ESTIMATES OF GENETIC PARAMETERS FOR CROSSBRED BEEF CATTLE

by

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GRADUATE COLLEGE
UNIVERSITY OF NEBRASKA

ESTIMATES OF GENETIC PARAMETERS FOR PERFORMANCE TRAITS IN BEEF CATTLE

Adolfo Pérez Marquez, Ph.D.
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Records of birth weight (BW), weaning weight (WW), gestation length (GL), calving difficulty (CD) and survival (SW), of calves produced in a crossing experiment involving originating with Hereford, Angus, Pinzgauer, Brahman, Tarentaise and Sahiwal bulls mated to Hereford and Angus cows were used in this study. The research presented here was divided into three parts: 1) Comparison of first cross dams mated by natural service to Red Poll (n=415), Simmental (n=1879), and Longhorn and Red Poll (n=86 and 81 respectively), or Charolais (n=398) bulls. 2) Estimates of differences among specific crosses resulting from reciprocal back crosses, of 2-way F_2 and 4-way F_1 progeny with known sires used artificially. Genetic variances and covariances among traits were also estimated with sire and dam models. 3) Estimation of differences due to parental inheritance for direct and maternal effects, estimation of differences in direct and maternal heterosis effects between *Bos taurus* x *Bos taurus* and *Bos taurus* x *Bos indicus* crosses, and estimation of (co) variance components among traits with an animal model and a sire and dam model. There were significant differences among breed groups for most traits studied. Generally breed groups characterized by higher birth weight and more calving difficulty were also heavier at weaning. Lowest birth

and weaning weights involved Sahiwal x Angus and Sahiwal x Hereford inheritance. The largest maternal effects on birth weight involved fraction of Pinzgauer, Hereford, and Angus inheritance. The largest direct effects on birth weight involved fraction of Brahman inheritance.

Ranking of breeds based on regression on breed fractions for maternal effects on weaning weight was Pinzgauer, Brahman, Sahiwal, Angus and Hereford with Pinzgauer and Brahman significantly larger than others. Direct breed effects ranked similarly except ranking of Angus and Hereford was reversed. The difference in heterosis due to effects of *Bos taurus* x *Bos taurus* and *Bos indicus* crosses was significant for direct and maternal effects at weaning. These results suggest that *Bos indicus* breeds can make a significant contribution to beef production in temperate climatic zones.

Gestation length was longer for calves with most European, breed inheritance. Analyses for survival at weaning indicated that crossbred calves with Hereford, Angus and Pinzgauer inheritance had the poorest rates of survival to weaning.

Most of the estimates of variance components were simular consistent for the animal and sire models. In most cases the pattern of estimated correlations among traits and heritability estimates were what might be reasonably expected in agreement with previous reports.

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Finally I dedicate this dissertation to my mother Concepción, my wife Evelia, and my two children Evelia and Adolfo.

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INTRODUCTION

Performance attributes of traits of greatest economic value for different breeds or breed crosses are important in determining the potential value of alternative germplasm resources for profitable beef production. To help define the most efficient system, theoretical considerations of crossbreeding and heterosis effects were presented by Dickerson (1969, 1973) and Hill (1971). Experiments have been conducted on crossbreeding (*e.g.*, Long, 1980; Gregory and Cundiff, 1980; Cundiff *et al.*, 1986; Cundiff *et al.*, 1994) to provide relevant information.

Estimates of genetic and phenotypic parameters for performance traits of beef cattle have been summarized by Mohiuddin (1994) and Koots, *et al.* (1994).

Best linear unbiased prediction (BLUP) of genetic values using mixed model methodology with animal models is the method of choice of animal breeders (Henderson, 1988). Restricted maximum likelihood (REML) estimation of variances and covariances and simultaneous prediction of breeding values is probably most optimum for unbalanced field data. Animal models are computationally demanding. Modifications introduced by Boldman and Van Vleck (1991) to use a sparse matrix solver (Sparspak, George *et al.*, 1980) increased the order of mixed model equations that can be used with REML. Multiple trait derivative-free REML estimates can be obtained, *e. g.*, by using the MTDFREML program of Boldman *et al.* (1993, 1994).

The research presented here is divided into three parts. The

traits studied in the three projects were calf weights, calving difficulty and calf survival. The first part (chapter III) involved the comparison of crossbred dams when mated by natural service to specific sire breeds. Red Poll and Longhorn sires were also compared when mated to 2 and 3 year-old crossbred cows.

In the second part (chapter IV), differences were estimated among specific crosses that resulted in reciprocal backcross, 2-way F_2, and 4-way F_1 progeny with known sires used artificially. Genetic variances and covariances among the traits were also estimated with an animal model and sire and dam models.

The third part (chapter V) deals with: 1) the evaluation of differences among parental breeds for direct and maternal effects 2) the estimation of differences in direct and maternal heterosis effects between *Bos taurus x Bos taurus* and *Bos taurus x Bos indicus* crosses, and 3) estimation of (co) variance components among traits with an animal model and a sire and dam model.

REVIEW OF LITERATURE

The review of literature consists of seven parts. The first section provides a review of genetic aspects of crossbreeding. The second and third sections discuss previous results regarding birth weight and weaning weight respectively. The fourth section provides a review of previous reports of maternal effects. The fifth section discusses previous results regarding gestation length. The sixth section discusses previous results regarding maternal effects. The seventh section provides a brief discussion of correlations among traits.

Genetic aspects of crossbreeding

The word heterosis was proposed by G.H. Shull in 1914 in order to describe the increase in vigor, yield, size, etc. of crossbreeding without any implied interpretation or restriction as to the mechanism of the vigor. This nomenclature has been of a very practical value, as there have been many theories on the exact mechanism of heterosis and inbreeding depression. Early explanations of the phenomenon of heterosis put forward by East (1908, 1909), G. H. Shull (1910, 1911) and A. F. Shull (1912) were summarized by G. H. Shull (1952), as cited by Lindhe (1968). East (1912) recognized a decline in vigor by inbreeding such species, as evidence of the same phenomenon. Hence an explanation of heterosis would also account for depressed vigor with inbreeding. The theory of dominance as a cause of heterosis was put forward by Keeble and Pellew (1910). This theory was confirmed by Bruce (1910) who proved mathematically that there were fewer

homozygous recessives at a particular locus in the F_1 population than the mean number in the two parent stocks. Assuming without evidence that dominance was positively related to fitness, he concluded that the cross of two pure breeds produces a mean vigor greater than the collective mean vigor of the parents. In addition to the dominance theory, another explanation suggested that heterozygosity produces a stimulating effect upon the physiological activities of the organism. This hypothesis was substantially modified by East (1936), who suggested that any increased divergence between alleles would also increase the additivity of their effects on physiological activity.

The overdominance theory of heterosis or hybrid vigor was put forward by Hull (1945). Analyses of collected data on the yield of corn led him to the conclusion that non-additive interactions between genes at different loci were small if they occurred at all. Instead he considered heterosis to be a result of interaction between genes at the same locus and applied to this the term, overdominance, which means that the heterozygote has a genetic value higher than either of the corresponding homozygotes. Jinks (1955) as cited by Lindhe (1968) showed, however, that the existence of interlocus as well as intralocular interaction cannot be ruled out. Bowman (1959) concluded that it is highly probable that there is not a single genetical explanation of heterosis, but that dominance, whether partial or complete, and all types of genetic interaction combined in different proportions in different situations, result in heterosis. He further pointed out the difficulty

of proving that interaction of the overdominance type exists, because under conditions of close linkage, true overdominance in a pair of alleles is indistinguishable from pseudo overdominance due to the effects of two pairs of alleles in the repulsion phase (Crow, 1952). Falconer explained (1964) the nature of inbreeding and heterosis, assuming that epistatic interaction is negligible. A change of a mean value with inbreeding is a consequence of dominance at the loci related to the character, and the direction of the change is toward the more recessive alleles. The dominance may be partial or complete, or may be overdominance; all that is necessary for a *locus* to contribute to a change of the mean due to dominance is that the heterozygote should be not be exactly intermediate between the two homozygotes. The change of the mean that can occur with inbreeding is predominantly in one direction depending on the dominance of the genes concerned.

Heterosis, as with inbreeding depression, depends on dominance of gene action. The amount of heterosis following crossing of two particular lines or populations depends on the square of the difference in gene frequency between the populations (Lindhe, 1952). If the populations do not differ there will be no heterosis. Heterosis will be greatest when one allele is fixed in one population and the other allele in the other population. Considering the combined effects of all loci, the occurrence of heterosis with crossing is dependent on directional dominance. Therefore the absence of heterosis is not sufficient ground for concluding that individual loci show no dominance. Johansson (1961) outlined the

possible mating systems by which the benefical effects of crossbreeding can be utilized: crossbreeding for production of an F_1 generation, double crossbreeding, rotational crossing, grading, and crossing for the foundation of new breeds. Falconer (1960) reported that the difference in the level of true allelic heterozygosity between two pure breeds and their crosses is directly related to the level of heterozygosity with respect to breeds of origin of genes. F_1 cross is totally heterozygous with respect to breed of origin. Nevertheless due to random association of genes, the F_2 cross is expected to be heterozygous in this respect at only half of all loci. Thus, with this heterozygosity, or dominance model, the F_2 is expected to show one half the hybrid vigor (increased value over average of pure breed means) of the F_1. The pure breed or additive genetic effects (A_A and A_B) of breeds A and B and dominance effect (d_{AB}) can be estimated knowing the values of the three mating types. However predictions based on the dominance model can prove to be inaccurate. Such inaccuracy would be of major economic importance where a long term breeding program is undertaken to set-up a production system involving complex multibreed individuals (Kinghorn, 1982).

Although the term "hybrid vigor" describes a phenotypic result of crossing and the term "heterosis" describes a mechanism to explain the underlying genetic factors mediating the phenotypic results, the terms are now often considered to be synonymous (Wyatt, 1986).

Crossbreeding research in the early part of the century was

directed toward the comparison of the performance of hybrid cattle with that of their purebreed contemporaries and the detection of heterosis (Franke *et al.*, 1986). Nevertheless as Black *et al.* (1934) as cited by Wyatt (1986) observed, crossbred cattle not only displayed generally greater vigor, but also displayed attributes peculiar to the breeds represented in the crossbred animals. Based on this principle, crossbreeding research has since been directed toward identifying and quantifying effects due to specific breeds and interactions between breeds.

Birth weight

In beef production, the animal weight represents the most important measurement of productivity, but weight as an expression of productive efficiency must be evaluated in relationship with age. Thus, the relationship between kilograms of weight and the required time to obtain them is an expression of growth (De Alba, 1970). Numerous reports have shown that most measurements of weight: at birth, daily gain between birth and weaning and after weaning, and market weight, are correlated (Cartwright *et al.*, 1958; Swiger and Hazel, 1961; Knapp and Clark, 1947; Lasley *et al.*, 1961). Values of phenotypic correlations between these traits are lower than genetic correlations. Weight increases in a subsequent period cannot be predicted with high precision from increases in measurements for initial periods.

The practical importance of birth weight (BW) as a selection tool depends on the age at which animals are marketed. In a study in Herefords, indirect selection resulted in bulls that weighed 36.5 kg at birth while those not selected for breeding weighed 35.8 kg (Brinks *et al.*, 1961). Thomas (1992) reported that birth weight is positively correlated with weaning, yearling, and mature weights. Therefore selection for any of these traits would cause some increase in birth weight. A major challenge to the beef industry is to find a way to minimize this correlated response in birth weight.

Strohbehn *et al.* (1993) reported that a program of selection for low birth weight could lead to declines in weaning and yearling weights, which does not seem desirable. Nevertheless the author

indicate that in the 1981 Angus sire evaluation report of 673 sires listed, 59 had below average (BW) but were above average on weaning weight, yearling weight, and maternal breeding value.

Much emphasis has been placed on birth weight because research has shown it is the single most important factor associated with calving difficulty especially in 2 year old cows where a one pound (454 grams) increase in birth weight results in a 2% in calving difficulty (Ritchie *et al.*, 1993). The same author also reported that increases in birth weight are not all bad because genetic correlations between it and components of postcalving growth are positive.

Strohbehn *et al.* (1993) evaluated the influence of expected progeny difference for birth weight of Angus sires on the performance of crossbred first-calf heifers, using crossbred heifers three size groups, small (S), medium (M), and large (L). Four Angus sires were used in each size group, with average birth weight EPD's ranging from very low (VL) -1.6; low (L), 1.6, average (A), 3.7, and high (H), 6.4. The authors found that birth weight increased, as expected, as sire EPD increased. Calves from sires with low, average, and high EPDS for birth weight were significantly heavier than calves from VL sires. Calves by L sires were significantly lighter than those by H sires, but were not significantly lighter than those by A sires. Yet the trend suggests that a difference exists. As expected, female size group significantly influenced calf birth weight, (Strohbehn *et al.*, 1993).

Birth weight is a more accurately and more frequently

recorded predictor for improving calving ease than gestation length. Virtually all sires with gestation length data also have progeny calving ease scores recorded (Wray *et al.*, 1987).

A total of 170 Simmental reference sires with 300 or more progeny had above average progeny ratios for both calving ease and yearling weight, which suggests that their daughters will calve more easily than daughters of hard calving sires. However, calving ease for first calving is moderately heritable (about 25%) so that selection is possible (Strohbehn *et al.*, 1993).

Most heritability and repeatability estimates of birth weight of calves have come from beef cattle data. Burris and Blunn (1952) (as cited by Anderson *et al.*, 1965) used paternal half-sib correlations to estimate heritability to be 0.22 for birth weight in beef cattle. Koch *et al.* (1955) estimated heritability and repeatability of birth weight in beef cattle from 4,533 calves. After the data had been adjusted for year and sex effects, they found a heritability of 0.35 and a repeatability of 0.4. Taylor *et al.* (1960) computed repeatability estimates of birth weight from 1,496 beef calves to be 0.10. From correlations between half sibs, Legates *et al.* (1962) computed heritability estimates in dairy cattle to be 0.38. When the authors computed estimates from regression of offspring on dam and from correlations between full sibs, they found heritability estimates of 0.47 and 0.51, respectively. Suchanek *et al.* (1961) (as cited by Anderson *et al.*, 1965) estimated repeatability of birth weight in Red Spotted cattle to be 0.22. Asker *et al.* (1953) (as cited by Anderson *et al.*, 1965) reported heritability of 0.42 and

repeatability of 0.50. The evidence from these studies indicates that heritability of birth weight is fairly high (Anderson *et al.*, 1965).

Frisch (1973) compared drought resistance of *Bos indicus* and *Bos taurus* crossbred herds under tropical conditions for different traits. The author found that birth weights of Zebu cross calves were significantly ($P < .05$) heavier than Shorthorn by Hereford calves, contrary to ranking of birthweights of calves of similar breeding reported previously by Seifert *et al.* (1966) and Kennedy *et al.* (1971). The mean birth weights from Brahman, Africander and Shorthorn by Hereford calves over a period of 4 years were 29.7, 31.0 and 31.8 kg, respectively. Kennedy *et al.* (1971) indicated that weights of Zebu cross calves were unaffected by the drought but that the mean weight of Shorthorn by Hereford calves was reduced by about 4 kg. The authors also found that calf birth weight was significantly ($P < .01$) affected by age of dam or day of year of birth ($b=0.110$ kg/day) but that ranking of the breeds was not altered when the effect of date of birth was removed.

Gregory *et al.* (1965) in an experiment involving 751 calves of Hereford, Angus and Shorthorn breeds and their reciprocal crosses reported a significant heterosis effect on birth weight, but neither interactions of years with breed of sire and breed of dam nor heterosis effects attributable to sires within a breed were important. Thus, the heterosis observed was characteristic of the breeds used rather than of specific sires. The authors also found that estimates of heterosis on BW, were almost twice as great for the Hereford-Angus cross and the Hereford-Shorthorn cross than for the Angus-

Shorthorn cross. The same authors reported that differences between reciprocal crosses were small for BW in crosses involving the Hereford breed with the other two breeds. Hereford sires excelled both Angus and Shorthorn sires in crosses with the third breed for birth weight, although these differences were not significant.

Smith (1976) found that for Hereford and Angus cows mated by artificial insemination (AI) with Hereford, Angus, Jersey, South Devon, Limousin, Charolais, and Simmental bulls that Charolais and Simmental crosses were heaviest at birth and Jersey crosses were lightest. Limousin and South Devon crosses were similar in birth weights and intermediate between the Charolais and Simmental crosses and the Hereford-Angus crosses. Straightbred Hereford calves were 8.4 lb heavier than straightbred Angus calves; a comparable 4.4 lb heavier weight was found for all crossbred calves from Hereford dams than for calves from Angus dams. Males were 5.9 lb heavier at birth than females (80.0 vs 74.1).

Ferrell (1993) reported that birth weights lower than optimum are associated with reduced energy reserves, lowered thermoregulatory capability, and increased calf deaths at or near birth. Low birth weights are also related to low rates of growth after birth and decreased mature size. Conversely, birth weights greater than optimum are associated with greater calving difficulty, calf losses at birth and increased difficulties with rebreeding the cow.

The fetal genotype determines the maximum potential for fetal growth. Nevertheless, it may be argued that the fetus rarely

expresses its full genetic potential for growth (Ferrell, 1993). The author suggested that maternal nutrition, number of fetuses, and environmental temperature may cause further limitation of fetal growth, because those factors are most apparent during the latter stages of gestation when fetal growing rate and nutrients needs are the greatest.

Gregory *et al.* (1993) estimated genetic and phenotypic parameters for several traits for nine pure breeds and three composite populations from records on females that produced calves as two-yr-old (2,942 females by 438 sires). Least squares analyses showed that for calf birth weight males was 7.66 % heavier than females (87.1 vs 80.9 lb) respectively. The heaviest birth weights for males were 98.3, 97.9 and 92.6 lb for Braunvieh, Pinzgauer, Braunvieh and MARC I, respectively. Estimated heritability for BW was .25 ± .10.

Gregory *et al.* (1991) reported differences in birthweight among parental breeds involving (Red Poll, Hereford, Angus, Limousin, Braunvieh, Pinzgauer, Gelbvieh, Simmental, and Charolais) that contributed to three composite populations. The same authors also reported that even though not significant, the level of heterosis for birthweight tended to increase with advancing generations. This tendency was not consistent with an expectation based on retained heterozygosity.

Comerford *et al.* (1986) using a four-breed diallel of Simmental (S), Limousin (L), Polled Hereford (H) and Brahman (B) cattle in five calf crops found that Brahman-sired calves were the