across all sire types. The lowest calf survival rates were from the 2-yr-old Angus-, Gray Brahman-, and Red Brahman-sired cows (73.3, 70.1, and 71.4%, respectively). The 2 and 3 year old cows sired by Nellore had least squares mean calf survival rates of 100.1 and 100%. Overall, the Nellore-sired cows had the highest calf survival rate among all breeds at 98.9%. Angus-sired cows had a calf crop weaned percentage as 3 yr olds of 71.5%. The 2 yr old Angus- and Red Brahman-sired cows had calf crop weaned percentages at 73.3 and 71.4%. The 2, 3, and 4 yr old Nellore-sired cows had calf crop weaned percentages of 95.8, 96.0, and 95.7%, respectively.

Cundiff (2005) reviewed data for 8,484 calves produced in the Germplasm Evaluation Program at the U.S. Meat Animal Research Center in Clay Center, Nebraska. The author compared tropically adapted sire breeds including Nellore, Longhorn, Brahman, Boran, Tuli, Beefmaster, Brangus, Bonsmara, and Romosinuano for growth and reproductive traits. Calves from the *Bos indicus* sire breeds Nellore, Brahman, and Boran had longer gestation lengths than all the other sire breeds. Also Nellore-, Boran-, and Brahman-sired animals ranked the highest (least desireable) for calving difficulty. The heaviest birth weight calves were sired by Brahman and Nellore bulls at 44.4 and 42.8 kg, respectively. Brahman-sired calves ranked the worst for survival to weaning at 88.1%, but Nellore-sired calves had a 95.5% survival to weaning. Calves out of Beefmaster bulls ranked the highest for weaning weight at 248.2 kg. The calves out of Brahman and Nellore sires had weaning weights of 246.4 and 243.6 kg, respectively. The author also analyzed the reproductive and maternal performance of F_1 cross females producing their first calves at 2 years of age. The F_1 females from Brahman sires ranked the lowest for calf crop born percentage (74.3%) and calf crop weaned percentage (64.5%). Females from Nellore sires had a calf crop born percentage of 90.0% and a calf crop weaned percentage of 72.9%. Females from Brangus sires had a calf crop born percentage of 90.4% and the females from Beefmaster sires had 95.8%. Percent calf crop weaned from Brangus sired females was 87.4% and from Beefmaster sired females was 88.5%. From 2 year old F_1 cross females the calves from Brahman and Nellore sires were the heaviest at 205 days (215.0 and 214.1 kg); however, for 205 day weaning weight per cow exposed calves sired by Brahman ranked the lowest at 140 kg. Comparatively, the F_1 females from Beefmaster sires had a 205 day weaning weight per cow exposed of 185.9 kg.

Sanders et al. (2005) evaluated cow reproduction and maternal traits in herd of Brahman, Angus, Nellore, Hereford, and crosses involving those breeds for heterosis and heterosis retention, although not all of the crosses were reported in this paper. The comparison herds were made up of a minimum of 50 cows in each of 14 different groups (4 purebred, three F_1, two F_2, 2 first generation groups of 3/8 *Bos indicus*/ 5/8 British breeding, 2 second generation 3/8 *Bos indicus*/ 5/8 British breeding, and 1 four-breed crossbred group). The cow breed groups included in the analysis were the purebred Angus (A), Brahman (B), and Hereford (H) groups as well as the F_1 BA, F_1 BH, F_1 HB, F_2 AB x BA, F_2 BA x BA, F_2 BH x BH, F_2 HB x HB, F_2 BH x HB, and F_2 HB x BH groups. The cow breed groups were analyzed for calf crop born, calf crop weaned, calf survival, and weaning weight of calf. The calf breeds presented in the paper were purebred Brahman and Hereford, F_1 HB, F_1 BH, F_2 BH x BH, F_2 HB x HB, F_2 BH x HB, F_2 HB x BH, $F_{2.5}$BH (BH x F_2 BH), and 2 four breed crosses (F_1 Nellore-Angus x F_1 Brahman-Hereford and F_1 Nellore-Angus x F_2 Brahman-Hereford). Calf breed groups were analyzed for calf survival and weaning weight. The authors found that the F_1 Brahman-Angus females ranked the highest for calf crop born at 0.90 among crossbred groups. The F_2 Brahman-Angus females ranked the lowest for calf crop born at 0.74. The F_1 and F_2 Brahman-Hereford females had calf crop born rates of 0.89 and 0.87, respectively. Similar results were seen for calf crop weaned with the F_1 Brahman-Angus and F_1 Brahman-Hereford ranking the highest at 0.82. The calf crop weaned rate for the F_2 Brahman-Angus was the lowest in the evaluation at 0.64. The F_2 Brahman-Angus females had a calf survival rate of 0.85. The calves out of F_1 Brahman-Hereford cows weighed 233.1 kg at weaning. For breed of calf, the calf survival rate of the 4 breed crossbred (Brahman, Angus, Nellore, Hereford) calves ranked among the lowest for crossbred animals at 0.89 out of F_1 Brahman-Hereford cows and 0.93 out of F_2 Brahman-Hereford cows. The 4 breed crossbred calves out of F_1 Brahman-Hereford cows ranked the heaviest for weight at weaning at 239.1 kg. For 4-year-old cows, the F_1 Brahman-Angus and F_2 Brahman-Hereford cows were the heaviest at 534.5 and 544.7 kg, respectively. The lightest 4-year-old cows were from the F_2 Brahman-Angus breed group. The authors concluded that more heterosis was lost in the F_2 Brahman-Angus cows than was predicted, yet more was retained in F_2 Brahman-Hereford cows than predicted, relative to breed heterozygosity (dominance model).

Brahman have been reported to have worse udders than many other beef cattle breeds. Cartwright (1980) stated that the Brahman cattle are known to have more malformed teats and udders than those of other beef breeds. Riley et al. (2001b) evaluated postpartum udder characteristics, aged cow mouth condition scores, and cow survival, longevity, and productivity through 15 yr of age on 116 F_1 cows in central Texas. One conclusion that could be made from this study was that the size, overall condition, and health of the cow's udder greatly affected the survival and growth characteristics of her calves. The study compared Angus-, Gray Brahman-, Gir-, Indu-Brazil-, Nellore-, and Red Brahman-sired cows, all out of Hereford dams. The authors concluded that the crossbred cows sired by Nellore had smaller postpartum teat length than all the other crossbred groups and smaller postpartum teat diameter than Indu-Brazil and Red Brahman crossbreds. The Nellore-sired cows also had larger udder support scores (less pendulous udders) than Indu-Brazil and Red Brahman crossbreds. Nellore crossbred cows had the highest percentage (60%) of cows remaining in the herd at the end of the 15 yr study. The authors maintained that this could have been due at least in part to the overall better condition of their udders. Of the 116 cows that were evaluated, 22.4% were removed because of udder problems, including structural problems, such as excessively large teats or udders, injured or diseased udders, inadequate milk production or combinations of these factors. This was the second largest reason for culling in the study behind reproductive failure. In this study cows were removed for reproductive failure when they failed to wean a calf for the second time. This study mainly concentrated on *Bos indicus* breed differences and the resulting productivity of F_1 *Bos indicus* x Hereford cows in central Texas.

Bailey et al. (1988) analyzed reproductive traits and preweaning growth from *Bos taurus* and *Bos indicus* x *Bos taurus* breed types from four calf crops. The breed types that were used were from young Hereford, Red Poll, Hereford x Red Poll, Red Poll x Hereford, Angus x Hereford, Angus x Charolais, Brahman x Hereford, and Brahman x Angus dams. For pregnancy rate the Brahman x Hereford and Brahman x Angus dams ranked the highest at 0.96 and 0.94, respectively. Similar results were seen for calf crop born with Brahman x Hereford and Brahman x Angus ranking the highest at 0.91. Brahman x Hereford dams ranked the highest for calf crop weaned at 0.88. Brahman x Angus dams had a calf crop weaned rate of 0.82. Brahman x Hereford and Brahman x Angus dams ranked the lowest for birth weight among the breed groups at 33.5 and 30.8 kg. Brahman x Hereford dams had calves with a weaning weight of 213.6 kg which was 9.4 kg more than the Brahman x Angus dams (204.2 kg).

Frisch (1982) analyzed the effect of bottle teats on calf pre-weaning growth and weaning weight in Queensland, Australia. Measurements were taken on 892 cows for teat length and diameter within 2 d of calving from 8 different breeding lines. The lines of cattle used were grade Brahman and Africander, F_4+ generations of Hereford x Shorthorn (HS), Brahman x HS (BX) and Africander x HS (AX), and F_1 and F_2 generations of AX x BX. The grade Brahman and Africander cows were from ¾ to purebred *Bos indicus*. In addition, data were collected from commercial lines of Herefords and F_1 Sahiwal x Hereford. Teats with a diameter greater than or equal to 35 mm were classified as bottle teats. Frisch found that calves born to cows with 4 bottle teats had much higher mortality rates between calving and 2 mo of age ($P < 0.001$). Also, cows with 4 bottle teats had calves that were significantly lighter 2 d after birth ($P < 0.01$). However, at weaning calves out of cows with no bottle teats had the lightest calves ($P < 0.01$), and calves out of cows with 4 bottle teats were the heaviest at weaning. This is assumed to be because cows with bottle teats had higher milk production. Among lines, the F_1 Sahiwal x Hereford and F_4+ generations of Brahman x Hereford/Shorthorn had the highest proportion of bottle teats and also had the highest mortality rates up to 2 mo of age. It is also important to note that the 7 cows in this study that had both 4 bottle teats and pendulous udders had calves that were not able to nurse and that were dead within a few days of birth. It was decided that teat diameter was a more important factor than teat length in the ability of the calf to nurse. However, an optimum range for teat length was established. Calves from cows with all 4 teats less than or equal to 50 mm long averaged 139 kg, which was 5 kg less ($P < 0.05$) than those from cows with at least one teat being longer than 50 mm. Cows with at least one teat longer than 90 mm had a calf mortality rate of 0.230, which was significantly higher ($P < 0.01$) than that for calves born to cows with 4 teats shorter than 90 mm (0.078).

Riley et al. (2004) evaluated calf vigor at birth (n = 3,253) and preweaning mortality (n = 3,631) due to proportion Brahman inheritance, cow age, dystocia, and birth date weather from a Brahman herd at the Subtropical Agricultural Research Station in Central Florida. Riley et al. (2004) discussed that possibly the structure and quality of the dam's udder was one of the most important age-dependent factors affecting calf mortality and referred to the work of Wythe (1970) and Edwards (1982). Wythe (1970) stated that any deviation from correct teats and udder results in a sharp decrease in nursing ability. Edwards (1982) noted that the udder conformation of the dam was the most important factor determining the time to first suckling in dairy calves. Riley et al. (2004) stated that notes were taken associated with calving records, and found that in 41 of the 392 calf deaths and in 46 of the 378 calves with poor calf vigor, the cows had poor udders or teats.

Meyer et al. (1994) evaluated milk production in beef cows in Australia and how it related to the growth of their calves. Using Polled Hereford and an Australian multi-breed, Wokalup, they identified strong correlations between direct effects for milk yield and maternal effects for weaning weight. They concluded that the main factor that determined maternal effects on growth of calves is milk production. They also stated that through selection for direct genetic effects for growth and improved maternal performance, overall growth can be significantly improved in beef cattle. However, they did not look at milk production or other maternal differences within families nor did they mention if dam's daughters' records were used in the study. Also, they did not report udder support scores or teat length/diameter to determine if the quality of the udder had anything to do with the amount of milk the cow can provide the calf.

Rohrer et al. (1988) analyzed productive longevity, mean life span, and reasons for removal from the herd in 498 cows of 15 breed-types in Texas. The 498 cows were produced in a five-breed diallel (reciprocals pooled together) involving Angus, Brahman, Hereford, Holstein, and Jersey. Cows were removed from this study based on

10 categories: reproductive failure, calving difficulty, experimental culling, mammary problems, structurally unsound, severe prolapse, general illness, cancer eye, nutritional abnormalities, and unknown causes. In this study, mammary-related problems were defined as removal due to severe mastitis or a nonfunctional udder. No cows were culled based on teat shape alone, and neonatal calves from cows with large, pendulous udders received assistance for a few days to promote nursing. Cows culled due to mammary problems accounted for 9.6% of the cows in the study. Mammary problems began to become important reasons for removal at around 5 yr of age and continued to have increasing importance as age increased.

MacNeil and Mott (2006) used Line 1 Hereford cattle maintained by the USDA-ARS at Miles City, Montana to evaluate variation in calf gain from birth to weaning, milk production, and udder score of cows. Udder score was assessed subjectively and scored on a 1-9 scale using a pictorial reference provided by the American Hereford Association. This study estimated heritability for udder score to be 0.23 ± 0.05. They found the correlation between maternal preweaning gain and weigh-suckle-weigh milk production to be 0.80 ± 0.08. They also found a negative correlation (-0.36 ± 0.16) between weigh-suckle-weigh milk production and udder score indicating that smaller, tighter udders tended to produce less milk. They concluded that selection purely for increasing maternal preweaning gain or milk production may not be the correct thing to do as it could lead to degradation of udder quality and conformation.

Sapp et al. (2004) used udder score data from the first parity of 9,418 Gelbvieh cows in conjunction with calf growth data from the first through third parities from these cows to evaluate the relationship of teat and udder suspensory score with calf growth traits. Birth weight, weaning weight, and yearling weight of the calves were measured. Cows included in this study had to be at least 50% Gelbvieh, have given birth to only one calf, be 4 yr of age or younger, and not have other teat and udder score records within 280 d of their first calf. Teat score was evaluated on a subjective scale of 0 (very large) to 50 (very small). Udder suspensory score was subjectively scaled from 0 (very pendulous) to 50 (very tight). They found that these 2 traits were very highly genetically correlated (0.95). The authors also reported the heritabilities of teat score (0.27 ± 0.005) and udder suspensory score (0.22 ± 0.003). The genetic correlations of teat and suspensory score with direct weaning gain were 0.38 and 0.31, respectively. The correlations between teat and suspensory score with maternal weaning gain were -0.47 and -0.55, respectively. These correlations between teat and udder suspensory score with direct weaning gain indicate that cows with larger, more pendulous udders tend to raise calves with more genetic growth potential for preweaning gain. The genetic correlation between direct and maternal preweaning ADG was -0.35, and it should be noted that this could be forcing a positive correlation between the udder observations and direct effects on growth. However, they also stated that even though these cows produce more milk than those cows with smaller teats and tighter udders, their calves may have trouble accessing the milk which could result in lesser growth than expected. The authors also maintained that cows with very small, tight udders might produce too little milk and it would be best to select cows with intermediate sized udders and teats. This study only really evaluated the correlations between udder and teat score and growth characteristics of the calves. It did not evaluate actual gain and growth averages of the calves. Also, the teat and udder support scores were subjectively evaluated by hundreds of producers all over the nation. No measurements were taken by trained evaluators.

Fuerst-Waltl et al. (1998) evaluated genetic relationships between 305 d milk yield and 17 type traits in first-lactation Holsteins. They used a total of 24,470 dam-daughter records and found a quadratic relationship between milk yield and front teat placement, fore udder attachment, udder depth, and final score. They estimated similar heritabilities for milk yield (0.34 ± 0.0089 and 0.36 ± 0.0042), teat length (0.23 and 0.25) and udder depth (0.25 and 0.31) by offspring-parent regression and paternal halfsib analysis, respectively. The authors did not report SE on individual type trait heritabilities, but stated that the SE ranged from 0.0092 to 0.012 with offspring-parent regression and 0.0026 to 0.0058 with halfsib analysis. Further research in beef cattle using first and more lactation records could be very beneficial to the industry in determining the relationships between milk and udder characteristics and other type traits.

Montaño-Bermudez and Nielsen (1990) allocated cattle into 3 different groups based on expected milking ability according to breed. The low milking group was Hereford x Angus cows, the medium group was Red Poll x Angus cows, and the high group was Milking Shorthorn x Angus cows. Females were bred to their respective sire breed (Hereford, Red Poll, or Milking Shorthorn) at one yr of age to produce backcross calves. Females were then bred to Charolais bulls at 2+ yr of age to produce terminalcross calves. All the cows were fairly similar in growth and mature size. The cows were also sorted by age at breeding into the categories 1, 2, or 3+. They found that no matter the age at breeding, the cows in the highest milking group produced the heaviest calves at weaning. Also, the older the cow at breeding, regardless of milking group, the heavier the calf at weaning. The authors did not discuss anything about udder or teat conformation, and it appeared that calf growth was not an in-depth topic of the study. Furthermore, heritability and cow's daughters' reproductive traits were not discussed. This study was mainly focused on the energy requirements of the 3 milking groups and their calves.

Fiss and Wilton (1992) used various breeds of beef cattle in 4 different breeding systems over an 8 yr period to determine associations of cow weight and milk yield with other characteristics within the different breeding systems. Records were kept on 216 cows with 469 calvings and on 183 first-calf heifers. The cattle were divided into one of 4 breeding systems: Hereford, small rotation, large rotation, and Angus-large rotation. The Hereford group was made up of straightbred Hereford cattle. The small rotation group had Angus, Gelbvieh, Pinzgauer, and Tarentaise. The large rotation group was composed of Charolais, Maine-Anjou, and Simmental. The Angus-large rotation group consisted of animals from Angus sires on large rotation heifers. They found breed differences for weight of cow at weaning, milk yield, milk fat percentage, feed intake, and pregnancy rate. Similarly, they found that as cow weight increased so did cow condition, milk yield, and feed intake within all the breeding systems. However, Hereford cows usually had different associations between weight and other traits than the crossbreds. For milk yield, the Herefords had a negative association with cow weight that was significantly different than the other breeding systems, which the authors contribute to a unique breed characteristic. They believe this breed effect to be due to the physical capacity of the animals or the greater condition of the heavier Hereford cows. They did not see any differences ($P > 0.05$) among breeding systems in association between feed intake and weight or feed intake and milk yield, and believed that this was due to the cows all being fed to production requirements. Measurements were kept mainly on cows, and no growth characteristics for calves were incorporated. Also, nothing was stated as to the condition of the cow's udders or teats.

Ventorp and Michanek (1992) studied the importance of udder and teat conformation on teat-seeking in newborn calves in 42 Swedish Holstein cow-calf pairs; 14 were first-calf heifers, 14 with their second calf, and 14 had calved for at least the third time. They found that cows with smaller, less pendulous teats had calves that had significantly lower amounts of time spent searching for the first suckle. They concluded that calves from cows with "low slung" or more pendulous udders cannot be expected to obtain colostrum soon enough by natural suckling. This concept would be expected to hold true in beef calves as well, but it has not been directly reported in the literature. The authors had previously stated that the effect of parity on time of the first suckle varied among different studies. The relationship between udder and other reproductive characteristics, including growth potential of calves, in cows and their daughters needs to be studied further.

Selman et al. (1970) recorded the behavior of 30 calves during the first 8 h postpartum. Dams were sorted into 2 categories of “good-shaped” and “poor-shaped” according to udder conformation. The dams were also divided into beef cows, dairy heifers, and dairy cows. They evaluated behavior of calves prior to standing and to teat-seeking activities. In analyzing teat-seeking activities the authors compared calves born from cows with good udder shape and those calves from cows with poor udder shape for mean first suckling time. First suckling time was measured from the time the calves first stood to when the calves found the teats of the cows and began to suck. The authors found that cows with good udders had a significantly ($P < 0.02$) lower mean first suckling time than those with poor udders (17.1 vs. 39.6 minutes). Also, the time from when the calf hit the ground to the time of the calf's first suckle, was significantly ($P < 0.01$) lower for calves from dams with good udders (79.4 minutes) than those calves born to dams with poor udders (220.1 minutes). The authors also determined that the mean time taken by calves to first suckle was significantly faster ($P < 0.01$) for calves out of beef cows than the other 2 groups. The authors did not conclude but this could be attributed to the fact that dairy udders tended to be more pendulous making it harder for calves to find the teats.

Day et al. (1987) performed 2 experiments to determine the effect of level of milk production on suckling behavior. The first experiment used 6 Hereford x Angus and 5 Milking Shorthorn x Angus cows and their calves and for the second experiment the authors used 10 Herefod x Angus and 10 Milking Shorthorn x Angus cow from the herd in the first experiment. In the first experiment, suckling behavior was observed at 3 stages of lactation (averaging 52, 104, and 167 d postpartum). At each stage the 11 cow-calf pairs were observed for two 24 h periods separated by 24 h without observation. In the second experiment 10 cow-calf pairs were evaluated much the same as in the first study. In this experiment, however, the pairs were observed for only one 24 h period and at an average of 17, 38, 59, and 80 d postpartum. The results from the first experiment indicated that as stage of lactation progressed, the frequency of nursing and total minutes nursed declined significantly ($P < 0.05$). The duration of nursing period did not change significantly, but tended to increase in length as stage of lactation increased. The authors found significant interactions between frequency of nursing and milk production ($P < 0.03$) and frequency of nursing and total minutes nursed ($P < 0.10$). Similar results were found in the second experiment with frequency of nursing and total minutes nursed declining as lactation progressed and the duration of nursing did not change. The frequency of nursing significantly ($P < 0.01$) declined as the milk production level increased but the interaction of production level with stage of lactation was not significant ($P > 0.10$). The authors did, however, find a significant interaction between milk production level and total minutes nursed ($P < 0.10$).

Based on the review of this literature, it is evident that substantial genetic influences exist for udder and teat characteristics in cattle, and that udder conformation is related to cow longevity and calf performance. It is also widely documented that *Bos indicus-Bos taurus* crossbred cows are highly productive especially as F_1 crosses. The objectives of this thesis were: (1) investigate differences in udder conformation characteristics within and across cow family lines, (2) study calf growth differences within and across cow family lines, (3) evaluate correlations among udder, cow disposition, and calf growth traits, and (4) conduct a preliminary analysis for female reproduction in young cows within and across family lines.

MATERIALS AND METHODS

This study involved data collected from cows and calves at the Texas A&M University Agricultural Research Center at McGregor in the McGregor Genomics Project. All procedures involving animals were approved by the Texas A&M University Institutional Animal Care and Use Committee (AUP # 2002-116 and 2005-147). The calves in this study were born in the Spring 2005, Spring 2006, and Spring 2007 seasons. There were available data on 255 calves: 22 spring-born 2005 calves from first parity cows, 76 spring-born 2006 calves from first and second parity cows, and 157 spring-born 2007 calves from first, second, and third parity cows. Some of the dams were born in the fall calving seasons, but only the fall-born females that failed to breed as 2-yr-olds and first calved at 2.5-yr are included in these analyses along with the spring-born females. Calves were out of 177 different cows that were born from 2003 to 2005. Of the 255 calves, 134 were female and 121 were male. A total of 168 calves were out of first parity cows, 70 calves came from second parity cows, and 17 calves were from third parity cows.

Cows were daughters of 4 different sires and belonged to one of 17 families. All 4 sires of the cows in the study were F_1 Nellore-Angus. The cows in family numbers 70 to 77 and 80 to 84 were all produced by embryo transfer and are full siblings to the others in their family. The dams of those cows were F_1 Nellore-Angus. Females were born at McGregor, except for 10 of the 2003-born cows which came from the Texas A&M Agricultural Research Center at Angleton. Cows in families 95 to 98 were all produced via natural service from the same 4 sires as the embryo transfer cows and are half siblings to the others in their families. The dams of those cows were either half Brahman and half Angus, or half Brahman and half Hereford. The dams were also either of the F_1 or F_2 generation. A list of calves by sire of the dam and family number is given in Table 1. The full sib (embryo transfer) dams were responsible for 164 of the calves born from 2005 to 2007 and the half sib (natural service) dams had 91 of those calves. A list of calves sorted by dam type, parity, and sex is given in Table 2. The cows were all bred via natural service to Angus sires to produce the 255 calves from 2005 to 2007.

All calves were born in the spring calving season (mid-February through late April) from 2005 through early 2007. The calves were weaned in early to mid-October of the same year. All calves, females and males, were then sold or removed from the herd.

Heifers that were to become cows in this project were mostly born in the spring calving season with the exception of embryo transfer females that were born in the fall calving seasons of 2003 and 2004. In the summer of 2004, all of the spring-born 2003 heifers were separated and kept together in a group. In the spring of 2005, the fall-born 2003 heifers were added to the group. In the summer of 2005, all of the 2003 cows were kept together with the 2004 spring-born heifers. In the spring of 2006, the fall 2004 heifers were added to the single group. In the spring of 2006, the 2003 cows were all kept together along with some other cows that were not in the Genomics project. The spring- and fall-born 2004 cows and heifers were kept together in a single group. The spring 2005 heifers were also kept together in a single group. In the spring of 2007, the

Table 1. Number of calves born by year, sire of dam, and family

Sire	Family	Calving Year		
		2005	2006	2007
297J	70	1	5	7
	71	2	6	12
	95	1	8	11
432H	72	2	9	11
	73	0	2	1
	82	0	0	2
	96	6	11	32
437J	74	3	2	3
	75	3	4	10
	81	0	7	11
	83	0	2	13
	97	0	2	4
551G	76	0	2	1
	77	0	5	12
	80	0	5	13
	84	0	0	8
	98	4	6	6
Total		22	76	157

Table 2. Number of calves born by parity, sex, and type of dam

Dam Type	Parity	Female	Male	n
Full sibs	1	52	57	109
	2	26	21	47
	3	4	4	8
				164
Half sibs	1	35	24	59
	2	14	9	23
	3	3	6	9
				91
Total		134	121	255

2003 cows were kept together separately from the 2004 cows and the 2005 cows and heifers. The 2006 heifers were also kept separate.

Cows were kept on various warm season pastures including coastal bermuda, Eastern Gama grass, Kleingrass, and native pastures. In the spring and summer they were supplemented with mineral and salt. In the winter they were supplemented with coastal bermuda hay or sudan hybrid hay.

At birth, cows and calves were evaluated for several different traits including calving ease, calf vigor, birth weight measured to the nearest lb (0.45 kg), udder support scores, teat length and diameter, body condition scores for cows, and disposition (temperament) scores. These traits, with the exception of birth weight, were subjectively evaluated by trained TAMU personnel at the McGregor research center. Calving data were generally recorded within 24 hr postpartum. Calving ease was scored in a range of 1 to 5 with 1 being easy and 5 being very difficult. Calf vigor ranged from 1 (very little to no vigor) to 5 (very vigorous). Udder support scores ranged from 1 to 9 with 1 being very loose and pendulous and 9 being very tight. Udder support relates to the degree and strength of the front and rear udder attachment. Body condition score is a subjective estimate with a range from 1 to 9 with 1 being extremely thin and 9 being obese. Disposition was scored on a 1 to 5 scale with 1 being calm and 5 being very nervous, wild, or crazy. In addition, all 4 teat lengths and diameters were individually recorded as subjective estimates from a single evaluator. The diameter and length were measured on the first few cows and then estimated to the nearest 1/8 inch (0.3175 cm) on the remaining cows. Teat diameter was taken at the midpoint of the teat. Teat length was estimated between the upper and lower extremity of the teat. On many cows the point at which the udder stops and the teat begins in not easy to determine but every effort was made to be consistent in what was considered the upper extremity of the teat.

At weaning, the weights of both the calves and the cows were recorded to the nearest lb (0.45 kg), as well as body condition scores and palpation scores. Palpation score was based on how many months bred the individual cow was estimated to be.

The embryo transfer and natural service dams were analyzed separately. Effects that were included in the final analysis of calves out of embryo transfer dams were sire of cow, calf sex x sire of cow interaction, family nested within sire of cow, calf sex, calf year of birth, cow age, and parity nested within cow age. Effects that were included in the final analysis of calves out of natural service dams included sire of cow, calf sex x sire of cow interaction, breed of the cow's dam, calf sex, calf year of birth, cow age, and parity nested within cow age. Regression on Julian birthday of the calf within calf year of birth was included for the analyses of birth weight, average teat length, average teat diameter, udder support score, and disposition score in both embryo transfer and natural service cows. Regression on calf weaning age in days was included for weaning weight of calf and cow weight at weaning for both types of cows as well. Pearson correlations among all traits were also evaluated within each cow type. Not all possible separations of least squares means were performed across families due to differing observation numbers, however Fisher's least significant differences (LSD) values were calculated for 5, 10 and 15 observations per family based on 80 df and α of 0.10 when a significant F-test was observed.

Analyses for heifer and cow reproduction measures of calving rate, calving date, and weaning rate were not formally conducted. Simple means for these traits were calculated across sires, families and cow age and were evaluated for apparent trends, but no mean separations were conducted.

RESULTS AND DISCUSSION

Simple means for traits in the analyses including birth weight, weaning weight, preweaning average daily gain, average teat length, average teat diameter, udder support score, cow disposition score at weaning, cow body condition score at weaning, and calf body condition score at weaning are shown in Table 3 for embryo transfer and Table 4 for natural service families. The results are presented by trait of study. The *P*-values from the analyses of variance are presented in Table 5 for embryo transfer, full sib families and Table 6 for natural service, half sib families.

Birth Weight

Sire of Cow. Substantial differences ($P = 0.014$) in birth weight were seen due to sire of cow among calves from embryo transfer cows. The heaviest weights belonged to calves out of daughters of 551G (31.7 kg), whereas the lightest calves were from daughters of 432H (27.3 kg). This can be attributed to the fact that two of the families sired by 432H (73 and 82) have a small number of calves with low birth weights. Further analysis of the least squares means (Table 7) showed that calves from sire 551G were heavier than the 3 other sires ($P < 0.10$).

In calves born to dams produced by natural service, sire of cow was not found to be a significant effect. The least squares means (Table 8) show calves from 437J daughters to rank the heaviest for birth weight (28.7 kg) with daughters of 551G ranking the second heaviest (27.6 kg), 432H the third heaviest (27.1 kg), and 297J the lightest (26.3 kg). One consideration that should be taken into account is that daughters of 437J

Table 3. Simple means for traits measured among full sib (embryo transfer) families

Trait[1]	Mean	Standard Deviation	Minimum	Maximum
BWT	29.90	4.49	18.64	42.73
WWT	193.86	28.33	118.64	268.18
ADG	0.75	0.10	0.47	1.00
AVTL	3.01	0.63	1.68	5.72
AVTD	1.81	0.26	1.27	2.86
USUP	6.88	0.47	6.00	8.00
DISP	2.49	1.23	1.00	5.00
CW	432.81	50.69	322.73	577.27
CowBCS	5.29	0.50	4.00	7.00
CalfBCS	5.03	0.21	4.00	6.00

[1] BWT = Birth weight (kg), WWT = Weaning weight (kg), ADG = Average daily gain (kg/d), AVTL = Average teat length (cm), AVTD = Average teat diameter (cm), USUP = Udder support score, DISP = Disposition score, , CW = Cow weight at weaning (kg), CowBCS = Cow body condition score at weaning, CalfBCS = Calf body condition score at weaning

Table 4. Simple means for traits measured among half sib (natural service) families

Trait[1]	Mean	Standard Deviation	Minimum	Maximum
BWT	28.34	4.44	17.27	38.18
WWT	185.81	27.28	124.55	252.73
ADG	0.75	0.10	0.49	0.99
AVTL	3.21	0.83	1.51	6.67
AVTD	1.87	0.36	1.43	3.81
USUP	6.66	0.62	5.00	9.00
DISP	2.00	1.05	1.00	5.00
CW	437.93	60.40	340.00	677.27
CowBCS	5.27	0.44	5.00	6.00
CalfBCS	5.02	0.15	5.00	6.00

[1] BWT = Birth weight (kg), WWT = Weaning weight (kg), ADG = Average daily gain (kg/d), AVTL = Average teat length (cm), AVTD = Average teat diameter (cm), USUP = Udder support score, DISP = Disposition score, , CW = Cow weight at weaning (kg), CowBCS = Cow body condition score at weaning, CalfBCS = Calf body condition score at weaning

Table 5. *P*-values and variance estimates for traits associated in calves from full sib (embryo transfer) cow families

Effect	Trait[1]							
	BWT	WWT	ADG	AVTL	AVTD	USUP	DISP	CW
Sire of cow	0.014	0.006	0.005	<0.001	0.314	0.002	0.002	0.045
Calf sex x sire of cow	0.881	0.213	0.165	0.682	0.860	0.637	0.308	0.803
Family(sire of cow)	0.420	0.061	0.032	0.132	0.838	0.482	0.015	0.001
Calf sex	0.025	0.024	0.074	0.738	0.235	0.272	0.418	0.486
Calf year of birth	0.068	0.001	0.000	0.443	0.160	0.622	0.800	<0.001
Cow age	0.006	0.313	0.259	0.241	0.018	0.127	0.041	<0.001
Parity(cow age)	0.361	0.104	0.156	0.816	0.116	0.821	0.683	0.007
Julian birthday(calf year of birth)	0.001	.	.	0.399	0.139	0.873	0.682	.
Calf weaning age	.	<0.001	0.084	.	.	.	.	0.452
Dam(family x sire)	1.594	342.920	0.007	0.158	0.037	0.041	0.684	856.080
Residual	13.641	130.660	0.002	0.173	0.030	0.151	0.516	160.720

[1] BWT = Birth weight of calf, WWT = Weaning weight of calf, ADG = Average daily gain, AVTL = Average teat length, AVTD = Average teat diameter, USUP = Udder support score, DISP = Disposition score, CW = Cow weight at weaning

Table 6. *P*-values and variance estimates for traits associated in calves from half sib (natural service) cow families

	Trait[1]							
Effect	BWT	WWT	ADG	AVTL	AVTD	USUP	DISP	CW
Sire of cow	0.632	0.448	0.381	0.013	0.022	0.212	0.536	0.186
Calf sex x sire of cow	0.017	0.426	0.868	0.262	0.580	0.867	0.152	0.330
Breed of cow's dam	0.064	0.293	0.171	0.633	0.962	0.392	0.648	0.847
Calf sex	0.075	0.005	0.009	0.742	0.863	0.770	0.667	0.510
Calf year of birth	0.624	0.599	0.399	0.343	0.833	0.379	0.354	0.012
Cow age	0.261	0.651	0.715	0.331	0.075	0.863	0.249	<0.001
Parity(cow age)	0.852	0.042	0.057	0.708	0.211	0.781	0.333	0.005
Julian birthday(calf year of birth)	0.026	.	.	0.147	0.257	0.373	0.476	.
Calf weaning age	.	<0.001	0.444	.	.	.	.	0.892
Dam(sire)	4.182	354.760	0.007	0.530	0.054	0.115	0.588	1024.820
Residual	9.067	164.160	0.004	0.090	0.056	0.271	0.444	238.170

[1] BWT = Birth weight of calf, WWT = Weaning weight of calf, ADG = Average daily gain, AVTL = Average teat length, AVTD = Average teat diameter, USUP = Udder support score, DISP = Disposition score, CW = Cow weight at weaning

Table 7. Least squares means and standard errors of birth weight, weaning weight, and average daily gain in calves among full sib (embryo transfer) cow families for calf sex and family effects

Effect		n	BWT[1]	n	WWT[1]	n	ADG[1]
Sire of cow							
	297J	33	29.1 ± 0.9[a]	32	209.1 ± 6.2[a]	32	0.83 ± 0.03[a]
	432H	27	27.3 ± 1.5[a]	26	175.7 ± 9.0[b]	26	0.69 ± 0.04[b]
	437J	58	28.9 ± 0.9[a]	55	197.6 ± 5.8[cd]	55	0.78 ± 0.02[c]
	551G	46	31.7 ± 1.1[b]	44	200.6 ± 7.0[ad]	44	0.78 ± 0.03[ac]
Calf sex x sire of cow							
	F 297J	16	28.0 ± 1.2	15	203.2 ± 7.1	15	0.81 ± 0.03
	F 432H	9	26.7 ± 1.9	9	169.7 ± 10.0	9	0.67 ± 0.04
	F 437J	35	28.4 ± 0.9	33	198.8 ± 6.1	33	0.79 ± 0.03
	F 551G	22	30.8 ± 1.2	21	198.0 ± 7.5	21	0.78 ± 0.03
	M 297J	17	30.2 ± 1.1	17	215.1 ± 6.6	17	0.86 ± 0.03
	M 432H	18	27.9 ± 1.5	17	181.6 ± 9.0	17	0.71 ± 0.04
	M 437J	23	29.3 ± 1.1	22	196.4 ± 6.5	22	0.77 ± 0.03
	M 551G	24	32.7 ± 1.3	23	203.2 ± 7.5	23	0.79 ± 0.03
Family(sire of cow)							
	70 297J	13	30.1 ± 1.3	12	213.5 ± 9.4	12	0.85 ± 0.04
	71 297J	20	28.1 ± 1.1	20	204.8 ±7.1	20	0.82 ± 0.03
	72 432H	22	28.3 ± 1.1	22	201.9 ± 7.3	22	0.80 ± 0.03
	73 432H	3	27.4 ± 2.6	2	174.6 ± 16.5	2	0.69 ± 0.07
	82 432H	2	26.0 ± 3.0	2	150.5 ± 17.4	2	0.58 ± 0.07
	74 437J	8	29.1 ± 1.6	8	215.1 ± 11.8	8	0.86 ± 0.05
	75 437J	17	26.9 ± 1.2	16	195.3 ± 7.8	16	0.78 ± 0.03
	81 437J	18	29.0 ± 1.3	18	199.3 ± 8.0	18	0.79 ± 0.03
	83 437J	15	30.5 ± 1.5	13	180.8 ± 9.5	13	0.69 ± 0.04
	76 551G	3	30.8 ± 2.5	3	207.2 ± 15.5	3	0.82 ± 0.07
	77 551G	17	31.7 ± 1.3	17	196.9 ± 8.1	17	0.77 ± 0.03
	80 551G	18	31.2 ± 1.3	17	198.0 ± 7.8	17	0.78 ± 0.03
	84 551G	8	33.2 ± 1.8	7	200.3 ± 11.1	7	0.77 ± 0.05
Calf sex							
	Female	82	28.5 ± 0.9[a]	78	192.4 ± 5.3[a]	78	0.76 ± 0.02[a]
	Male	82	30.0 ± 0.8[b]	79	199.1 ± 5.2[b]	79	0.78 ± 0.02[b]

[a,b,c] Means in the same column without a common superscript differ ($P < 0.10$).

[1] BWT = Birth weight of calf (kg), WWT = Weaning weight of calf (kg), ADG = Average daily gain (kg/d).

Table 8. Least squares means and standard errors of birth weight, weaning weight, and average daily gain in calves among half sib (natural service) cow families for calf gender and genetic considerations

Effect	n	BWT[1]	n	WWT[1]	n	ADG[1]
Sire of cow						
297J	20	26.3 ± 1.4	19	193.3 ± 9.5	19	0.79 ± 0.04
432H	48	27.1 ± 1.4	46	188.1 ± 9.2	46	0.76 ± 0.04
437J	6	28.7 ± 2.1	5	207.3 ± 14.5	5	0.86 ± 0.06
551G	15	27.6 ± 1.4	16	192.2 ± 9.9	15	0.78 ± 0.04
Calf sex x sire of cow						
F 297J	11	27.6 ± 1.7[ab]	10	191.8 ± 10.4	10	0.77 ± 0.05
F 432H	29	25.5 ± 1.4[b]	28	179.7 ± 9.3	28	0.73 ± 0.04
F 437J	4	28.4 ± 2.3[ab]	3	197.5 ± 15.8	3	0.81 ± 0.07
F 551G	8	24.4 ± 1.8[b]	8	180.1 ± 11.1	8	0.74 ± 0.05
M 297J	9	25.0 ± 1.8[b]	9	194.8 ± 10.8	9	0.81 ± 0.05
M 432H	19	28.6 ± 1.5[a]	18	196.5 ± 10.0	18	0.80 ± 0.04
M 437J	2	29.0 ± 2.9[ab]	2	217.2 ± 17.4	2	0.90 ± 0.08
M 551G	7	30.9 ± 1.7[a]	8	204.4 ± 10.5	7	0.82 ± 0.05
Breed of cow's dam						
Brahman-Angus	26	26.4 ± 1.6[a]	26	199.0 ± 10.3	26	0.82 ± 0.05
Brahman-Hereford	63	28.4 ± 1.1[b]	60	191.5 ± 7.6	60	0.78 ± 0.03
Calf sex						
Female	52	26.5 ± 1.3[a]	49	187.3 ± 8.6[a]	49	0.76 ± 0.04[a]
Male	37	28.4 ± 1.4[b]	37	203.2 ± 8.8[b]	37	0.83 ± 0.04[b]

[a,b] Means in the same column without a common superscript differ ($P < 0.10$).

[1] BWT = Birth weight of calf (kg), WWT = Weaning weight of calf (kg), ADG = Average daily gain (kg/d).

had only 6 calves as compared with daughters of 432H who had 48. Cundiff (2005) reported that Nellore-sired calves (42.8 kg) weighed significantly ($P < .05$) less than those sired by Brahman (44.4 kg) in Nebraska.

Calf Sex by Sire of Cow Interaction. The calf sex by sire of cow interaction was not significant in calves out of embryo transfer cows born. However, it might be noted that the heaviest birth weights of both types of cows were from male calves born to sire 551G, with calves from embryo transfer cows weighing 32.7 kg and those from natural service dams weighing 30.9 kg.

The calf sex by sire of cow interaction was important in calves born to natural service dams ($P = 0.017$). Least squares means of the 8 different calf sex by sire of cow combinations are located in Table 8. In these calves, female calves out cows sired by 551G (24.4 kg) and male calves out of cows sired by 297J (25.0 kg) had the smallest birth weights whereas, similar to calves from embryo transfer cows, male calves out of cows sired by 551G had the heaviest birth weights (30.9 kg). It should be noted that the heifer calves were heavier than the bull calves out of daughters of 297J (27.6 vs. 25.0 kg).

Family Nested within Sire of Cow. For calves out of embryo transfer dams, family nested within sire was not significant for calf birth weight. The least squares means are shown in Table 7 for completeness.

Calf Sex. Differences in birth weight were observed due to calf sex in calves with embryo transfer dams ($P = 0.025$). The least squares means in Table 7 show that male calves weighed 1.5 kg more than the female calves. A similar result was seen in calves from natural service dams. Table 8 shows that male calves were 1.9 kg heavier at birth than females ($P = 0.075$).

Calf Year of Birth. The effect of calf year of birth was found to affect birth weight ($P < 0.068$) for calves out of embryo transfer dams. However, when looking at the least squares means in Table 9 there is no particular year that is significantly different from another. Calves born in 2007 ranked the heaviest at 30.1 kg, followed by calves born in 2006 at 29.3 kg, and calves born in 2005 ranked the lightest at 28.3 kg.

Calf year of birth was not found to be a significant effect on birth weight in calves born to calves out of natural service dams. However, the same trend was seen in Table 10 in these calves as those out of embryo transfer dams. Calves born in 2007 ranked heaviest at 29.0 kg, calves born in 2006 weighed 27.6 kg, and those born in 2005 weighed 25.7 kg at birth.

Cow Age. The age of the cow affected birth weight in calves out of embryo transfer dams ($P = 0.006$). The least squares means are shown in Table 9. Calves out of 3-yr-old cows had the heaviest birth weights (31.7 kg). Somewhat surprisingly, however, calves out of 3.5 year old calves were the lightest (26.8 kg). The age of cow did not affect birth weight for calves out of natural service dams, however, calves out of 3-yr-old cows ranked the heaviest (29.5 kg).

Parity Nested within Cow Age. Parity nested within cow age was not found to be a significant effect on birth weight for calves out of either embryo transfer or natural service dams. However, the least squares means (Tables 9 and 10) show somewhat similar results for calves from both types of cows where calves out of 3-yr-old dams

Table 9. Least squares means and standard errors of birth weight, weaning weight, and average daily gain in calves among full sib (embryo transfer) cow families for year, cow age, and parity

Effect		n	BWT[1]	n	WWT[1]	n	ADG[1]
Calf year of birth							
	2005	11	28.3 ± 1.6	11	201.9 ± 9.4[a]	11	0.80 ± 0.04[a]
	2006	49	29.3 ± 0.9	46	186.8 ± 5.2[b]	46	0.73 ± 0.02[b]
	2007	104	30.1 ± 0.5	100	198.5 ± 3.0[a]	100	0.78 ± 0.01[a]
Cow age							
	2	70	28.1 ± 0.6[a]	65	186.2 ± 3.6	65	0.73 ± 0.02
	2.5	32	29.8 ± 1.0[bc]	31	193.6 ± 5.2	31	0.76 ± 0.02
	3	37	31.7 ± 1.2[bd]	36	197.9 ± 6.7	36	0.77 ± 0.03
	3.5	13	26.8 ± 1.4[a]	13	201.2 ± 7.9	13	0.81 ± 0.03
	4	12	29.7 ± 1.7[acd]	12	199.9 ± 9.8	12	0.79 ± 0.04
Parity(cow age)							
	1 2	70	28.1 ± 0.6	65	186.2 ± 3.6	65	0.74 ± 0.02
	1 2.5	32	29.8 ± 1.0	31	193.6 ± 5.2	31	0.76 ± 0.02
	1 3	7	32.4 ± 1.8	6	207.5 ± 9.8	6	0.80 ± 0.04
	2 3	30	31.0 ± 1.1	30	188.3 ± 6.1	30	0.73 ± 0.03
	2 3.5	13	26.8 ± 1.4	13	201.2 ± 7.9	13	0.81 ± 0.03
	2 4	4	31.3 ± 2.3	4	205.3 ± 11.5	4	0.81 ± 0.05
	3 4	8	28.2 ± 1.8	8	194.4 ± 10.2	8	0.77 ± 0.04

[a,b,c,d] Means in the same column without a common superscript differ ($P < 0.10$).

[1] BWT = Birth weight of calf (kg), WWT = Weaning weight of calf (kg), ADG = Average daily gain (kg/d).

Table 10. Least squares means and standard errors of birth weight, weaning weight, and average daily gain in calves among half sib (natural service) cow families for year, cow age, and parity

Effect		n	BWT[1]	n	WWT[1]	n	ADG[1]
Calf year of birth							
	2005	11	25.7 ± 2.0	11	201.3 ± 12.8	11	0.83 ± 0.06
	2006	27	27.6 ± 1.3	27	193.7 ± 8.6	27	0.79 ± 0.04
	2007	51	29.0 ± 1.0	48	190.7 ± 6.5	48	0.77 ± 0.03
Cow age							
	2	56	27.6 ± 0.7	54	192.3 ± 4.5	54	0.78 ± 0.02
	3	24	29.5 ± 1.8	22	203.6 ± 13.8	22	0.83 ± 0.06
	4	9	25.1 ± 2.4	10	189.8 ± 14.1	9	0.79 ± 0.06
Parity(cow age)							
	1 2	56	27.6 ± 0.7	54	192.3 ± 4.5[a]	54	0.78 ± 0.02[a]
	1 3	2	30.3 ± 3.1	1	209.7 ± 25.0[ac]	1	0.86 ± 0.11[ac]
	2 3	22	28.7 ± 1.2	21	197.4 ± 7.7[a]	21	0.80 ± 0.03[a]
	2 4	1	24.7 ± 4.0	1	165.3 ± 20.8[a]	1	0.67 ± 0.10[a]
	3 4	8	25.6 ± 1.8	9	214.4 ± 11.8[bc]	8	0.90 ± 0.05[bc]

[a,b,c] Means in the same column without a common superscript differ ($P < 0.10$).

[1] BWT = Birth weight of calf (kg), WWT = Weaning weight of calf (kg), ADG = Average daily gain (kg/d).

with their first parity were the heaviest, 32.4 kg and 30.3 kg, respectively. The lightest birth weights out of the full sib families were from 3.5-yr-old cows with their second calf (26.8 kg). The lightest calves from the half sib families were from 4 year old cows with their second calf (24.7 kg), but this number could be skewed as there is only information about birth weight from one animal. It should be noted that for both the embryo transfer and natural service families, females that skipped a calf, 3-yr-old with 1 parity, and 4 yr of age with 2 parities, had heavier calves than the 3-yr-old females in their second parity and the 4-yr-old cows with their third parity (except for the 4-yr-old with her second parity in the natural service families). In the embryo transfer females, the 3-yr-old females with their first parity had calves that weighed 32.4 kg compared to the 3-yr-old females with their second parity at 31.0 kg. Likewise, the 4-yr-old cows with their second calf had birth weights of 31.3 kg versus 28.2 kg for the 4-yr-old females in their third parity. For the natural service families, the 3-yr-old calves with their first parity had calves that weighed 30.3 kg at birth, compared to 28.7 kg for the 3-yr-old females with their second calf.

Breed of Cow's Dam. The breed of the cow's dam affected (P = 0.064) birth weight of calves from natural service dams. Calves out of cows that were half Brahman, half Hereford were 2.0 kg heavier at birth (28.4 kg) than those out of cows that were half Brahman, half Angus (26.4 kg) as shown in Table 8. Bailey et al. (1988) reported similar results. Calves out of Brahman-Hereford F_1 dams had birth weights of 33.5 kg which was 2.7 kg more than calves out of Brahman-Angus F_1 dams (30.8 kg).

Regression on Julian Birthday within Calf Year of Birth. The regression on Julian birthday within calf year of birth was important ($P = 0.012$) for those calves born to dams produced by embryo transfer. It was found to be highly influential in 2006 ($P < 0.01$) at 0.11 ± 0.03 kg/d, but not in 2005 (0.01 ± 0.06 kg/d) or 2007 (0.02 ± 0.03 kg/d).

The regression on Julian birthday within calf year of birth was also important ($P = 0.026$) for the calves out of natural service cows. It was influential for the years 2006 and 2007 ($P < 0.10$) at 0.07 ± 0.04 and 0.08 ± 0.03 kg/d, respectively, but not for 2005 (0.09 ± 0.06 kg/d).

Weaning Weight

Sire of Cow. Differences ($P = 0.006$) in weaning weight were seen due to the sire of cow for embryo transfer cows. The least squares means are shown in Table 7. The calves out of cows from sire 297J had the heaviest weaning weights at 209.1 kg and were significantly different from daughters of 432H and 437J. Calves from daughters of 551G and 437J were not different from each other with weaning weights of 200.6 kg and 197.6 kg, respectively. The sire whose daughters had the lightest calves at weaning was 432H at 175.7kg. Daughters of 432H had calves that were lighter at weaning than all the other cows' sires ($P < 0.10$). As with birth weight, this can be attributed to the fact that two of the families from sire 432H (73 and 82) had small numbers of calves.

The sire of cow was not a significant effect for weaning weights of calves out of half sib cow families. Out of the 4 sires, 432H daughters ranked the lightest in calf weaning weight at 188.1 kg (Table 8), similarly as in full sib cow families.

Calf Sex by Sire of Cow Interaction. Calf sex by sire of cow interaction was not a significant effect in either calves born to dams produced by embryo transfer or natural service. However, in both types of cows, female calves out of 432H daughters were the lightest at weaning. Also in the embryo transfer families, the female calves from daughters of 437J (198.8 kg) weighed 2.4 kg more than the male calves (196.4 kg). Least squares means are in Tables 7 and 8.

Family Nested within Sire of Cow. There were differences (P = 0.061) due to family nested within sire of cow for weaning weight of calves in the full sib families. The least squares means for family nested within sire are shown in Table 7. Two of the families from sire 432H (82 at 150.5 kg and 73 at 174.6 kg) were the lightest at weaning of all the families, but these families only had 2 calves in each. Family 74 produced by sire 437J had the heaviest calves at weaning for all families at 215.1 kg. Family 70 (sired by 297J) ranked second for weaning weight at 213.5 kg. All possible separations of least squares mean were not performed; however, the least significant difference (LSD) comparing two families with 5 observations each would be approximately 12.03 kg, with 10 observations would be approximately 8.51 kg, and the LSD value for comparing two families with 15 observations would be approximately 6.95 kg.

Calf Sex. Calf sex had an impact on weaning weight for calves born in the full sib cow families (P = 0.024; Table 7), with a 6.7 kg difference between male and female calves at weaning (199.1 kg vs. 192.4 kg).

Calf sex was also important for weaning weight of calves born to families with dams produced by natural service (P = 0.005). Table 8 shows that male calves weighed 203.2 kg at weaning as compared to 187.3 kg for female calves, a difference of 15.9 kg.

Calf Year of Birth. Calf year of birth affected (P = 0.001) weaning weights of calves out of cows produced by embryo transfer. Least squares means for calf year of birth on weaning weight can be found in Tables 9 and 10. Calves born in 2005 and 2007 were significantly heavier at weaning (201.9 kg and 198.5 kg) than calves born in 2006 (P < 0.10) for embryo transfer families.

For calves born to cow families produced via natural service, calf year of birth was not significant; however, calves born in 2005 ranked the heaviest in terms of weaning weight (201.3 kg).

Cow Age. Cow age did not affect weaning weight among either the calves from full sib or half sib families. The trend among the least squares means (Tables 9 and 10) was that the older animals, 3, 3.5, and 4 yr old dams, tended to have calves with heavier weaning weights in both types of families.

Parity Nested within Cow Age. The effect of parity nested within cow age was not significant on weaning weight in calves out of dams that were produced via embryo transfer. However, for 3-yr-old females with their first parity had calves that weighed 207.5 kg at weaning. The 3-yr-old females with their second parity had calves that weighed 188.3 kg at weaning. Similarly, the 4-yr-old cows with their second parity had calves that weighed 205.3 kg at weaning, which was 10.9 kg more than the 4-yr-old cows with their third parity (188.3 kg). This is similar to birth weight as the females with a skip in calving had heavier calf weaning weights.

Parity nested within cow age was not significant for weaning weight in calves out of natural service cows. Table 10 shows the heaviest ranking calves at weaning came from 4-yr-old cows with their third calf (214.4 kg), but the lightest ranking came from the 4-yr-old cow with her second calf (165.3 kg). The 3-yr-old females in their second parity had calves that weighed 12.3 kg less at weaning (197.4 kg) than did 3-yr-old cows with their first parity (209.7 kg).

Breed of Cow's Dam. The breed of the dam of the cow was not significant for weaning weight in those families that were produced by natural service. The least squares means are presented in Table 8. However, those cows whose dam's breed was half Brahman and half Angus did tend to have calves with heavier weaning weights (199.0 kg) than the calves out of cows with dam's that were half Brahman, half Hereford (191.5 kg). In contrast, Bailey et al. (1988) found that calves from Brahman-Hereford dams weighed 213.6 kg at weaning, compared to 204.2 kg for calves out of Brahman-Angus dams. Sanders et al. (2005) evaluated similar calves, Brahman/Angus/Nellore/Hereford, and found that calves out of F_1 cows weighed 239.1 kg at weaning compared to calves out of F_2 cows that weighed 220.6 kg.

Regression on Weaning Age. The regression on weaning age was important ($P <$ 0.001) for those calves born to dams produced by embryo transfer at 0.85 ± 0.09 kg/d. The regression on weaning age for calves out of natural service cows was also influential ($P < 0.001$) at 0.77 ± 0.13 kg/d.

Average Daily Gain

Sire of Cow. Sire of cow was significant for average daily gain of calves from embryo transfer families ($P = 0.005$). The least squares means are presented in Table 7. The calves from cows sired by 432H had lower ($P < .10$) average daily gains than calves from cows out of the other 3 sires (0.69 kg/d). As with birth weight and weaning weight, the two numerically small families (73 and 82) had a large effect on this least squares mean. Calves from cows sired by 551G and 437J had similar average daily gains at 0.78 kg/d. Calves out of cows sired by 297J ranked the highest for average daily gain at 0.83 kg/d.

Sire of cow was not significant for average daily gain in calves out of natural service cows. Least squares means (Table 8) show that calves from 432H daughters ranked the lowest for average daily gain at 0.76 kg/d. The calves with the highest average daily gain were out of 437J daughters (0.86 kg/d).

Calf Sex x Sire of Cow Interaction. There was no calf sex by sire interaction on average daily gain for calves out of embryo transfer cows. Least squares means are shown in Table 7 for completeness. The highest average daily gains were from male and female calves out of cows sired by 297J (0.86 and 0.81 kg/d). Male and female calves out of cows sired by 432H ranked the lowest for average daily gain (0.67 and 0.71 kg/d).

For calves from natural service families there also was no calf sex by sire of cow interaction. Table 8 provides the least squares means and shows that female calves from cows sired by 432H ranked the lowest for average daily gain at 0.73 kg/d. Male calves from cows sired by 437J ranked the highest for average daily gain among natural service families (0.90 kg/d).

Family Nested within Sire of Cow. Substantial differences (*P* = 0.032) in average daily gain were seen due to family nested within sire of cow among calves from embryo transfer cows. Least squares means are shown in Table 7. Families 74 (437J) and 70 (297J) ranked the highest for average daily gain at 0.86 and 0.85 kg/d among embryo transfer families. Calves from family 82 (432H) ranked the lowest (only two calves in this family) for average daily gain at 0.58 kg/d. All possible separations of least squares mean were not performed; however, the least significant difference (LSD) comparing two families with 5 observations each would be approximately 0.05 kg/d, and the LSD value for comparing two families with 10 to 15 observations would be approximately 0.03 kg/d.

Calf Sex. Calf sex had affected average daily gain in calves out of embryo transfer cows (*P* = 0.074). Further analysis of least squares means (Table 7) indicate that male calves (0.78 kg/d) averaged 0.02 kg/d more gain than female calves (0.76 kg/d) in embryo transfer families (*P* < .10).

There was a difference (*P* = 0.009) in average daily gain due to calf sex in natural service families. The least squares means (Table 8) show that male calves had average daily gains of 0.83 kg/d and female calves had average daily gains of 0.76 kg/d.

Calf Year of Birth. Calf year of birth was important for calves out of embryo transfer dams (*P* < 0.001). Calves born in 2006 (0.73 kg/d) had lower (*P* < 0.10) average daily gain than those born in 2005 (0.78 kg/d) and 2007 (0.80 kg/d) (Table 9).

Calf year of birth did not impact average daily gain in calves out of natural service cows. Least squares means are shown in Table 10.

Parity Nested within Cow Age. Parity nested within cow age was not significant for calves out of embryo transfer dams. Least squares means are in Table 9. The 3-yr-old dams with their first parity averaged more gain (0.80 kg/d) than did 3-yr-old females with their second parity (0.73 kg/d). The 4-yr-old dams with their second parity had an average daily gain of 0.81 kg/d, compared to the 4-yr-old females with their third parity at 0.77 kg/d.

For calves out of natural service dams, parity nested within cow affected average daily gain (P = 0.057). Further analysis of least squares means (Table 10) show that calves out of 4-yr-old cows with their third parity ranked the highest for average daily gain (0.90 kg/d). The 4-yr-old cow with her second calf ranked the lowest for average daily gain at 0.67 kg/d, however, there is only information from one animal. Similarly to the embryo transfer dams the 3-yr-old dams with their first parity average more daily gain at 0.86 kg/d than did the 3-yr-old females with their second parity at 0.80 kg/d.

Breed of Cow's Dam. The breed of the cow's dam was not significant for natural service families. Average daily gain was 0.82 kg/d for calves out of cows with dams that were half Brahman, half Angus and 0.78 kg/d for calves out of cows with dams that were half Brahman, half Hereford (Table 8).

Cow Age. Cow age was not significant for average daily gain for either the embryo transfer or natural service families; however, for both groups (embryo transfer and natural service families), average daily gain tended to be higher for calves out of the older cows. The least squares means are provided in Table 9 and 10 for embryo transfer and natural service families for completeness.

Regression on Weaning Age. The regression on weaning age was important (P = 0.084) for calves out of embryo transfer dams at 0.0006 ± 0.0003 kg/d, but was not in calves out of natural service cows at 0.0005 ± 0.0006 kg/d, although the value was similar.

Average Teat Length

Sire of Cow. There were differences (P < 0.001) for sire of cow on average teat length in embryo transfer cows. Least squares means for sires of cows are presented in Table 11. Cows out of sire 551G had longer (P < 0.10) average teat lengths than the other 3 sires with an average length of 3.7 cm. The average teat length of cows by sire 297J (3.3 cm) were also longer (P < 0.10) than those of 437J (2.9 cm) and 432H (2.7 cm).

Substantial differences (P = 0.013) due to sire of cow were also observed in natural service females. The same trend was seen in the natural service cows (Table 12) with 551G daughters with the longest average length (3.9 cm), followed by 297J (3.5 cm), and 437J (3.2 cm). Cows out of sire 432H had the shortest teats with an average length of 2.8 cm.

Table 11. Least squares means and standard errors of average teat length, average teat diameter, udder support scores, disposition scores, and cow weight at weaning among full sib (embryo transfer) cow families for calf sex and family effects

Effect		n	AVTL[1]	n	AVTD[1]	n	USUP[1]	n	DISP[1]	n	CW[1]
Sire of cow											
	297J	33	3.3 ± 0.2^{a}	33	1.9 ± 0.1	33	6.7 ± 0.1^{a}	33	1.7 ± 0.3^{a}	39	435.4 ± 9.2^{a}
	432H	27	2.7 ± 0.2^{b}	27	1.8 ± 0.1	27	7.0 ± 0.2^{b}	27	2.0 ± 0.4^{ac}	30	460.6 ± 13.1^{bc}
	437J	59	2.9 ± 0.1^{b}	59	1.9 ± 0.1	58	7.0 ± 0.1^{b}	59	2.9 ± 0.3^{b}	63	462.4 ± 8.6^{bc}
	551G	46	3.7 ± 0.2^{c}	46	2.0 ± 0.1	46	6.5 ± 0.1^{a}	46	2.4 ± 0.3^{bc}	50	452.5 ± 10.3^{ac}
Calf sex x sire of cow											
	F 297J	16	3.3 ± 0.2	16	1.9 ± 0.1	16	6.7 ± 0.1	16	1.9 ± 0.4	16	435.3 ± 10.1
	F 432H	9	2.7 ± 0.3	9	1.7 ± 0.1	9	7.1 ± 0.2	9	1.7 ± 0.5	9	461.5 ± 14.1
	F 437J	35	2.9 ± 0.2	35	1.9 ± 0.1	35	7.0 ± 0.1	35	2.8 ± 0.3	35	460.6 ± 9.0
	F 551G	22	3.6 ± 0.2	22	1.9 ± 0.1	22	6.6 ± 0.1	22	2.3 ± 0.4	22	448.9 ± 10.8
	M 297J	17	3.3 ± 0.2	17	1.9 ± 0.1	17	6.7 ± 0.1	17	1.5 ± 0.3	17	435.5 ± 9.6
	M 432H	18	2.7 ± 0.2	18	1.8 ± 0.1	18	6.9 ± 0.2	18	2.3 ± 0.4	18	459.8 ± 13.1
	M 437J	23	2.9 ± 0.2	23	1.9 ± 0.1	22	7.0 ± 0.1	23	2.9 ± 0.3	23	464.3 ± 9.4
	M 551G	24	3.8 ± 0.2	24	2.0 ± 0.1	24	6.5 ± 0.1	24	2.5 ± 0.4	24	456.1 ± 10.9

[a,b,c] Means in the same column without a common superscript differ ($P < 0.10$).

[1] AVTL = Average Teat Length (cm), AVTD = Average Teat Diameter (cm), USUP = Udder Support Score, DISP = Disposition Score, CW = Cow Weight at Weaning (kg).

Table 11. (continued)

Effect	n	AVTL[1]	n	AVTD[1]	n	USUP[1]	n	DISP[1]	n	CW[1]
Family(Sire)										
70 297J	13	3.2 ± 0.2	13	1.9 ± 0.1	13	6.7 ± 0.1	13	2.3 ± 0.4	16	423.5 ± 13.1
71 297J	20	3.3 ± 0.2	20	1.9 ± 0.1	20	6.7 ± 0.1	20	1.2 ± 0.3	23	447.3 ± 10.6
72 432H	22	2.7 ± 0.2	22	1.8 ± 0.1	22	6.8 ± 0.1	22	2.3 ± 0.4	24	430.7 ± 10.8
73 432H	3	3.1 ± 0.4	3	1.7 ± 0.2	3	7.4 ± 0.3	3	0.8 ± 0.8	4	478.6 ± 23.9
82 432H	2	2.4 ± 0.5	2	1.8 ± 0.2	2	6.8 ± 0.3	2	2.9 ± 0.9	2	472.6 ± 25.5
74 437J	8	2.8 ± 0.3	8	1.9 ± 0.1	8	7.1 ± 0.2	8	2.5 ± 0.6	9	446.5 ± 17.9
75 437J	17	3.0 ± 0.2	17	1.9 ± 0.1	17	6.9 ± 0.1	17	3.4 ± 0.4	19	454.0 ± 11.6
81 437J	19	2.9 ± 0.2	19	1.8 ± 0.1	18	7.1 ± 0.2	19	3.4 ± 0.4	20	455.0 ± 11.9
83 437J	15	3.0 ± 0.2	15	1.9 ± 0.1	15	6.8 ± 0.2	15	2.2 ± 0.5	15	494.3 ± 14.0
76 551G	3	4.5 ± 0.4	3	1.9 ± 0.2	3	6.5 ± 0.3	3	2.0 ± 0.8	4	409.6 ± 23.0
77 551G	17	3.4 ± 0.2	17	1.9 ± 0.1	17	6.6 ± 0.1	17	2.4 ± 0.4	17	452.7 ± 12.1
80 551G	18	3.2 ± 0.2	18	1.9 ± 0.1	18	6.7 ± 0.1	18	2.4 ± 0.4	21	485.3 ± 11.5
84 551G	8	3.8 ± 0.3	8	2.1 ± 0.1	8	6.3 ± 0.2	8	2.9 ± 0.5	8	462.4 ± 16.3
Calf sex										
Female	82	3.2 ± 0.1	82	1.9 ± 0.1	82	6.8 ± 0.1	82	2.2 ± 0.3	82	451.6 ± 7.8
Male	82	3.2 ± 0.1	82	1.9 ± 0.1	81	6.8 ± 0.1	82	2.3 ± 0.3	82	453.9 ± 7.7

[a,b,c] Means in the same column without a common superscript differ ($P < 0.10$).

[1] AVTL = Average Teat Length (cm), AVTD = Average Teat Diameter (cm), USUP = Udder Support Score, DISP = Disposition Score, CW = Cow Weight at Weaning (kg).

Table 12. Least squares means and standard errors of average teat length, average teat diameter, udder support scores, disposition scores, and cow weight at weaning among half sib (natural service) cow families for calf sex and genetic effects

Effect	n	AVTL[1]	n	AVTD[1]	n	USUP[1]	n	DISP[1]	n	CW[1]
Sire of cow										
297J	20	3.5 ± 0.3[a]	20	2.1 ± 0.1[a]	20	6.6 ± 0.2	20	2.4 ± 0.4	22	462.6 ± 14.8
432H	47	2.8 ± 0.3[bc]	47	1.7 ± 0.1[bc]	47	6.8 ± 0.2	48	2.1 ± 0.4	54	474.0 ± 14.4
437J	6	3.2 ± 0.5[ac]	6	1.6 ± 0.2[bc]	6	6.9 ± 0.4	6	2.0 ± 0.6	7	483.0 ± 22.8
551G	16	3.9 ± 0.3[a]	16	1.9 ± 0.1[ac]	16	6.4 ± 0.2	16	2.6 ± 0.6	18	441.0 ± 15.7
Calf sex x sire of cow										
F 297J	11	3.2 ± 0.3	11	2.0 ± 0.1	11	6.6 ± 0.3	11	2.3 ± 0.5	10	457.8 ± 15.8
F 432H	28	2.8 ± 0.3	28	1.7 ± 0.1	28	6.8 ± 0.2	28	2.2 ± 0.4	29	471.4 ± 14.5
F 437J	4	3.4 ± 0.5	4	1.7 ± 0.2	4	6.9 ± 0.4	4	2.6 ± 0.7	4	492.1 ± 24.1
F 551G	8	4.0 ± 0.4	8	1.8 ± 0.2	8	6.2 ± 0.3	8	2.2 ± 0.5	8	448.1 ± 16.9
M 297J	9	3.7 ± 0.3	9	2.1 ± 0.2	9	6.5 ± 0.3	9	2.6 ± 0.5	9	467.5 ± 16.3
M 432H	19	2.9 ± 0.3	19	1.7 ± 0.1	19	6.8 ± 0.3	20	2.0 ± 0.4	20	476.5 ± 15.3
M 437J	2	3.0 ± 0.5	2	1.5 ± 0.3	2	7.0 ± 0.5	2	1.4 ± 0.8	2	473.9 ± 26.0
M 551G	8	3.9 ± 0.3	8	2.0 ± 0.1	8	6.5 ± 0.3	8	3.0 ± 0.5	8	433.9 ± 16.3
Breed of cow's dam										
Brahman-Angus	25	3.3 ± 0.3	25	1.8 ± 0.1	25	6.6 ± 0.3	26	2.2 ± 0.4	32	464.1 ± 16.1
Brahman-Hereford	64	3.4 ± 0.2	64	1.8 ± 0.1	64	6.7 ± 0.2	64	2.3 ± 0.3	69	466.2 ± 11.8
Calf sex										
Female	51	3.3 ± 0.3	51	1.8 ± 0.1	51	6.6 ± 0.2	51	2.3 ± 0.4	51	467.3 ± 13.3
Male	38	3.4 ± 0.3	38	1.8 ± 0.1	38	6.7 ± 0.2	39	2.2 ± 0.4	39	463.0 ± 13.6

[a,b,c] Means in the same column without a common superscript differ ($P < 0.10$).

[1] AVTL = Average Teat Length (cm), AVTD = Average Teat Diameter (cm), USUP = Udder Support Score, DISP = Disposition Score, CW = Cow Weight at Weaning (kg).

Calf Sex by Sire of Cow Interaction. No significant differences were seen in the calf sex by sire of cow interaction on average teat length for either embryo transfer or natural service cows. The least squares means (Table 11 and 12) show that cows out of sire 551G with male and female calves had the longest teats in both embryo transfer and natural service families. Also, dams out of sire 432H with male and female calves tended to have the shortest teats in both family types as expected from the sire of cow effects since the interaction was not significant.

Family Nested within Sire of Cow. Family nested within sire of cow was not significant for average teat length among embryo transfer dams. However, the least squares means (Table 11) show that families 76 (small family) (4.5 cm), 84 (3.8 cm), and 77 (3.4 cm), all out of sire 551G, had the longest average teat lengths and families 72 (2.7 cm), and 82 (another small family) (2.4 cm) out of sire 432H had the shortest average teat lengths.

Cow Age and Parity Nested within Cow Age. There were no significant differences for cow age or parity nested within cow age on average teat length in either embryo transfer or natural service cows. However, the least squares means (Table 13) demonstrate that the 4-yr-old embryo transfer cows tended to have the longest average teat lengths. In the natural service cows, those that were 3-yr-old tended to have longer average teat lengths. Least squares means are shown in Table 14 for natural service cows. Riley et al. (2001b) found that for females sired by Brahman bulls, 2-yr-olds had the shortest average teat length at 3.58 cm, followed by 3-yr-old cows at 4.27 cm, and 4-yr-old cows had an average of 4.76 cm. In the same study for Nellore-sired females, 2-

Table 13. Least squares means and standard errors of average teat length, average teat diameter, udder support scores, disposition scores, and cow weight at weaning among full sib (embryo transfer) cow families for year, cow age, and parity

Effect		n	AVTL[1]	n	AVTD[1]	n	USUP[1]	n	DISP[1]	n	CW[1]
Calf year of birth											
	2005	11	3.3 ± 0.2	11	1.9 ± 0.1	11	6.7 ± 0.2	11	2.3 ± 0.5	12	476.6 ± 13.5[a]
	2006	49	3.1 ± 0.1	49	1.8 ± 0.1	48	6.9 ± 0.1	49	2.0 ± 0.3	59	439.3 ± 7.6[b]
	2007	105	3.1 ± 0.1	105	1.8 ± 0.0	105	6.8 ± 0.1	105	2.5 ± 0.1	111	442.4 ± 4.3[b]
Cow age											
	2	70	3.1 ± 0.1	70	1.8 ± 0.0[a]	69	7.0 ± 0.1	70	2.1 ± 0.2[a]	78	401.2 ± 5.2[a]
	2.5	32	3.0 ± 0.1	32	1.9 ± 0.1[bcd]	32	7.0 ± 0.1	32	2.7 ± 0.3[bc]	34	420.9 ± 7.5[b]
	3	38	3.2 ± 0.2	38	1.9 ± 0.1[bcd]	38	6.8 ± 0.1	38	2.3 ± 0.3[ac]	43	467.3 ± 9.6[c]
	3.5	13	3.1 ± 0.2	13	1.8 ± 0.1[ac]	13	6.8 ± 0.2	13	1.8 ± 0.4[a]	15	466.1 ± 11.4[c]
	4	12	3.6 ± 0.3	12	2.0 ± 0.1[bd]	12	6.5 ± 0.2	12	2.3 ± 0.5[ac]	12	508.2 ± 14.1[d]
Parity(cow age)											
	1 2	70	3.1 ± 0.1	70	1.8 ± 0.0	69	7.0 ± 0.1	70	2.1 ± 0.2	70	401.2 ± 5.2[a]
	1 2.5	32	3.0 ± 0.1	32	1.9 ± 0.1	32	7.0 ± 0.1	32	2.7 ± 0.3	32	420.9 ± 7.5[b]
	1 3	8	3.1 ± 0.3	8	2.1 ± 0.1	8	6.8 ± 0.2	8	2.3 ± 0.5	7	486.6 ± 13.7[de]
	2 3	30	3.2 ± 0.2	30	1.8 ± 0.1	30	6.8 ± 0.1	30	2.3 ± 0.3	30	448.0 ± 8.8[c]
	2 3.5	13	3.1 ± 0.2	13	1.8 ± 0.1	13	6.8 ± 0.2	13	1.8 ± 0.4	13	466.1 ± 11.4[d]
	2 4	4	3.6 ± 0.3	4	2.1 ± 0.1	4	6.5 ± 0.3	4	2.6 ± 0.6	4	520.3 ± 15.8[f]
	3 4	8	3.5 ± 0.3	8	2.0 ± 0.1	8	6.6 ± 0.2	8	2.1 ± 0.5	8	496.1 ± 14.5[e]

[a,b,c,d,e,f] Means in the same column without a common superscript differ (*P* < 0.10).

[1] AVTL = Average Teat Length (cm), AVTD = Average Teat Diameter (cm), USUP = Udder Support Score, DISP = Disposition Score, CW = Cow Weight at Weaning (kg).

Table 14. Least squares means and standard errors of average teat length, average teat diameter, udder support scores, disposition scores, and cow weight at weaning among half sib (natural service) cow families for year, cow age, and parity

Effect		n	AVTL[1]	n	AVTD[1]	n	USUP[1]	n	DISP[1]	n	CW[1]
Calf year of birth											
	2005	10	3.4 ± 0.4	10	1.8 ± 0.2	10	6.8 ± 0.3	10	2.4 ± 0.6	11	484.2 ± 19.8^{a}
	2006	27	3.2 ± 0.3	27	1.8 ± 0.1	27	6.7 ± 0.2	27	2.0 ± 0.4	29	452.8 ± 13.2^{bc}
	2007	52	3.5 ± 0.2	52	1.9 ± 0.1	52	6.6 ± 0.2	52	2.4 ± 0.3	61	458.4 ± 9.7^{ac}
Cow age											
	2	55	3.2 ± 0.2	55	1.8 ± 0.1^{a}	55	6.7 ± 0.1	56	1.9 ± 0.2	63	403.8 ± 7.0^{a}
	3	24	3.7 ± 0.4	24	2.1 ± 0.2^{b}	24	6.6 ± 0.3	24	2.7 ± 0.5	28	446.8 ± 21.6^{b}
	4	10	3.2 ± 0.3	10	1.6 ± 0.2^{a}	10	6.7 ± 0.4	10	2.2 ± 0.7	10	545.0 ± 20.9^{c}
Parity(cow age)											
	1 2	55	3.2 ± 0.2	55	1.8 ± 0.1	55	6.7 ± 0.1	56	1.9 ± 0.2	57	403.8 ± 7.0^{d}
	1 3	2	3.9 ± 0.7	2	2.3 ± 0.3	2	6.5 ± 0.5	2	3.3 ± 0.9	1	437.2 ± 38.9^{bcd}
	2 3	22	3.6 ± 0.3	22	1.9 ± 0.1	22	6.6 ± 0.2	22	2.2 ± 0.3	22	456.3 ± 11.9^{c}
	2 4	1	3.0 ± 0.6	1	1.5 ± 0.3	1	7.0 ± 0.7	1	2.6 ± 1.0	1	587.4 ± 28.3^{a}
	3 4	9	3.3 ± 0.4	9	1.7 ± 0.2	9	6.5 ± 0.3	9	1.8 ± 0.5	9	502.5 ± 18.5^{b}

^{a,b,c,d} Means in the same column without a common superscript differ ($P < 0.10$).

[1] AVTL = Average Teat Length (cm), AVTD = Average Teat Diameter (cm), USUP = Udder Support Score, DISP = Disposition Score, CW = Cow Weight at Weaning (kg).

yr-old females had an average teat length of 3.29 cm, the 3-yr-olds 3.98 cm, and 4-yr-olds averaged 4.07 cm.

Analysis of the simple means for average teat length of the 4-yr-old cows with 3 parities by year of age for the embryo transfer cows shows that those 8 cows had the longest average teat length at age 4 with their third parity (3.23 cm). Interestingly, however, those cows at age 3 with their second parity had the shortest average teat length of 3.00 cm. At age 2 and with one calf those females had an average teat length of 3.06 cm. The analysis of the simple means for average teat length by year of age for the 9 natural service females that were 4 years of age with their third parity shows that those females at 2 years of age with their first parity had the longest average teat length at 3.18 cm. The shortest average teat length for those cows was for the 3 year old cows with their second parity at 3.04 cm. Those cows at 4 years of age with their third parity had an average teat length of 3.10 cm.

Breed of the Cow's Dam. In the natural service cows the breed of the cow's dam was not significant for average teat length. Table 12 shows that the half Brahman, half Hereford dams had cows that tended to have slightly longer average teat lengths (3.4 cm) than did the half Brahman, half Angus dams (3.3 cm).

Calf Sex and Calf Year of Birth. Calf sex and calf year of birth were not significant influences on average teat length in cows from full sib or half sib families. The least squares means for calf sex and calf year of birth are in Table 11 and 13 for full sib cow families and 12 and 14 for half sib cow families.

Average Teat Diameter

Sire of Cow. Sire of cow was not a significant influence on average teat diameter for embryo transfer cows. Least squares means are located in Table 11. However, differences (P = 0.022) for sire of cow on average teat diameter were seen for cows produced via natural service. Least squares means (shown in Table 12) indicate that cows out of sire 297J ranked the largest average teat diameter at 2.1 cm. Cows out of 551G had an average teat diameter of 1.9 cm, 432H-sired cows had an average teat diameter of 1.7 cm, and the smallest average teat diameter cows were out of sire 437J (1.6 cm).

Calf Sex by Sire of Cow Interaction. Calf sex by sire of cow interaction was not significant for average teat diameter in either the embryo transfer or natural service cows. Table 11 indicates that cows out of sire 432H with female calves (1.7 cm) tended to have the smallest average teat diameter whereas cows out of sire 551G with male calves (2.0 cm) tended to have the largest of the embryo transfer cows.

Of the natural service cows (Table 12), cows sired by 297J with male (2.1 cm) and female calves (2.0 cm) tended to have the largest average teat diameters. Those cows sired by 437J with male calves had the smallest (1.5 cm).

Cow Age. Differences (P = 0.018) in teat diameter occurred due to cow age among embryo transfer cows. Table 13 indicates that 4-yr-old cows had the largest average teat diameter (2.0 cm), whereas cows that were 2 yr old had the smallest average teat diameter (1.8 cm).

Cow age also affected average teat diameter in natural service cows (P = 0.075). Cows that were 3 yr old had significantly larger average teat diameters (2.1 cm) as compared to 2- and 4-yr-old cows (1.8 cm and 1.6 cm). Riley et al. (2001b) found that for 2-yr-old cows sired by Brahman bulls the average teat diameter was 1.72 cm whereas those sired by Nellore bulls had an average teat diameter of 1.52 cm. For 4-yr-old cows, the Nellore sired cows were still smaller at 2.02 cm compared to 2.25 cm for those out of Brahman bulls.

Family Nested within Sire of Cow and Breed of Cow's Dam. No significant differences were observed for family nested within sire on average teat diameter for embryo transfer dams. Similarly, the breed of the cow's dam was not significant for average teat diameter in natural service cows. Tables 11 and 12 show the least squares means of both of these effects, respectively, on average teat diameter.

Calf Sex, Calf Year of Birth, and Parity Nested within Cow Age. Calf sex, calf year of birth, and parity nested within cow age were not significant effects on average teat diameter in either embryo transfer or natural service cows. Least squares means are presented in Tables 11, 12, 13, and 14 for completeness.

Udder Support Score

Sire of Cow. Sire of cow affected (P = 0.002) udder support score among embryo transfer dams. The least squares means (Table 11) show that cows sired by 432H (7.0) and 437J (7.0) had significantly higher udder support scores than cows sired by 297J (6.7) and 551G (6.5).

Sire of cow was not significant for udder support score in natural service dams. Although, the least squares means in Table 12 show a similar trend as the embryo transfer dams. Dams sired by 437J (6.9) and 432H (6.8) ranked higher for udder support scores than dams sired by 297J (6.6) and 551G (6.4).

Calf Sex by Sire of Cow Interaction. No significant calf sex by sire of cow interaction was found on udder support scores in either the embryo transfer cows or those produced via natural service. Least squares means (Tables 11 and 12, respectively) for udder support scores ranged from 6.5 to 7.1 for embryo transfer dams and 6.2 to 7.0 for natural service dams among the sex and sire combinations.

Family Nested within Sire of Cow and Breed of Cow's Dam. Family nested within sire of cow was not significant for udder support score in embryo transfer cows. Least squares means are shown in Table 11.

The breed of the cow's dam was not significant for udder support score in natural service cows. Table 12 shows least squares means of 6.7 for udder support for cows out of dams that were half Brahman, half Hereford. Cows out of dams that were half Brahman, half Angus had udder support scores of 6.6.

Cow Age. No substantial differences were seen due to cow age on udder support score for embryo transfer cows. However, the least squares means (Table 13) show a trend that as cows begin to get older, udder support score gets lower. Udder support scores were 7.0 for 2- and 2.5-yr-old cows and become lower with 4-yr-old cows having a score of 6.5.

There was no significant difference for cow age on udder support score for natural service cows. The least squares means are shown in Table 14. Riley et al. (2001b) found that for 2-, 3-, and 4-yr-old cows the average udder support score for Nellore-sired females (5.62, 5.14, and 4.93) was less than the udder support scores for Brahman-sired females (5.68, 5.18, and 4.99).

Parity Nested within Cow Age. Parity nested within cow age was not significant on udder support score for either the embryo transfer or natural service cows. Least squares means are shown in Tables 13 and 14. The 2- and 2.5-yr-old first parity cows had udder support scores of 7.0 and 7.0, whereas the 4-yr-old cows with 2 parities had an udder support score of 6.5 and the 4-yr-old cows with 3 parities had an udder support score of 6.6.

Calf Sex and Calf Year of Birth. Calf sex and calf year of birth were not significant influences on udder support scores in either embryo transfer or natural service dams. Least squares means are in Tables 11, 12, 13 and 14, respectively.

Cow Disposition Score at Calf Birth

Sire of Cow. Substantial differences (P = 0.002) were seen in disposition score due to sire of cow among the embryo transfer cows. Cows sired by 437J had the highest disposition score (least desirable) at 2.9 (Table 11). The second highest disposition score came from cows sired by 551G (2.4). The third highest score was from 432H sired cows (2.0), followed by cows sired by 297J (1.7).

Sire of cow was not significant on disposition for natural service cows. However, a somewhat similar trend was seen in the natural service cows, as those sired by 437J ranked the highest for disposition score (2.6), but cow sired by 297J ranked second (2.4). Least squares means are shown in Table 12.

Calf Sex by Sire of Cow Interaction. There was no significant calf sex by sire of cow interaction for disposition score for embryo transfer dams. The least squares means in Table 11 show that dams sired by 437J with male and female calves ranked the two highest disposition scores at 2.9 and 2.8, respectively. Likewise, calf sex by sire of cow interaction was not significant for disposition in the cows produced by natural service. The least squares means are in Table 12.

Family Nested within Sire of Cow. Family nested within sire of cow accounted for variation in disposition (P = 0.015) in embryo transfer cows. The two highest cow disposition scores came from families 75 and 81, both sired by 437J, at 3.4. The lowest disposition score was 0.8 from family 73 (small family) (432H). Family 71 ranked the next lowest for disposition score at 1.2. Least squares means are shown in Table 11. All possible separations of least squares mean were not performed; however, the least significant difference (LSD) comparing two families with 5 observations each would be approximately 0.76, with 10 observations would be approximately 0.53, and the LSD value for comparing two families with 15 observations would be approximately 0.44.

Cow Age. Substantial differences (P = 0.041) were found for cow age on disposition score in embryo transfer cows. According to the least squares means in Table 13, cows that were 2.5 yr old had the highest disposition scores (2.7). The 3- and

4-yr-old cows both had disposition scores of 2.3. The lowest disposition scores came from 3.5-yr-old cows at 1.8.

There was no significant difference for cow age on disposition score for the natural service cows. The 3-yr-old cows had the highest disposition score (2.7) for natural service dams. Least squares means are shown in Table 14.

Parity Nested within Cow Age. Parity nested within cow age was not significant for disposition score in either the embryo transfer or the natural service cows. The least squares means are listed in Tables 13 and 14, respectively.

Breed of Cow's Dam. The breed of the cow's dam had no effect on the disposition score in natural service dams. The least squares means (Table 12) show that cows from half Brahman, half Hereford dams had a disposition score of 2.3, while cows out of half Brahman, half Angus dams had a disposition score of 2.2.

Calf Sex and Calf Year of Birth. Calf sex and calf year of birth were not significant for disposition score for either the embryo transfer or natural service dams.

Cow Weight at Weaning

Sire of Cow. Sire of cow on cow weight at weaning was significant (P = 0.045) for the embryo transfer cows. Least squares means (Table 11) for cows out of sire 437J had the heaviest weight at weaning (462.4 kg). Cows out of 432H weighed 460.6 kg at weaning which was 8.4 kg more than cows out of 551G (452.5 kg). The lightest cows at weaning were sired by 297J and weighed 435.4 kg.

Sire of cow was not significant for cow weight at weaning for natural service dams. However, the 2 heaviest types of cows at weaning were by sires 437J (483.0 kg) and 432H (474.0 kg) as shown in Table 12.

Calf Sex by Sire of Cow Interaction. There was no significant calf sex by sire of cow interaction for cow weight at weaning for embryo transfer cows. The least squares means (Table 11) show that the heaviest cows had male calves and were sired by 437J (464.3 kg). The lightest cows were sired by 297J and had both female and male calves (435.3 kg and 435.5 kg).

Calf sex by sire of cow interaction on cow weight at weaning was not significant for natural service cows either. The heaviest cows (Table 12) had female calves and were sired by 437J (492.1 kg). The lightest cows had male calves and were sired by 551G (433.9 kg).

Family Nested within Sire of Cow. Family nested within sire of cow was highly significant (P = 0.001) on cow weight at weaning for embryo transfer cows. Least squares means (Table 11) show that families 83 (437J) and 80 (551G) ranked the heaviest for cow weight at weaning at 494.3 and 485.3 kg, respectively. The embryo transfer families that ranked the lightest for cow weight at weaning were 76 (small family) (551G) and 70 (297J) at 409.6 and 423.5 kg. All possible separations of least squares mean were not performed; however, the least significant difference (LSD) comparing two families with 5 observations each would be approximately 13.34 kg, with 10 observations would be approximately 9.43 kg, and the LSD value for comparing two families with 15 observations would be approximately 7.70 kg.

Calf Sex. Calf sex was not significant for cow weight at weaning in cows produced by embryo transfer. Table 11 shows that cows with male calves weighed 2.3 kg more at weaning than those with female calves (453.9 kg vs. 451.6 kg).

Calf sex was not significant for cow weight at weaning for natural service cows either. Cows with female calves weighed 4.3 kg more at weaning than those with male calves as shown in Table 12 (467.3 kg vs. 463.0 kg).

Calf Year of Birth. Differences ($P < 0.001$) were found for calf year of birth on cow weight at weaning in embryo transfer cows. Table 13 shows that cows with calves born in 2005 (small number of cows and all were 2-yr-olds) were significantly ($P < .10$) heavier (476.6 kg) at weaning than those with calves born in 2006 (439.3 kg) and 2007 (442.4 kg). There is more discussion below relative to the simple means.

Calf year of birth was also important ($P = 0.012$) for cow weight at weaning for natural service cows. Similar trends seen in embryo transfer cows are seen in Table 14 for the natural service cows. Cows with calves born in 2005 were the heaviest (small number of cows and all were 2-yr-olds) at weaning and weighed 484.2 kg. Cows with calves born in 2007 weighed 5.6 kg more than those with calves born in 2006 (458.4 kg vs. 452.8 kg).

However, when analyzing the simple means for the embryo transfer cows for cow weight at weaning by calf year of birth the lowest average weight is from the females with calves born in 2005 at 417.0 kg. This is due to the fact that all the females in this project were 2 years old at that point. The embryo transfer dams with calves born in 2006 had an average weight at weaning of 418.4 kg and the dams with calves born in

2007 weighed much more at 442.2 kg. The simple means for cow weight at weaning for natural service dams show that the cows that had calves in 2007 were the heaviest at 451.1 kg. The lightest, however, were the dams with calves born in 2006 who weighed 417.1 kg at weaning. The natural service dams with calves born in 2005 weighed 420.2 kg at weaning.

Cow Age. Substantial differences ($P < 0.001$) in cow weight at weaning were found for cow age in embryo transfer cows. The least squares means (Table 13) show the 4-yr-old cows were significantly heavier at weaning (508.2 kg) than any of the other ages. Cows aged 3 and 3.5 ranked the next heaviest at 467.3 kg and 466.1 kg, respectively. Cows that were 2.5 years of age were heavier ($P < 0.10$; 420.9 kg) and weighed 19.7 kg more than cows that were 2 (401.2 kg).

Cow age also affected ($P < 0.001$) cow weight at weaning for natural service cows also. Table 14 shows 4-yr-old cows (545.0 kg) were heavier than the 3- and 2-yr-old cows ($P < 0.10$). The 3-yr-old cows were heavier ($P < 0.10$) than the 2-yr-olds (446.8 kg vs. 403.8 kg).

Parity Nested within Cow Age. Parity nested within cow age was important ($P = 0.007$) on cow weight at weaning in embryo transfer cows. Least squares means are in Table 13. Cows that were 4 years old with their second parity (520.2 kg) were significantly heavier than all others ($P < 0.10$). The 4-yr-old cows with their third calf were the next heaviest at weaning (496.1 kg) and weighed 9.5 kg more than the next heaviest, the 3-yr-old cows with their first calf (486.6 kg). The 3.5-yr-old cows with their second calf weighed 466.1 kg, which was 18.1 kg more than the 3-yr-old cows with their second calf (448.0 kg). The 2.5-yr-old cows with their first calf weighed 19.7 kg more than did the 2-yr-old cows with their first calf (420.9 kg vs. 401.2 kg). It is important to note that the cows that had skipped a calf were much heavier at weaning than those that had had a calf every year. The 3-yr-old dams with their first parity weighed 486.6 kg at weaning, which was 38.6 kg more than the 3-yr-old females with her second parity (448.0 kg). The 4-yr-old dams with their second parity weighed 520.3 kg at weaning compared to 496.1 kg for the 4-yr-old dams with their third parity.

Parity nested within cow age was also important for cow weight at weaning for the natural service cows ($P = 0.005$). The least squares means (Table 14) show the 4-yr-old cows with 2 calves were significantly heavier ($P < .10$) at weaning than all other cows in the study (587.4 kg). The 4-yr-old cows with 3 calves weighed 46.2 kg more than the 3-yr-old cows with their second calf (502.5 kg vs. 456.3 kg). The 3-yr-old cows with their first calf weighed 437.2 kg. The lightest cows at weaning were the 2-yr-old cows with their first calf (403.8 kg). Somewhat similar to the embryo transfer cows, the 4-yr-old females with their third parity weighed 84.9 kg less at weaning (502.5 kg) than did the 4-yr-old females with their second parity (587.4 kg). It should be noted that the single 3-yr-old dam with her first parity is actually lighter than the other 3-yr-old cows with their second parity.

Breed of Cow's Dam. The breed of the cow's dam was not significant for cow weight at weaning in the natural service cows ($P > .10$). Table 12 shows the least squares means for cows born to half Brahman, half Hereford dams was 466.2 kg which was only 2.1 kg more than the cows born to half Brahman, half Angus dams (464.1 kg).

Riley et al. (2001a) reported that cows out of Brahman sires weighed 585.57 kg at weaning compared to 549.54 kg for Nellore-sired cows. Sanders et al. (2005) found that F_1 Brahman-Angus cows weighed 534.5 kg which was 10.2 kg more than F_1 Brahman-Hereford cows at 4 years of age.

Correlations

Correlations were calculated for the traits birth weight, average teat length, average teat diameter, udder support score, cow disposition score at birth, weaning weight of the calf, cow weight at weaning, calf body condition score at weaning, cow body condition score at weaning, and average daily gain of the calf. Correlation coefficients and *P*-values are shown in Table 15 for traits measured in full sib, embryo transfer cow families and Table 16 for half sib, natural service cow families.

Among full sib cow families there were positive correlations between birth weight and both average teat length ($P = 0.009$) and average teat diameter ($P = 0.004$) of 0.20 and 0.23, respectively. However, among half sib cow families these correlations (0.17 and 0.17, respectively) were not significant. In both embryo transfer and natural service families, there was a negative correlation for birth weight and udder support score. The correlation was -0.28 in the embryo transfer families and -0.25 in natural service families. Birth weight and weaning weight were positively correlated among (and within) embryo transfer families at 0.32 ($P < 0.001$), and this correlation among (and within) natural service families was 0.22 ($P = 0.042$). Cow weight at weaning was lowly correlated with birth weight for embryo transfer families at 0.14 ($P = 0.070$). This

Table 15. Pearson correlation coefficients and *P*-values among traits measured in full sib (embryo transfer) cow families

	Trait[1]								
Trait	AVTL	AVTD	USUP	DISP	WWT	CW	CalfBCS	CowBCS	ADG
BWT	0.20264	0.2262	-0.27715	0.11855	0.32272	0.14201	0.02905	0.06284	0.2591
	0.009	0.004	<0.001	0.131	<0.001	0.070	0.718	0.424	0.001
AVTL		0.53044	-0.38736	-0.11734	0.15227	0.02169	0.08516	-0.02818	0.13907
		<0.001	<0.001	0.133	0.057	0.783	0.289	0.720	0.082
AVTD			-0.39878	-0.13431	0.2491	0.16612	0.1192	0.12465	0.26522
			<0.001	0.085	0.002	0.034	0.137	0.112	0.001
USUP				0.01996	-0.17725	-0.14099	-0.02777	-0.1469	-0.19035
				0.800	0.027	0.073	0.731	0.061	0.017
DISP					0.06236	-0.06596	0.00901	-0.08346	0.00475
					0.438	0.401	0.911	0.288	0.953
WWT						0.25009	0.23211	0.17991	0.87576
						0.002	0.003	0.024	<0.001
CW							0.2856	0.43438	0.15952
							<0.001	<0.001	0.046
CalfBCS								0.19912	0.19616
								0.012	0.014
CowBCS									0.19218
									0.016

[1] BWT = Birth weight, AVTL = Average teat length, AVTD = Average teat diameter, USUP = Udder support score, DISP = Disposition score, WWT = Weaning weight, CW = Cow weight at weaning, CalfBCS = Calf body condition score at weaning, CowBCS = Cow body condition score at weaning, ADG = Average daily gain

Table 16. Pearson correlation coefficients and *P*-values among traits measured in half sib (natural service) cow families

	Trait[1]								
Trait	AVTL	AVTD	USUP	DISP	WWT	CW	CalfBCS	CowBCS	ADG
BWT	0.17006	0.16513	-0.25352	0.08321	0.22105	0.25631	0.02075	0.05972	0.27826
	0.115	0.126	0.018	0.441	0.042	0.016	0.851	0.580	0.010
AVTL		0.47262	-0.40191	0.09176	0.16745	0.08249	-0.03593	0.05614	0.12014
		<0.001	<0.001	0.392	0.128	0.445	0.746	0.603	0.279
AVTD			-0.47774	0.21845	0.128	0.02416	-0.07988	-0.14767	0.19541
			<0.001	0.040	0.246	0.823	0.470	0.170	0.077
USUP				-0.0002	-0.151	-0.05652	-0.03857	0.02118	-0.24623
				0.999	0.170	0.601	0.728	0.845	0.025
DISP					-0.08303	0.16904	0.16176	-0.00673	-0.04705
					0.45	0.113	0.139	0.950	0.671
WWT						0.15809	0.08851	0.11643	0.85077
						0.146	0.418	0.286	<0.001
CW							0.40287	0.37301	0.13689
							<0.001	<0.001	0.212
CalfBCS								0.27147	0.03689
								0.012	0.738
CowBCS									0.08692
									0.429

[1] BWT = Birth weight, AVTL = Average teat length, AVTD = Average teat diameter, USUP = Udder support score, DISP = Disposition score, WWT = Weaning weight, CW = Cow weight at weaning, CalfBCS = Calf body condition score at weaning, CowBCS = Cow body condition score at weaning, ADG = Average daily gain

correlation ($P = 0.016$) was higher in half sib cow families (0.26). The correlation between birth weight and average daily gain was important for both full sib ($P = 0.001$) and half sib cow families ($P = 0.010$) at 0.26 and 0.28, respectively. Average teat length and average teat diameter were correlated ($P < 0.001$) in embryo transfer families at a moderate level (0.53). The correlation was slightly lower for natural service families at 0.47 ($P < 0.001$). Udder support score was negatively correlated with both average teat length and average teat diameter in both types of families ($P < 0.001$). For average teat length the correlations were similar at -0.39 for full sib cow families and -0.40 for half sib cow families. The correlation between average teat diameter and udder support score was -0.40 and -0.48 for embryo transfer and natural service families, respectively. Average teat diameter was also correlated with calf average daily gain among both embryo transfer families ($P = 0.001$) and natural service families ($P = 0.077$) at 0.27 and 0.20, respectively. Correlations ($P < 0.10$) between average teat length and weaning weight (0.15), and average teat diameter and both weaning weight (0.25) and cow weight at weaning (0.17) were observed in full sib families, but these correlations were much smaller and not significant for the natural service families. Udder support was negatively correlated with calf average daily gain for both the embryo transfer ($P = 0.017$) and natural service ($P = 0.025$) cows at -0.19 and -0.25, respectively. In embryo transfer families udder support was also correlated with weaning weight (-0.18), cow weight at weaning (-0.14), and cow body condition score at weaning (-0.15).

The only trait that cow disposition score at calf birth was correlated with was average teat diameter for both embryo transfer and natural service families. The correlation for embryo transfer families was slightly negative (-0.13); however, the correlation for natural service families was positive (0.22).

The highest correlation in the data analysis was between weaning weight and average daily gain in both full sib and half sib cow families. There was a correlation of 0.88 in the embryo transfer families ($P < 0.001$) and 0.85 in the natural service families ($P < 0.001$). Among full sib families weaning weight was also correlated with cow weight at weaning (0.25), calf body condition score at weaning (0.23), and cow body condition score at weaning (0.18). These traits were not significantly correlated in half sib cow families, and were all substantially lower.

Cow weight at weaning was correlated with calf body condition score at weaning and cow body condition score at weaning for both embryo transfer and natural service families. For full sib cow families there was a correlation of 0.29 for cow weight at weaning and calf body condition score at weaning ($P < 0.001$). The correlation was 0.40 for half sib families ($P < 0.001$). The correlation was 0.43 between cow weight at weaning and cow body condition score at weaning in full sib families ($P < 0.001$) and 0.37 in half sib families ($P < 0.001$). Cow weight at weaning was correlated with calf average daily gain in full sib families (0.16, $P = 0.046$), but not in half sib families (0.14, $P > 0.10$). Cow body condition score and calf body condition score at weaning were also correlated for both types of families. In embryo transfer families, the correlation was 0.20 ($P = 0.012$) and in natural service families the correlation was 0.27 ($P = 0.012$). In embryo transfer families, average daily gain was correlated with calf body condition score at weaning (0.20) and cow body condition score at weaning (0.19). There was no significant correlation between these traits in half sib families, and the correlation coefficients were much lower.

Heifer Reproductive Performance

Simple means and standard deviations for calving rate, Julian calving date, and weaning rate are presented in Tables 17 and 18 for embryo transfer and natural service heifers, respectively. The females were considered for this analysis were ages 2 and 2.5 for those produced through embryo transfer and age 2 for those produced through natural service. The simple means and standard deviations are presented and discussed for informational purposes.

Calving Rate. Calving rate for heifers ranged from 0.750 to 1.000 among embryo transfer families. Heifers sired by 297J ranked the lowest for calving rate among the 4 sires at 0.810. Calving rate for heifers sired by 437J was the highest at 0.974. There were 8 embryo transfer families that had a calving rate of 1.000. Three of those families, 76, 77, 84, were sired by 551G. Also 2 of those families, 75 (437J) and 77 (551G) had over 10 heifers. The lowest calving rate among embryo transfer families was 0.7500 for family 70 sired by 297J. Females that calved first at 2.5 years had a higher calving rate (0.941) than did those that calved first as 2 yr olds (0.897) among embryo transfer heifers. Females that calved first at 2.5 yr were fall-born and did not breed to calve as fall-calving, 2-yr-olds.

The calving rate for natural service heifers ranged from 0.786 to 1.000 across the 4 families. Natural service heifers sired by 437J and 551G had a calving rate of 1.000.

Table 17. Simple means and standard deviations for heifer reproductive performance in full sib (embryo transfer) cow families

Effect	n	Calving rate	Julian calving date	Weaning rate
Sire of cow				
297J	21	0.810 (0.402)	69 (21)	0.810 (0.402)
432H	16	0.875 (0.342)	69 (20)	0.813 (0.403)
437J	39	0.974 (0.160)	69 (18)	0.897 (0.307)
551G	36	0.917 (0.280)	65 (14)	0.861 (0.351)
Family(sire of cow)				
70 297J	8	0.750 (0.463)	73 (22)	0.750 (0.463)
71 297J	13	0.846 (0.376)	66 (20)	0.846 (0.376)
72 432H	12	0.833 (0.389)	71 (23)	0.833 (0.389)
73 432H	2	1.000 (0.000)	58 (6)	0.500 (0.707)
82 432H	2	1.000 (0.000)	65 (1)	1.000 (0.000)
74 437J	3	1.000 (0.000)	72 (18)	1.000 (0.000)
75 437J	11	1.000 (0.000)	71 (19)	0.909 (0.302)
81 437J	12	0.917 (0.289)	62 (22)	0.917 (0.289)
83 437J	13	1.000 (0.000)	73 (15)	0.846 (0.376)
76 551G	2	1.000 (0.000)	69 (2)	1.000 (0.000)
77 551G	12	1.000 (0.000)	70 (14)	1.000 (0.000)
80 551G	14	0.786 (0.426)	62 (17)	0.714 (0.469)
84 551G	8	1.000 (0.000)	63 (13)	0.875 (0.354)
Cow age				
2	78	0.897 (0.305)	68 (18)	0.833 (0.375)
2.5	34	0.941 (0.239)	67 (17)	0.912 (0.288)

Table 18. Simple means and standard deviations for heifer reproductive performance in half sib (natural service) cow families

Effect	n	Calving rate	Julian calving date	Weaning rate
Sire of cow				
297J	14	0.786 (0.426)	75 (26)	0.786 (0.426)
432H	39	0.872 (0.339)	70 (19)	0.821 (0.389)
437J	5	1.000 (0.000)	56 (7)	0.800 (0.447)
551G	7	1.000 (0.000)	59 (11)	1.000 (0.000)
Breed of cow's dam				
Brahman-Angus	26	0.846 (0.368)	72 (24)	0.846 (0.368)
Brahman-Hereford	39	0.897 (0.307)	66 (17)	0.821 (0.389)

Heifers sired by 432H had a calving rate of 0.872. The lowest calving rate came from heifers sired by 297J (0.786) among natural service heifers It is important to consider that there were only 5 heifers sired by 437J, and 7 sired by 551G, whereas 39 were sired by 432H in this analysis. Heifers that were out of half Brahman, half Angus dams had a lower calving rate (0.846) than those from half Brahman, half Hereford dams (0.897). Cundiff (2005) reported that for 2-yr-old heifers sired by Brahman had a calf crop born percentage of 74.3%, but heifers from Nellore sires had a calf crop born percentage of 90.0%. Riley et al. (2001a) found that for 2-yr-old females, Nellore-sired females had a calf crop born percentage of 95.7%, whereas Brahman-sired females had percentage of 95.2%.

Julian Calving Date. Average calving dates among embryo transfer heifers ranged from day 58 to day 73. Heifers out of sire 551G calved the earliest of the 4 sires at day 65, and heifers sired by 297J, 432H, and 437J all had an average calving day of 69. Heifers from families 70 (297J) and 83 (437J) had the latest average calving date of 73. Heifers out of family 73 (432H) had the earliest average calving date at 58. The 2-yr-old heifers had a average calving date of 68 and the 2.5-yr-old heifers had an average calving date of 67.

Average calving date for natural service heifers ranged from day 56 to day 75. Heifers sired by 297J had the latest average calving date at day 75. Heifers out of 437J (day 56) and 551G (day 59) had the earliest average calving date. Heifers out of half Brahman, half Hereford dams had an earlier average calving date (day 66) than heifers from half Brahman, half Angus dams (72).

Weaning Rate. The range in weaning rate was from 0.714 to 1.000 among embryo transfer families. The highest weaning rate was for heifers sired by 437J at 0.897, and the lowest weaning rate was 0.810 for heifers sired by 297J. There were 4 families that had a weaning rate of 1.000 (82, 74, 76, and 77). The lowest weaning rate among families was 0.500 for heifers in family 73 (432H), but there were only 2 heifers in this family. The 2-yr-old heifers had a weaning rate of 0.833, whereas the 2.5-yr-old heifers had a weaning rate of 0.912 among the embryo transfer heifers. Riley et al. (2001a) reported that for females that calved at 2.5 years of age those with Nellore sires had a calf crop weaned percentage of 95.8% which was significantly higher than those females sired by Brahman bulls (66.7%).

Natural service heifers had weaning rates that ranged from 0.786 to 1.000 across families. Heifers out of sire 297J weaned at a rate of 0.786, the lowest among the 4 sires. Heifers out of sire 551G had a weaning rate of 1.000. Heifers sired by 432H and 437J had similar weaning rates of 0.821 and 0.800. The heifers out of Brahman-Angus dams had a weaning rate of 0.846, and those out of Brahman-Hereford dams had a weaning rate of 0.821. This is a switch in order from calving rate as the heifers out of Brahman-Hereford dams had a higher calving rate. Cundiff (2005) reported that for 2-yr-old heifers with Nellore sires the calf crop weaned percentage was 72.9% and for Brahman-sired heifers that percentage was 64.5%, the lowest of any of the sire breeds in the study in Nebraska.

Calf Survival. Calf survival in this analysis was determined as the ratio of calves that survived to weaning relative to the calves born. Among families of embryo transfer heifers, calf survival ranged from 0.500 to 1.000. Heifers sired by 297J had a calf survival rate of 1.000. Heifers out of 437J had the lowest calf survival rate of 0.921. Heifers out of 432H and 551G had calf survival rates of 0.929 and 0.939, respectively. There were 8 families that had calf survival rates of 1.000. The lowest calf survival rate was from family 73 (432H) at 0.500, but this family only had 2 heifers. The 2-yr-old heifers had a calf survival rate of 0.929 compared to the 2.5-yr-old heifers with a calf survival rate of 0.969. Riley et al. (2001a) reported that for heifers that calved at 2.5 years of age, females sired by Brahman had a calf survival rate of 70.1% compared to 100.1% for Nellore-sired females.

Natural service heifers had calf survival rates that ranged from 0.800 to 1.000 across families. Heifers sired by 297J and 551G had calf survival rates of 1.000. The lowest calf survival rate among natural service heifers came from those heifers sired by 437J (0.800). Calf survival rate for heifers out of Brahman-Angus dams was 1.000, whereas heifers out of half Brahman, half Hereford cows had a calf survival rate of 0.914.

Cow Reproductive Performance

Simple means and standard deviations for calving rate, Julian calving date, and weaning rate across all cow ages are presented in Tables 19 and 20 for embryo transfer and natural service families, respectively. The simple means and standard deviations are presented for informational purposes to evaluate trends.

Table 19. Simple means and standard deviations for cow reproductive performance in full sib (embryo transfer) cow families

Effect	n	Calving rate	Julian calving date	Weaning rate
Sire of cow				
297J	39	0.846 (0.366)	66 (19)	0.821 (0.389)
432H	31	0.871 (0.341)	67 (17)	0.839 (0.374)
437J	64	0.922 (0.271)	67 (16)	0.859 (0.350)
551G	50	0.920 (0.274)	64 (15)	0.880 (0.328)
Family(sire of cow)				
70 297J	16	0.813 (0.403)	72 (21)	0.750 (0.447)
71 297J	23	0.870 (0.344)	62 (17)	0.870 (0.344)
72 432H	25	0.880 (0.332)	69 (18)	0.880 (0.332)
73 432H	4	0.750 (0.500)	54 (9)	0.500 (0.577)
82 432H	2	1.000 (0.000)	65 (1)	1.000 (0.000)
74 437J	9	0.889 (0.333)	68 (16)	0.889 (0.333)
75 437J	19	0.895 (0.315)	69 (17)	0.842 (0.375)
81 437J	21	0.905 (0.301)	63 (17)	0.857 (0.359)
83 437J	15	1.000 (0.000)	71 (15)	0.867 (0.352)
76 551G	4	0.750 (0.500)	52 (29)	0.750 (0.500)
77 551G	17	1.000 (0.000)	70 (13)	1.000 (0.000)
80 551G	21	0.857 (0.359)	59 (15)	0.810 (0.402)
84 551G	8	1.000 (0.000)	63 (13)	0.875 (0.354)
Cow age				
2	78	0.897 (0.305)	68 (18)	0.833 (0.375)
2.5	34	0.941 (0.239)	67 (17)	0.912 (0.288)
3	45	0.844 (0.367)	64 (12)	0.800 (0.405)
3.5	15	0.867 (0.352)	58 (17)	0.867 (0.352)
4	12	1.000 (0.000)	65 (20)	1.000 (0.000)

Table 20. Simple means and standard deviations for cow reproductive performance in half sib (natural service) cow families

Effect	n	Calving rate	Julian calving date	Weaning rate
Sire of cow				
297J	25	0.800 (0.408)	73 (25)	0.760 (0.436)
432H	55	0.891 (0.315)	70 (19)	0.836 (0.373)
437J	7	0.857 (0.378)	62 (16)	0.714 (0.488)
551G	18	0.889 (0.323)	65 (15)	0.889 (0.323)
Cow age				
2	65	0.877 (0.331)	68 (20)	0.831 (0.378)
3	30	0.800 (0.407)	73 (21)	0.733 (0.450)
4	10	1.000 (0.000)	66 (13)	1.000 (0.000)
Breed of Cow's Dam				
Brahman-Angus	34	0.765 (0.431)	74 (24)	0.765 (0.431)
Brahman-Hereford	71	0.916 (0.280)	68 (18)	0.845 (0.364)

Calving Rate. Calving rate ranged from 0.750 to 1.000 among embryo transfer families. Cows sired by 437J ranked the highest for calving rate at 0.922, and cows sired by 297J ranked the lowest at 0.846. There were 4 embryo transfer families that had a 1.000 calving rate. Of those families, 2 (77 and 84) were from cows sired by 551G. Also, families 83 (437J) and 77 (551G) had a 1.000 calving rate with over 15 observations. The 2 families with a calving rate of 0.750 (73 and 76) only had 4 observations each. Cows that were 4 years of age had a 1.000 calving rate. The lowest calving rate based on cow age came from 3-yr-old cows at 0.844.

For natural service families, calving rate ranged from 0.765 to 1.000. Similar to the embryo transfer families, the cows sired by 297J ranked the lowest for calving rate at 0.800, and cows sired by 432H ranked the highest at 0.891. The 4-yr-old cows ranked the highest for calving rate based on age at 1.000 for natural service families, similar to what was seen in the embryo transfer females. Also similar to the full sib cow families, the 3-yr-old cows ranked the lowest for calving rate at 0.800. Cows out of Brahman-Angus dams had a lower calving rate than cows out of Brahman-Hereford dams (0.765 and 0.916, respectively). Sanders et al. (2005) found that F_1 Brahman-Angus cows had a calf crop born rate of 0.90 and for F_1 Brahman-Hereford cows the rate was 0.89. For F_2 Brahman-Angus cows the calf crop born rate was 0.74 and for the F_2 Brahman-Hereford cows it was 0.87. Cundiff (2005) found that for cows calving at 3 through 7 years of age, cows with Brahman sires had a calf crop born percentage of 92.8%, whereas those with Nellore sires had a calf crop born percentage of 97.5%.

Julian Calving Date. Julian calving date means ranged from day 52 to day 72 among full sib cow families. Cows by sire 551G ranked the earliest for average calving date at day 64 as compared to the other sires. Across families, the earliest average calving dates came from families 76 (551G) and 73 (432H) at day 52 and day 54, respectively. The latest average calving date was from family 70 (297J) at day 72. Across cow ages, the earliest average calving date came from 3.5-yr-old cows at day 58 among these embryo transfer females.

For natural service families, cows sired by 437J ranked the earliest for calving date at day 62, and cows out of sire 297J had an average calving date of day 73. Cows that were 4 years old had an average calving day of 66 for natural service families. The 3-yr-old cows had the latest average calving date at day 73. Cows out of Brahman-Angus dams had an average calving date (day 74) that was 6 days later than cows out of Brahman-Hereford dams (day 68).

Weaning Rate. Among embryo transfer families weaning rate ranged from 0.500 to 1.000. Across sires, cows sired by 551G ranked the highest for weaning rate at 0.880, and cows sired by 297J ranked the lowest at 0.821. In these embryo transfer families, family 73 by 432H ranked the lowest at 0.500 but had only 2 observations. Families 82 by 432H and 77 by 551G had a calving rate of 1.000. It is important to consider, however, that family 77 had 17 observations compared to family 82 which only had 2. The 4-yr-old cows ranked the highest for weaning rate based on cow age at 1.000, and the lowest weaning rate due to age was for 3-yr-olds at 0.800 among these embryo transfer families.

For natural service families, cows sired by 551G ranked the highest for weaning rate at 0.889, and cows sired by 437J ranked the lowest at 0.714. Across cow ages, the 4-yr-old cows had the highest weaning rate of 1.000, and the 3-yr-old cows had the lowest weaning rate at 0.733. Cows out of Brahman-Angus dams had a lower weaning rate (0.765) than cows out of half Brahman, half Hereford dams (0.845). Sanders et al. (2005) reported that F_1 Brahman-Angus and F_1 Brahman-Hereford cows had calf crop weaned rates of 0.82. The F_2 Brahman-Angus and F_2 Brahman-Hereford cows had calf crop weaned rates of 0.64 and 0.81, respectively. In a study by Cundiff (2005) of 3 to 7 year old cows in Nebraska, cows out of Brahman sires had a calf crop weaned percentage of 84.3%, compared to Nellore-sired cows at 91.4%.

Calf Survival. Calf survival among embryo transfer families ranged from 0.667 to 1.000. Cows sired by 297J had the highest calf survival rate at 0.970, and cows sired by 437J had the lowest calf survival rate at 0.932. Cows by 432H and 551G had calf survival rates of 0.963 and 0.957, respectively. Among embryo transfer females, 6 families had a calf survival rate of 1.000. Family 73 (432H) had the lowest calf survival rate at 0.667 among these embryo transfer families, but this family only had 4 calves born. For cow age the 3.5- and 4-yr-old cows had a calf survival rate of 1.000, the 2.5-yr-old cows had a calf survival rate of 0.969, and the 2-yr-old cows ranked the lowest for calf survival rate at 0.929. The 3-yr-old cows ranked the second lowest with a calf survival rate of 0.947 among embryo transfer cows.

The natural service cows had calf survival rates that ranged from 0.833 to 1.000 across the four sire families. Cows by sire 437J ranked the lowest for calf survival rate at 0.833, and cows by 432H ranked the next lowest with a calf survival rate of 0.939. Cows sired by 551G ranked the highest for calf survival at 1.000, followed by cows out of 297J with a calf survival rate of 0.950. The natural service cows that were 4 years old had a calf survival rate of 1.000. Cows that were 3 years of age ranked the lowest for calf survival with a rate of 0.917. The 2-yr-old cows had a calf survival rate of 0.947. Cows with Brahman-Angus dams had a calf survival rate of 1.000, and cows out of half Brahman, half Hereford dams had a calf survival rate of 0.923. Calves sired by Nellore-Angus F_1 bulls, had calf survival rates of 0.89 for those out of F_1 Brahman-Hereford cows and 0.93 for those out of F_2 Brahman-Hereford cows in a study by Sanders et al. (2005). Cundiff (2005) reported a higher calf survival rate for calves out of Nellore sires (95.5%) than Brahman-sired calves (88.1%) in Nebraska. Riley et al. (2001a) reported that for calf survival rate for cows across ages 2 to 14 yr, Brahman-sired cows had a rate of 92.3% and Nellore-sired cows had a calf survival rate of 98.9%.

SUMMARY AND CONCLUSIONS

The purpose of this thesis was to evaluate the effects of sire and family on calf growth, udder and teat conformation, and reproduction in young cows. These traits are all important to cow productivity. Understanding the importance of these effects is economically essential for people in the beef cattle industry.

For calf birth weight, sire of cow was significant among embryo transfer cows. As expected, male calves were significantly heavier at birth in both embryo transfer and natural service families. Calf year of birth and cow age were significant for birth weight in embryo transfer cows as well. Among natural service cows there was a calf sex by sire of cow interaction. Male calves out of 551G daughters were the heaviest at birth, however, female calves out of 551G daughters were the lightest; also, the heifer calves out of 297J daughters were heavier than the bull calves. For natural service families the breed of the cow's dam was significant for birth weight. Calves out of cows from Brahman-Hereford dams were 2.0 kg heavier at birth than calves from cows out of Brahman-Angus dams.

Calves out of 297J-sired cows were the heaviest at weaning among full sib cow families. However, calves from family 74 (437J) were slightly heavier at weaning than family 70 (297J). Family was significant for weaning weight, and 2 of the families from sire 432H (73 and 82) were the lightest at weaning among embryo transfer families, but they were very small families (3 and 2 calves, per family, respectively). Calves born in 2005 were the heaviest at weaning for embryo transfer families. As expected, calf sex was significant for weaning weight for both embryo transfer and natural service families with the males calves outweighing the females. Calves out of 4-yr-old cows with their third parity were the heaviest at weaning for natural service families. It should be noted that there was only one calf out of a four year old cow with her second parity for natural service cows.

Sire of cow and family significantly affected average daily gain in embryo transfer families. Calves out of 297J daughters averaged the most gain, whereas those out of 432H daughters averaged the least gain. Males tended to average more gain than did females in embryo transfer families, and calves in 2005 averaged the highest amount of gain. For natural service families, there was a similar trend for sex as male calves averaged more gain per day than did females. Similar to weaning weight, calves out of 4-yr-old cows with their third parity had the highest average daily gain in natural service families.

For average teat length, sire of cow was highly significant among embryo transfer families. Cows by sire 551G had the longest average teat length, whereas cows by sire 432H had the shortest. The same trend was seen in the natural service families as cows by 551G had the longest average teat length and those by 432H the shortest.

Cow age was the only significant effect on average teat diameter for embryo transfer cows. The 4-yr-old cows had the largest average teat diameter. The smallest average teat diameter belonged to the 2-yr-old females. Cow age was also important for average teat diameter in natural service families, however, the 3-yr-old cows had the largest teat diameter. This could be influenced by the fact that there were only 10 animals that were 4 yr of age. Sire of cow was significant for natural service dams on average teat diameter, and cows by sire 297J had the largest average teat diameter.

The only effect that was significant in the analysis of udder support score was sire of cow for the embryo transfer cows. Cows sired by 432H and 437J had the higher, more desirable udder support scores among embryo transfer cows. The same trend, although not significant, was seen in the natural service families.

Cows sired by 437J had the highest (least desirable) average cow disposition score at birth among embryo transfer cows. Family was also significant for cow disposition score at birth for embryo transfer cows. No effects were significant on cow disposition score for natural service families.

Family and sire of cow were significant factors on cow weight at weaning for embryo transfer cows. Cows by sires 432H and 437J were the heaviest. Least squares means show embryo transfer cows were the heaviest in 2005, but in the following year, 2006, they were the lightest. However, analysis of simple means show that cows with calves born in 2007 were the heaviest and dams with calves born in 2005 were the lightest and there were fewer observations in 2005. The effects of cow age and parity nested within cow age were also significant among embryo transfer cows. The 4-yr-old cows were significantly heavier than all other ages among embryo transfer cows. Also the 4-yr-old cows with their second parity were the heaviest followed by the 4-yr-old cows with their third calf. Among natural service dams the calf year of birth trend was significant and similar to the embryo transfer cows. The cows were the heaviest in 2005 and the lightest in 2006. Simple means, however, show that cows with calves born in

2007 were the heaviest at weaning, whereas cows born in 2006 were the lightest. The cows that were 4 yr old were the heaviest at weaning among natural service cows and the 4-yr-old cows with their second calf were the heaviest.

For heifer reproductive performance there appear to be differences in calving and weaning rate due to sire of cow and family for embryo transfer heifers. Females sired by 437J had the highest calving rate and weaning rate. However, females by 297J, who had the lowest calving and weaning rates, had the highest calf survival rate. Among natural service females the trend is similar. Heifers sired by 437J and 551G had the highest calving rate, although they had a lower number of animals. Once again, cows sired by 297J had the lowest calving and weaning rate, but had a perfect calf survival rate. For the embryo transfer females, the heifers that were 2.5 years of age at their first calving had a higher calving, weaning, and calf survival rate than did the females that were 2 at the time of their first calving. Among natural service dams, females out of Brahman-Hereford dams had the highest calving rate, but had a lower weaning rate than did the females from Brahman-Angus dams.

Similar to the heifer reproductive reference for embryo transfer families, there appear to be sire/family differences for calving and weaning rate among natural service females. Cows sired by 437J had the highest calving rate and weaning rate. The 4-yr-old cows had the highest calving, weaning, and calf survival rates of all the ages among embryo transfer cows. In natural service families, cows by sire 432H had the highest calving rate. However, cows sired by 551G had the highest weaning and calf survival rates. The 4-yr-old cows had the highest calving and weaning rate among the cow ages.

The cows out of Brahman-Hereford dams had a much higher calving rate than did cows from Brahman-Angus dams, but, similar to the heifer reproductive summary, the Brahman-Angus dams had a higher calf survival rate.

This research will be continued and used to measure lifetime cow productivity. As there appear to be substantial differences across families for many traits, the results of this research will be used to help identify genetic markers for cow productivity. These genetic markers, and ultimately the causative genes, could be used in the future as part of breeding strategies to aid producers in selection for important cow productivity traits.

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