

**GENETIC PARAMETERS FOR CALVING RATE AND  
AGE AT FIRST CALVING IN HEREFORD HEIFERS**

**by**

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**B.S., TEXAS A&M UNIVERSITY, 2005**

**A THESIS**

**Submitted in partial fulfillment of the  
requirements for the degree**

**MASTER OF SCIENCE**

**Department of Animal Sciences and Industry  
College of Agriculture**

**KANSAS STATE UNIVERSITY  
Manhattan, Kansas  
2010**

**Approved by:**

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## **ABSTRACT**

The purpose of this study was to estimate the heritability of calving rate and age at first calving in Hereford heifers, and evaluate whether age at calving would add accuracy to a genetic evaluation of calving rate. Pedigree and performance data on Hereford heifers born between 2001 and 2007 was provided by the American Hereford Association. After editing to exclude animals that did not fit inclusion criteria, the evaluated dataset contained 94,709 heifers with calving status information. Data were analyzed using single and two-trait animal models to obtain heritability estimates, and genetic correlation between calving rate and age at first calving was determined using MTDFREML. Contemporary groups for calving traits were defined as heifers that were in the same yearling weight contemporary group, and remained in the ownership of the same breeder through the age that they would be expected to calve. Estimates of heritability for calving rate and age at first calving from single-trait models were 0.25, and 0.12, respectively. Genetic correlation between calving rate and age at first calving was -0.01. Calving rate is moderately heritable in Hereford heifers, and can be used in genetic evaluation of sires to improve the trait through selection. Age at first calving has minimal genetic relationship to calving rate, and is not useful in increasing accuracy of selection for calving rate.

Keywords: heifers, calving rate, age at first calving

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## **ACKNOWLEDGEMENTS**

I would like to thank Dr. Dan Moser, major professor, for his guidance, support, and allowing me to pursue my education in venues other than the classroom or research. I would also like to thank my other committee members, Dr. Jenny Bormann, who always had an open door and open mind, for contributing her knowledge of statistical analysis and animal breeding, and Dr. Larry Hollis for his professional support.

I would like to express my sincere appreciation to Dr. Scott Schaake for allowing me to work with the Livestock judging program and his mentoring, guidance, and friendship. This experience enriched my education beyond belief and gave me the chance to work with so many talented individuals. I was able to work with three judging teams, and I would like to thank them, for their hard work and dedication. I would also like to thank Dr. Twig Marston for his direction and advice early in my stint here at Kansas State.

I would like to thank my officemates, especially Dr. Douglas Eborn for his assistance and patience with my many questions, as well as Garrett Parsons, Brad Buttrey, Matt Burns, and Andrea Garman for their friendship and help whenever I asked.

I need to thank my parents, Dwight and Lorena, my siblings, Cornelius and Ashley for their love.

Special thanks go to my loving and devote wife, Kelly, and son Braedon. I want to thank you guys for all the patience, understanding, support and love.

## **CHAPTER 1 - LITERATURE REVIEW**

## **Scrotal Measurements**

Reproductive efficiency of both cows and bulls plays an important part in determining net return for cattle producers across all phases of the cattle industry. We often use scrotal circumference (SC) of sires as an indicator trait for female reproductive capacity of their offspring.

In 1978, Brinks et al. conducted a study that supports this idea. They utilized records on 202 females (16 Red Angus, 45 Angus, 141 Hereford) and 287 bulls (16 Red Angus, 36 Angus, and 235 Hereford). They found that scrotal circumference in bulls was most closely correlated (-0.71) to age at puberty in heifers, indicating that as scrotal circumference in bulls increased, their half-sibling heifer mates reached puberty at earlier ages.

In 1983, Toelle and Robison analyzed data from two Hereford herds that had been involved in long-term data collection for the North Carolina Extension Service. They took several testicular measurements, such as circumference, diameter, length, and volume at 205 days and 365 days of age. Yearling heifers were given two breeding seasons to conceive and produce a calf. They utilized several traits from females: three age-at-first-breeding traits, two age-at-first-calving traits, two pregnancy rate traits, rebreeding interval and calving interval. They used sire-daughter analysis and paternal half sibs for genetic correlations. Seventy five percent or more of the correlations of testicular measurements with pregnancy rates, age at first breeding, and age at first calving were positive. Average correlations were 0.62, -0.55, and -0.66, respectively. They also found that heritabilities for testicular measurements tended to be moderate to

high, while those for female reproduction tended to be low to moderate. This was a key experiment in that it supported the idea that selection for an increase in testicular size would lead to the improvement of female reproduction.

In 2003, Martinez-Velazquez et al. performed a study that evaluated the genetic relationships between scrotal circumference and female reproductive traits. They used data collected on 12 Bos taurus breeds at the U.S. Meat Animal Research Center between 1978 and 1991. They set up several models to perform this evaluation. They scored pregnancy status as either a 1 for heifers calving or weaning a calf, or a 0 for all other females. Their final model for scrotal circumference included fixed effects for age of dam, year of breeding, and breed type. The ages of the females were used as a covariate. The model for age at puberty and age at first calving had the same fixed effects with the inclusion of month of birth. For all traits, random effects were direct genetic, maternal genetic, maternal permanent environmental, and residual. They conducted a three-trait analysis with a derivative-free restricted maximum likelihood algorithm to estimate (co)variance components. They found that variation due to maternal genetic effects was small for all traits.

Morris and Cullen (1993) found very favorable correlations between scrotal circumference and female pubertal traits. For scrotal circumference, genetic correlation estimates with yearling pregnancy rate were  $0.53 \pm 0.66$  and with lifetime pregnancy rates of  $0.34 \pm 0.40$ . The data generally supported the concept of a favorable genetic correlation between pubertal traits (higher SC and lower age at first ovulation and signs of first ovulation (SFO)) and lifetime pregnancy rate. They selected heifers for earlier age at puberty, and saw no correlated response in calving date. This posed an

interesting question of whether or not female fertility could improve by selecting on something other than scrotal circumference.

Eler et al.(2004) conducted a study with Nelore cattle that evaluated the additive genetic relationships between heifer pregnancy and scrotal circumference. They took 43,611 records from both heifers and their bull mates. Heifer pregnancy was considered as a categorical trait, with the value of 1 for the successes and a value of 0 for those females not bred as determined by rectal palpation 60 days after the end of a 90 day breeding season. They reported heritability of 0.68 and 0.61 for yearling heifer pregnancy. When run as a two-trait analysis with scrotal circumference they found heritabilities of 0.69 and 0.63. Through their research they concluded that an EPD for heifer pregnancy was a viable option in the selection of bulls to produce more precocious daughters. Hopefully this measure of genetic potential would be better than utilizing the indicator trait of scrotal circumference in Nelore cattle. They also noted that scrotal circumference would still be valuable in a two-trait analysis to increase the accuracy of the heifer pregnancy EPD for young sire prospects.

### **Calving Date**

There are several ways of predicting reproductive performance in young beef breeding animals such as scrotal measurements, age at puberty, and calving interval. Calving date is another viable option. Calving date is likely to be more heritable and has clear economic significance on profits for the producer. When a producer can have females that calve earlier in the calving season they in turn have calves that weigh more at weaning, and this translates to more pounds and more dollars when marketed. In some studies calving date was preferred over calving interval, because measuring

calving day and selecting for earlier calving date should not lead to adverse response in other reproductive traits. Another concern with using calving interval is the fact that selection for a shorter interval could have some unexpected results. Cows that usually have shorter average calving intervals are those who typically calve later in the calving season. Selecting for these animals could result in an indirect selection for cattle that have a later age at puberty. Maybe one of the more important reasons to use calving date would be that the date is easy to collect. Many ranchers do collect or record calving date and breed associations have the date of birth of all cattle in the registry.

A high calf crop percentage is an essential part of the profitable beef cattle enterprise (Burris and Priode, 1958). They found a correlation of 0.95 between the percentage of cows not calving and the time in which they calved in the previous year. They also evaluated correlations between successive calving dates within three breeds, Angus, Hereford, and Shorthorn. They found correlations of 0.33, 0.38, and 0.46 respectively. Their observations indicated that selection for early calving date would result in an increase in calving percentage and an earlier calving date in the next year when the breeding season is limited to approximately 90 days.

In 1987, Meacham and Notter conducted research that found very encouraging heritabilities when evaluating calving date in Simmental cattle. They also found results that supported the research done by Bourdon and Brinks in 1983. The data analyzed by Meacham and Notter suggested that simultaneous genetic improvement in calving date and calving interval would be difficult. They found that genetic correlations between calving interval and first and second calving dates in were  $-0.83 \pm 0.37$  and  $-0.09 \pm$

0.88, respectively. In contrast the estimated genetic correlation between first and second calving dates was  $0.66 \pm 0.41$ .

The evaluation of calving day is more than just the pregnancy rate of a female, but it also encompasses age at puberty and a heifer's ability to conceive and deliver a calf. The economical significance behind calving day could be very beneficial. Early calving cows have a greater chance of getting rebred within a fixed breeding season. Cows that calve early are given more chances to get bred without extending the calving period of the ranch. Also a desired and indirect effect of earlier calving is a heavier weighing calf at weaning. Burris and Priode (1958) found that earlier calving cows produce more weaning weight the first year, and have a higher percentage calf crop in successive years. Others have found that cows that calve earlier wean more total calf weight during their productive lifetime than those cows that calf later in the calving period.

Several other countries have evaluated calving day as a measure of fertility. In 1990, Meyer et al. showed the heritability and repeatability of calving day with respect to breeding season for Australian Herefords and Angus. Heritability and repeatability estimates were 0.05 and 0.22 for Hereford and 0.08 and 0.10 for Angus, respectively. A subsequent study was performed in 1991 and they found heritabilities and repeatabilities to be 0.13 and 0.29 for Hereford and 0.08 and 0.12 for Angus. New Zealand data showed the heritability for calving day to be 0.02 (Morris et al., 1993a) 0.05 (Morris et al., 1987) and 0.05 (Morris and Cullen, 1994). These New Zealand studies reported repeatabilities of 0.10 (Morris et al., 1993a) and 0.19 (Morris et al., 1987) in crossbreds, and 0.19 in Angus (Morris et al., 2000). The genetic correlations

between subsequent calving days, and repeatability of calving day indicate that early calving in one year is associated with early calving the next year (Rege and Famula, 1993; Marshall et al., 1990). Meyer et al., (1990) reported significant genetic variation in calving day, concluding that it could be utilized as a trait for selection.

One of the potential problems with using calving day is the bias that is developed by culling open cows. The early work that has been done with calving day has excluded the open cows. In 1988, Notter argued that culling open cows would cause the genetic parameters to be biased downward, or underestimated. Notter proposed assigning open cows a calving day based on the calving distribution of the group (Notter and Johnson, 1988). This assumed that all cows would indeed calve if the calving season were long enough.

In 1989 Mackinnon et.al., conducted a study that evaluated genetic variation and covariation in beef cow and bull fertility. In 1990, Buddenberg et al., did a study with Hereford cattle where open cows were excluded from the data set, or they were assigned a calving day and included. He found that there were more open cows in his 2<sup>nd</sup> and 3<sup>rd</sup> groups (25.3 and 23.4%) than in classes 1 and 4 (16.9 and 14.9%).

Measuring female fertility can offer some complications especially when we are dealing with a binary trait such as pregnancy. We not only need an inventory-based record system, but also we need to keep in mind that this is a threshold trait. In some cases we use a threshold model to compute the value for female fertility. In the past, researchers used traditional analytical methods for analyzing pregnancy data. But these traditional methods did not adequately account for the unique properties of categorical information (Golden, et al., 2000).

Golden et al., (2000) also reported that fertility traits are much more heritable than previously thought. They attributed this to measuring fertility with the threshold model. They also stated that the heritabilities of female fertility can be as heritable as most growth traits, such as weaning and yearling weights. In their study they found a heritability value of 0.27 for fertility. The Red Angus Association of America and Colorado State University (Doyle et al., 2000) also conducted a study on heifer pregnancy and scrotal circumference (of their sires). In this study they observed the relationship by looking at the heifer pregnancy genetic merit for five progressively larger additive genetic groups of SC. For the three middle groups they found the relationship to be favorable; however in the two groups on the outer edges they found inconsistency in the relationship. This suggested that maybe there were better ways to evaluated heifer pregnancy than just SC.

Fertility traits have received little attention due to their difficulty in being measured. Another question that is hard to answer is what do we do with the animals that fail to calve? How do we account for them? In 2003, Donoghue et al. attempted to address this problem. Several studies in the past (Notter and 1988, Buddenberg et al., 1990, Meyer et al. 1990), and others have tried to address this issue as well. The Donoghue et al. (2003) study examined three different methods of including this data. One group penalized the open cattle by giving them a penalty value. The next group gave the animal a value from its truncated normal distribution, and finally the third group simply deleted the records of the open cows. They found that there was little difference in the first two methods of data handling. However, the larger estimate of the residual variance under the penalty method suggests that the simulation approach provides a

better method for handling censored records in beef fertility data. They also explained that the lack of significant differences in the sires rankings suggests that both the penalty and simulation methods can be successfully utilized when handling data for a days to calving evaluation.

Donoghue et al. (2004) conducted a study that evaluated female fertility by using threshold-linear analysis of fertility data. They utilized data from several Australian Angus herds where they examined the relationship between days to calving (DC) and two measures of fertility calving at first insemination (CFI) and calving success (CS). A threshold-linear Bayesian model was used for both analyses. Posterior means (SD) of additive covariance and corresponding genetic correlation between DC and CFI were -0.62d (0.19d) and -0.66 (0.12d), respectively. The corresponding point estimates (SD) between the DC and CS were -0.70d (0.14d) and -0.73d (0.06d), respectively. They also stated that these genetic correlations indicate a strong, negative relationship between DC and both measures of fertility in AI data. They concluded that selecting for animals with shorter DC intervals genetically will lead to correlated increases in both CS and CFI. Finally this study stated that the results found with CFI and CS suggested that both could be useful measures for fertility. The definition of CFI allows the identification of animals that not only record a calving event, but they also calve to their first insemination. Thus the values generated from this study would make these traits stronger in a more complete data set.

In 2006, Bormann et al. conducted a study that measured the genetic control of conception rate and pregnancy rate in Angus heifers. They found that heifer pregnancy rate varied from 75 to 95% between herds and 65 to 100% between sires, arriving at an

overall pregnancy rate of 93%. This was measured as the percent of heifers pregnant at pregnancy check after the breeding season. They fitted a single-trait animal model with a relationship matrix in this project. They found heritability of pregnancy and first conception rates of  $0.13 \pm 0.07$  and  $0.03 \pm 0.03$ , respectively. They also used a two-trait model that included growth traits and pregnancy rate, but found that this did not change the heritability of pregnancy rate. They concluded that genetic improvement of fertility traits would be slow if we used pregnancy rate as a selection tool. They also noted that there is still some hope for using pregnancy rate as a selection tool due to the range of breeding values observed for this trait. It is also good that producers keep in mind that favorable measures of pregnancy rate does not equal more calves weaned. There are still other factors that will affect the success of the calf crop. Pregnancy percentage merely means that a heifer became pregnant, not that she had a calf. Controlling environmental factors are, at this time, still the best way to affect or manage a successful calving season.

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**CHAPTER 2: GENETIC PARAMETERS FOR CALVING RATE AND AGE AT FIRST  
CALVING IN HEREFORD HEIFERS**

## INTRODUCTION

Fertility or reproductive performance is one of the most important components of production efficiency and genetic gain in beef production systems. It has been reported to be at least twice as important, economically, as production traits under a conventional cow-calf operation (Melton, 1995). Reproductive traits in cattle are difficult to measure and interpret. In pasture situations it is extremely difficult due to the limited information on the cow; other than the fact that she did or did not have a calf. Reproductive data is complex in nature and is affected by many events that occur during the breeding season. Very few breed associations have genetic measures for reproductive potential. Some steps have been taken with the addition of breeding values for traits like stayability, which is a measure of a cow's predicted productive life. Cattlemen and scientists also use scrotal circumference as a proxy for bulls' daughter's age at puberty.

Traditionally, management has been used to maximize herd reproductive efficiency. Recently there has been great interest in the development of an expected progeny difference that helped predict female reproductive efficiency. In 1998, the Red Angus Association of America and Colorado State University performed a collaborative study to create a heifer pregnancy EPD. The purpose of this study was to generate a heifer calving rate EPD from whole-herd calving data, and to investigate the use of calving date as an indicator trait. Currently there are several breeds associations with reproductive measures that have been converted to EPDs. The American Angus Association publishes a heifer pregnancy evaluation that puts heifer pregnancy in a value that you rank with a percentile table.

## **MATERIALS AND METHODS**

A complete copy of the pedigree and performance databases was received from the American Hereford Association (AHA), Kansas City, Missouri, beginning in 2008. The most recent data extract, used in the final analysis, was received in June 2010. AHA began collecting whole herd data from an inventory-based recording system in 2001. Data used in the study were from calving years 2001 through 2007. Heifers born after 2007 might not have complete calving data recorded in the database as of June 2010 and were excluded.

Contemporary groups for calving traits were defined as heifers that were in the same yearling weight contemporary group, and remained in the ownership of the same breeder through the age that they would be expected to calve (up to three years of age). Yearling weights must have been collected within AHA age requirements, 300 to 450 days of age. For heifers that did calve, their calves must have been in the same birth weight contemporary group. Heifers not calving were assigned to the same calving contemporary group as the largest group of their herdmates.

Heifers that were transferred to ownership other than the original breeder were deleted from the data. Disposal codes provided by breeders were also used in data editing. Heifers that were disposed due to calving difficulty remained in the data, and were assumed to have calved. Heifers that were disposed due to infertility or non-pregnant status also remained in the data and were assumed to not have calved. All other disposed heifers were deleted from the data.

After contemporary groups were formed, small contemporary groups of less than five heifers were deleted. Also, groups with no variation for calving rate (all calved or all open) were also deleted. After editing, 94,709 heifers in 4,810 contemporary groups were used in the single-trait analyses. While it was possible to analyze this amount of data with single-trait models with our computing resources, a two-trait analysis was not possible. Further editing removed all contemporary groups with less than 25 heifers. The resulting dataset, used for the two-trait analysis, included 65,131 heifers in 1700 contemporary groups.

Three generations of pedigree data on each heifer were extracted from the AHA pedigree database. The final pedigree file in the single trait analyses included 157,604 animals, while the two-trait analysis included 152,452 animals. For our analysis we used MTDFREML to compute the variances, correlations, and heritability. A generalized linear animal model, using the relationship matrix, was fitted.

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}\mathbf{u} + \mathbf{e},$$

$\mathbf{y}$  = vector of phenotypic records,  
 $\mathbf{X}$  = incidence matrix relating fixed effects to records,

$\boldsymbol{\beta}$  = vector of fixed effects,

$\mathbf{Z}$  = incidence matrix relating animals to records,

$\mathbf{u}$  = vector of random additive direct genetic effects, and

$\mathbf{e}$  = vector of residuals.

Expectations, variances, and covariances, respectively, were:

$$E(\mathbf{y}) = \mathbf{X}\boldsymbol{\beta},$$

$$Var(\mathbf{y}) = \mathbf{Z}\mathbf{G}\mathbf{Z}' + \mathbf{R},$$

$Var(\mathbf{u}) = \mathbf{G}$ ,  $\mathbf{G} = \mathbf{A}\sigma^2_G$  and  $\mathbf{A}$  = numerator relationship matrix

$Var(\mathbf{e}) = \mathbf{R}$ ,  $\mathbf{R} = \mathbf{I}\sigma^2_E$  and  $\mathbf{I}$  = identity matrix

$$Cov(\mathbf{u}, \mathbf{e}) = 0$$

REML estimates for calving rate, expressed on a binomial scale, were transformed to the supposed underlying normal scale utilizing the formula described by Robertson (1950).

## **RESULTS AND DISCUSSION**

When evaluating calving rate, our estimate of heritability, 0.18, was slightly higher than those found in the literature. In comparison, Bormann et al., (2006) estimated heritability of calving rate to be 0.13.

Doyle et al. (2000) found a heritability estimate of 0.21 for heifer pregnancy. In 2000 Golden et al. reported heritability for heifer pregnancy to be 0.27.

For age at first calving, our estimate of heritability was 0.05. These results are lower than those found in the literature. Bormann et al. (2010) found a heritability of 0.28, Our estimate was also lower than the 0.24 heritability found by Frazier et al. (1999), and Toelle and Robison, (1985).

In our data, the genetic correlation between calving rate (CR) and age at first calving (AFC) was -0.01 indicating no genetic relationship between these traits. Sires whose daughters calve early do not necessarily have a genetic advantage in calving rate. Adding AFC as a correlated trait in a genetic evaluation of CR will not add accuracy to CR EPD. In contrast, Morris and Cullen (1994) reported a correlation between pregnancy rate and SC of 0.53 for yearling pregnancy rate and 0.34 for life time pregnancy rate. The correlation found between CR and AFC was -0.01. Table 2 shows the heritabilities, and the genetic and phenotypic correlations between AFC and CR. When compared to the study by Bormann et al. (2006), the heritability for calving rate was similar.

## **IMPLICATIONS**

Female reproduction is possibly the most economically significant trait that producers rely on to help generate profit. It is also one of the most difficult traits to find an accurate and useful means of measurement genetically. Our data indicates that calving rate data from whole herd reporting programs can be used in genetic evaluation to identify superior sires. Age at first calving was found to have very little genetic relationship with calving rate, and including it in a multiple-trait evaluation would add very little additional information.

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## Tables

**Table 1: Means and standard deviations for single and two-trait analysis**

	N	Contemporary Groups	Mean	Std. Dev.
<b>Single-trait analysis</b>				
Calving rate %	94709	4809	0.664805	0.472061
Age at first calving(d)	62895	4809	782.073	129.896
<b>Two-trait analysis</b>				
Calving Rate %	65131	1700	0.666288	0.471542
Age at first calving(d)	43345	1700	775.238	123.813

**Table 2: Covariances, heritabilities, and genetic correlation for single and two-trait analyses.**

	Additive Genetic	Residual	Genetic	
	(Co)Variance	(Co)Variance	Heritability	Correlation
<b>Single-trait analysis</b>				
Calving Rate%	0.03405	0.15011	0.18	
Age at first calving(d)	505.02	9261.27	0.05	
<b>Two-trait analysis</b>				
Calving Rate%	0.03782	0.14349	0.21	
Age at first calving(d)	697.97	8945.95	0.07	
Calving Rate with	-0.03182	0.34338		-0.01
Age at First Calving				

