A GENETIC ANALYSIS OF YEARLING MEASURES IN BEEF CATTLE

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A GENETIC ANALYSIS OF YEARLING

MEASURES IN BEEF CATTLE

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INTRODUCTION

Consumer preference indicates that the breeder and feeder should produce cattle which have high edible muscle yields without excess fat. Identification of these cattle is most effective in the carcass, yet the breeder needs to identify the live animals which satisfy this requirement. In addition, the cattle must meet requirements for structural soundness and weight for age for the breeder to make maximum progress in his breeding program.

Subjective appraisal is, perhaps, the most widespread method for evaluating conformation and condition of livestock. Yet, if these subjective appraisals are to contribute to genetic improvement, the breeders must be able to identify and control environmental sources of variation affecting these appraisals, in order to accurately measure genetic variation, and then to use the genetic variation in his breeding programs. It is also necessary to know the genetic and phenotypic relationships between these and other traits of economic importance.

The purpose of this study was to determine if yearling conformation and condition scores had appreciable value in a breeding program. Did birth date of calf or age of dam affect scores and measures of carcass fatness, and were standard corrections for age of calf and age of dam sufficient for adjusting yearling weight? What were the heritabilities of the measures? Were conformation and condition scores two measures of the same thing? How were conformation and condition scores phenotypically and genetically correlated with each other and with measures of weight and carcass fatness?

REVIEW OF LITERATURE

Use of Yearling Measures

Steers are usually slaughtered after they reach a year of age rather than at weaning age. The standardized environment in the feedlot and the additional time which allows for traits to be expressed should permit the breeder to more effectively select for economically important traits such as conformation, condition and yearling weight. Environmental variation associated with milk production of the dam and differences in pastures and season of birth should be substantially reduced. Reduction in environmental variation should increase heritability estimates for these traits.

Koch and Clark (1955) estimated heritability, repeatability, and genetic and environmental correlations for several economically important characteristics on 4,553 Hereford calves. Heritability and repeatability estimates (measured as a permanent characteristic of the cow) were 0.24 and 0.34 for weaning weight, 0.21 and 0.34 for preweaning gain, 0.18 and 0.22 for weaning score, 0.47 and 0.20 for yearling weight, 0.39 and 0.09 for postweaning gain, and 0.27 and 0.02 for yearling score, respectively. Maternal environment appeared to be of little importance for gain from weaning to 365-day weight and for yearling score. Yearling gain was almost independent, genetically, of gain from conception to birth (0.06) and from birth to weaning (-.05).

Postweaning gains of beef calves were evaluated by Swiger *et al.*

(1963) on 1,671 beef calves. Age of dam had no appreciable effect on postweaning gain or score. Pooled estimates of heritability for weaning weight, 396-day weight and 550-day weight were 0.28, 0.45 and 0.53, respectively. The pooled estimates for all calves suggest that 200- and 396-day weights would be about 0.52 and 0.81 as efficient, respectively, as 550-day weight in selecting for 550-day weight.

Genetic and environmental factors affecting performance traits of Hereford bulls were studied by Brinks et al. (1962). Age of dam effects on birth weight, and age of dam and age of calf effects on 180-day gain, 180-day weaning weight, weaning score, 196-day postweaning gain and final weight were studied. Age of dam was a significant source of variation for all traits studied except 196-day postweaning gain.

The theoretical composition of paternal and maternal half-sib correlations, the correlations between offspring and dam, and the correlations between offspring and sire were compared with observed values to estimate the influence of maternal environment by Koch and Clark (1955). These comparisons suggested that maternal environment from conception to birth and from birth to weaning had a large influence on birth weight, gain from birth to weaning, and weaning score, but a small influence on yearling gain and yearling score.

Wilson et al. (1963) obtained estimates of phenotypic and genetic parameters involving conformation and weight for use in selection indexes for beef cattle. A negative genetic correlation of -.39 was obtained between weaning weight and final conformation score. Genetic and phenotypic correlations between weaning weight and daily gain and between final conformation score and daily gain were small and positive. Postweaning daily gain was the most important factor in determining the theoretical progress in weight gain.

Turner (1966) stated that heritability estimates of postweaning growth rate were higher than preweaning growth rate estimates. Consideration of the general standardized environment of feedlot tests and the independence of the calf from his dam allows for fewer environmental conditions to contribute variation in postweaning growth rate. This should result in higher heritabilities as determined by differences among sires.

Some Factors Affecting Yearling Measures

Birth Date of Calf

The relationship of weight and age during short growth periods of cattle appears to be essentially linear. However, other traits may not be affected in the same way by age of calf or by day of birth within season. Differences due to birth date of calf include differences in age of calf and effects associated with day within season differences.

Present adjustments, based on average daily gain from birth to weaning, for age of calf effects on growth traits may be satisfactory. Brinks *et al.* (1962) studied age of calf effects on performance traits of Hereford bulls and concluded that adjustments based on average daily gain were satisfactory, although data previously adjusted had a significant age of calf effect on final weight. Marlowe (1962) also concluded that present adjustments for age of calf at weaning do a satisfactory job on growth traits during the postweaning period. Swiger *et al.* (1963) found the net effect of age of calf on gain past 200 days to be small enough not to need adjustment.

However, results reported by Neville et al. (1965) showed that late born calves had significantly higher fattening gains and weight per day of age at slaughter than calves born early in the season. Early born calves had significantly higher slaughter weights than late born calves. According to work by Swiger et al. (1961) least squares analysis for the effects of weaning age indicated that perhaps age at weaning should be considered in evaluating calves for postweaning gains. Warren et al. (1965) found highly significant quadratic effects for age of calf effect on weight when the range in age was 145-265 days at weaning.

Brown (1961) found that age of calf affected the size of the sex difference in calves with curvilinear differences up to 480 days of age. Age of calf and type of management were also important in choosing correction factors for season of birth adjustments. Swiger (1961) also suggested that different regressions of weaning weight on age of calf should be used for bull and heifer calves to adjust weaning weight for age at weaning.

In work reported by Swiger et al. (1963), postweaning grade showed a 0.015 units change of score per day of age on a scale of 1-15 with most calves in the 8-13 range. Marlowe (1962), however, found that age had no significant influence on grade among 11-24 month old bulls of the Angus, Polled Hereford, and Horned Hereford breeds. In later work, Marlowe et al. (1965) concluded that adjusting average daily gain and grade for differences in age of calf does not appear to be justified if calves are weighed and graded within the age range of 150 to 240 days.

Based on this review, birth date of calf is a major source of variation to consider when adjusting weights during the growth period, and present adjustments based on the assumption that growth rate during the suckling period is essentially linear appear to be satisfactory when postweaning growth is measured. However, reports that average daily gain may decrease with increasing age suggests that further adjustment for age differences may be desirable if the range in age is large. Results for birth date of calf effects on postweaning grades are inconclusive and suggest that further work be done in this field.

Age of Dam

Age of dam is an important source of variation in preweaning growth of calves, but appears to have less influence on postweaning performance.

Gregory (1965) stated that additional research was needed to determine the conditions under which age of dam effect on postweaning gains exist, the possible compensating mechanisms involved and to gain a better understanding of the biology involved.

Postweaning gain of calves was evaluated by Swiger *et al*. (1963) and it was concluded that age of dam effects on postweaning gains and scores were not important. Postweaning weights were adjusted using the same age of dam adjustments used for weaning weights. Neville *et al*. (1962) reported that postweaning performance of Hereford cattle was not significantly influenced by differences due to sires, age of dam, or weight of dam. McCormick *et al*. (1956) had previously reported that age of dam was not related to feedlot gain and that yearling weight and weaning weight were affected about the same by age of dam.

Other results, however, have shown that postweaning traits were affected by age of dam. If the effect of age of dam on weaning weight was independent of subsequent gains, we would expect the same difference at yearling age as at weaning. Koch and Clark (1955) reported less difference in yearling weights than weaning weights, and concluded that the smaller difference at yearling age probably illustrated the tendency of calves to grow more rapidly following periods of limited feed supply, in this case possibly because of differences in milk supply. Fall yearling score, however, was not significantly influenced by age of dam in this study. Brinks et al. (1962) also found that age of dam was a significant source of variation for yearling weight.

Genetic and environmental influences on gain of beef cattle during various periods of life were studied by Swiger (1961). Least squares constants for the effects of age of dam and weaning age indicated that age of dam and perhaps weaning age should be considered when evaluating calves for postweaning gains.

Brown (1961) studied the weight record of 892 Hereford and Angus calves at sixty-day intervals. Calves increased in weight as age of dam increased in early years of cow production and declined after years of peak production. There were distinct differences in time required for cows to reach peak production and in the decline in production of aged cows. These data suggested that age of dam correction factors should be developed in herds and under environmental conditions similar to those in which they would be applied. In contradiction with these results, Cundiff et al. (1966) reported that the effect of age of dam on weaning weights of calves was essentially the same regardless of sex, breed, type of pasture, season of birth, or type of management. This study was based on 13,937 weaning weight records on Hereford and Angus calves recorded with the Oklahoma Beef Cattle Improvement Program over a four year period.

These reports indicate that age of dam is an important source of variation when adjusting performance records. Age of dam effects appear to be smaller for postweaning growth than for weaning and preweaning growth. Results reported are inconclusive on the effect of age of dam on scores and on the best method of computing age of dam corrections.

MATERIALS AND METHODS

Data

The data used in this study were three liveweight measures from 660 bull and steer calves and four carcass measures from 349 of the same calves. Data were collected over a three year period from 1963 through 1965 and included data from four herds in 1963, four herds in 1964, and three herds in 1965. The herds represented were a purebred Angus herd in which twenty-six sires were used over a three year period, a purebred Hereford herd in which nine sires were used over a three year period, a commerical Hereford herd in which twenty-one sires were used over a two year period, and a progeny test herd of Angus cattle in which thirty-five sires were used over a three year period. The progeny test herd was located at the Lake Carl Blackwell Experimental Range, Stillwater, Oklahoma, and the other herds were located at the Fort Reno Livestock Research Station, El Reno, Oklahoma.

All calves were born in the spring. Individual records were classified by year, herd, sire, sex, age of dam, and birth date of calf. A random one-half of the male calves from the progeny test herd were castrated. All male calves from the commercial Hereford herd were castrated, and no males were castrated in the purebred herds. The calves were group-fed in sex and breeding groups. All calves were self-fed the ration found in Table I for a period of 168 days.

TABLE I

COMPOSITION OF RATION

Ingredient	Percent
Corn-and-cob-meal	35.0
Whole oats	10.0
Wheat bran	10.0
Cottonseed meal	10.0
Molasses	5.0
Cottonseed hulls	20.0
Ground alfalfa hay	10.0
	100.0

Liveweight measures were taken at the conclusion of the feeding test conducted at the Fort Reno Livestock Research Station. All calves were placed on feed immediately at weaning and successive 28-day weights taken during a 168-day feeding period. Most calves were weighed on 14-day intervals during the last 28-day period in order to obtain an average 154-day feedlot weight. Following the feeding period, calves from the commercial Hereford herd (steers) and from the progeny test herd (bulls and steers) were transported to the Maurer-Neurer Packing Company, Arkansas City, Kansas, where they were slaughtered and carcass measures obtained.

Variables

Seven variables were selected for analysis in this study. They were adjusted yearling weight, yearling conformation score, yearling condition score, single fat thickness, carcass cutability, estimated percentage kidney fat, and fat thickness per hundredweight of carcass.

Live Weight Measures

Adjusted Yearling Weight

Adjusted yearling weight is a constructed variable that was calculated by the formula:

adjusted yearling weight = postweaning average daily gain x 160 days + 205-day weaning weight adjusted for age of dam.

Postweaning average daily gain was obtained by the formula:

$$\text{postweaning average daily gain} = \frac{\text{final feedlot wt. - actual weaning wt.}}{\text{number of days between weights}}$$

This measure of yearling weight (365 days of age) is considered adjusted for the effects of age of calf and age of dam through use of the 205-day adjusted weaning weight value.

Actual weaning weight was adjusted to a standard 205 days by the following formula:

$$\text{205-day weight} = \frac{\text{(actual wt. - birth wt.)}}{\text{age in days}} \times \text{205 days} + \text{birth weight.}$$

The resulting 205-day weaning weight was adjusted for the effect of age of dam by multiplicative factors as adopted by the U.S.D.A. Federal Extension Service Beef Cattle Records Committee. These factors are presented in Table II.

TABLE II

MULTIPLICATIVE ADJUSTMENT FACTORS FOR AGE OF DAM EFFECTS ON 205-DAY WEANING WEIGHT

Age of Dam (Years)	Factor
2	1.15
3	1.10
4	1.05
5-10	1.00
11-over	1.05

Yearling Conformation Score

Yearling conformation score was measured by visual appraisal of the calves upon completion of the 168-day feeding period. Three judges in 1963 and five judges in succeeding years scored each calf on relative desirability of conformation by considering structural soundness and thickness of muscling. An average of the scores to the nearest one decimal point was used as the individual conformation score, thus, dividing the scores to the nearest one-tenth of one-third of a grade. A numerical scale of 15 points was used in 1963 and 1964 and a numerical scale of 17 points was used in 1965. Values of 11 and 13 represented an "Average Choice" quality score for the two periods, respectively, and one point intervals represented each one-third of a grade.

Yearling Condition Score

Yearling condition score was also measured by visual appraisal by the same panel of judges. Each calf was scored on the relative amount of finish. The score was taken on the same day, on the same numerical scale, and averaged in the same manner as the yearling conformation score.

Carcass Measures

Single Fat Thickness

Fat thicknesses were measured from acetate tracings made in the cooler after the carcasses were ribbed in the normal manner between the 12th and 13th ribs. The single fat measure was taken at a representative point approximately three-fourths the distance from the medial end of the *longissimus dorsi* cross section. The distance was measured on the long axis of the cross section, and the fat thickness was measured perpendicular to the fat surface.

Percent Kidney Fat

Percentage kidney fat was estimated subjectively by well trained and qualified personnel from the beef division of Maurer-Neurer Packing Company at Arkansas City, Kansas.

Carcass Cutability

Carcass cutability was computed by the following equation developed and reported by Murphey *et al.* (1960):

Percentage boneless retail cuts from round, loin, rib and chuck = 52.56 - 4.95 (single fat thickness over rib-eye, inches) - 1.06 (percentage kidney fat) + 0.682 (area of rib-eye, square inches) - 0.008 (carcass weight, pounds).

Fat Thickness Per Hundredweight

Fat thickness per hundredweight was calculated by the formula:

$$\text{Fat thickness/cwt.} = \frac{\text{single fat thickness}}{\text{carcass weight}} \times 100.$$

This measure was used to adjust fat thickness for differences in carcass weight in an attempt to give more accurate comparisons among carcasses of different weights.

Statistical Procedures

All statistical analyses were carried out by use of a 7040 IBM computer located at the Oklahoma State University Computing Center. Statistical analyses included determination of adjustment factors for birth date of calf and age of dam effects on the seven variables, estimation of the heritabilities for these variables, and determination of genetic and phenotypic correlations among the variables.

Adjustments

Linear and quadratic effects for birth date of calf and age of dam were investigated on each variable by least squares (multiple regression analysis). The model assumed for the least squares analysis was as follows:

$$Y_{ij} = \mu_i + \beta_1 X_{1ij} + \beta_2 X^2_{1ij} + \beta_3 X_{2ij} + \beta_4 X^2_{2ij} + e_{ij}$$

where:

Y_{ij} = weight, conformation score, condition score, fat thickness, cutability, % kidney fat, or fat thickness per hundredweight for the j'th calf in the i'th sire, sex, and year group

μ_i = mean for the i'th sire, sex, and year group,

β_1 = a constant associated with linear birth date of calf effect,

X_{1ij} = deviation of the j'th observation from the i'th group mean for birth date of calf,

β_2 = a constant associated with quadratic birth date of calf effect,

X^2_{1ij} = deviation of the j'th observation from the i'th group mean for birth date of calf squared,

β_3 = a constant associated with linear age of dam effect,

X_{2ij} = deviation of the j'th observation from the i'th group mean for age of dam,

β_4 = a constant associated with quadratic age of dam effect,

X^2_{2ij} = deviation of the j'th observation from the i'th group mean for age of dam squared and

e_{ij} = random effect peculiar to each calf.

The normal equations for this model using matrix notation were:

$$[X'X]\ [\beta] = [X'Y]$$

where [X'Y] was comprised of the corrected sums of squares and cross products pooled from 115 matrices for individual sire, sex, and year groups for the liveweight measures and from 72 matrices for the carcass measures. Regressions in each group were assumed to be equal. The X'X, X'Y arrays were as described by Brackelsberg (1966).

Solutions of the normal equations were obtained by use of the Forward Doolittle procedure as presented by Steel and Torrie (1960).

Analysis of variance of reduction sums of squares for each of seven dependent variables was as shown in Table III.

TABLE III

SOURCES OF VARIATION IN THE ANALYSIS OF VARIANCE FOR REDUCTION SUMS OF SQUARES

Source	df	ss
Total	545	
Reduction due to β_1[a]	1	
Reduction due to β_2/β_1[b]	1	
Reduction due to $\beta_3/\beta_1, \beta_2$[c]	1	
Reduction due to $\beta_4/\beta_1, \beta_2, \beta_3$[d]	1	
Error	541	

[a]Reduction due to β_1 = reduction in sum of squares associated with linear birth date of calf effect after correction for the mean,

[b]Reduction due to β_2/β_1 = reduction associated with quadratic birth date of calf effect after reduction for the mean and β_1,

[c]Reduction due to $\beta_3/\beta_1, \beta_2$ = reduction associated with linear age of dam effect after reduction for the mean, β_1, and β_2,

[d]Reduction due to $\beta_4/\beta_1, \beta_2, \beta_3$ = reduction associated with quadratic age of dam effect after reduction for the mean, β_1, β_2, and β_3.

Genetic Analysis

The analysis of variance was employed for estimation of genetic and environmental variances and covariances. Estimation of genetic and environmental variances and covariances from an hierarchal classification analysis of variance was discussed by Turner (1966). A standard library program for computing an hierarchal classification analysis of variance was available at the Oklahoma State University Computing Center. A complete analysis of variance was obtained through use of the program. All expected mean square variance component coefficients were listed with the tabular analysis of variance obtained.

An hierarchal analysis of variance showing the expected mean squares used for estimating genetic and environmental variances for each variable is found in Table IV.

TABLE IV

SOURCES OF VARIATION AND EXPECTED MEAN SQUARES IN THE ANALYSIS OF VARIANCE FOR SINGLE VARIABLES

Source	Degrees of Freedom	Expected Mean Squares
Total	659	
Sex/year	5	
Among-sires/sex/year	110	$\sigma_w^2 + k\sigma_s^2$
Within sire/sex/year	544	σ_w^2

σ_w^2 = variance among offspring within sire groups,

σ_s^2 = variance among sires, within sex, and year groups and

k = the average number of offspring per sire.

If two variables are added and an analysis of variance computed on the resulting sum, a means of estimating the genetic and environmental covariance is available. The variance of a sum of two variables is the sum of the two individual variances plus twice the covariance. Therefore, the among-sire component as estimated is equal to one-fourth the among sire variance of one trait and one-fourth the among sire variance of the second trait plus one-half the among sire covariance between the traits. Having an estimate of one-fourth the genetic variance of each trait from a previous analysis of variance, the genetic covariance can be evaluated. A similar consideration of the within-sire components allows for estimation of the environmental covariance.

An analysis of variance for the sum of two variables showing the expected mean squares is found in Table V.

TABLE V

SOURCES OF VARIATION AND EXPECTED MEAN SQUARES IN THE ANALYSIS OF VARIANCE FOR SUMS OF VARIABLES

Source	Degrees of Freedom	Expected Mean Squares
Total	659	
Sex/year	5	
Among sires/sex/year	110	$\sigma_{w_1}^2 + \sigma_{w_2}^2 + 2\sigma_{w_1w_2} + k\sigma_{s_1}^2 + k\sigma_{s_2}^2 + 2k\sigma_{s_1s_2}$
Within sire/sex/year	544	$\sigma_{w_1}^2 + \sigma_{w_2}^2 + 2\sigma_{w_1w_2}$

$\sigma^2_{w_1}$ = variance within sire groups for variable 1,

$\sigma^2_{w_2}$ = variance within sire groups for variable 2,

$\sigma^2_{s_1}$ = variance among sire groups for variable 1,

$\sigma^2_{s_2}$ = variance among sire groups for variable 2,

$\sigma_{w_1 w_2}$ = covariance between the two variables within sire groups,

$\sigma_{s_1 s_2}$ = covariance between the two variables among sire groups and

k = the average number of offspring per sire.

The mathematical model for the phenotypic value of an individual is

$$P = G + E$$

where P is the phenotypic value, G is the genotypic value and E is the environmental deviation. In the estimation of the parameters the assumptions were made that σ^2_s was an estimate of 1/4 the additive genetic variance and σ^2_w included 3/4 the additive genetic variance plus the environmental variance.

The formula for the parameters estimated were as follows:

$$\text{heritability } (h^2) = \frac{4\sigma^2_s}{\sigma^2_w + \sigma^2_s}$$

$$\text{genetic correlation } (r_G) = \frac{\sigma_{s_1 s_2}}{\sqrt{\sigma^2_{s_1} \cdot \sigma^2_{s_2}}}$$

$$\text{phenotypic correlation } (r_P) = \frac{\sigma_{P_1P_2}}{\sqrt{\sigma^2_{P_1} \cdot \sigma^2_{P_2}}}$$

σ^2_s = sire component variance,

$\sigma_{s_1s_2}$ = sire component covariance between traits,

$\sigma_{P_1P_2}$ = phenotypic covariance between traits and

σ^2_P = within sire variance plus sire variance.

Standard errors were calculated for heritability estimates and genetic correlations according to the methods of Robertson (1959). The formulae used were:

$$\text{standard error } h^2 = [h^2 + \frac{4}{M}] \cdot \sqrt{\frac{2}{N}}$$

standard error of the genetic correlation $\doteq$

$$\frac{1 - r^2_G}{\sqrt{2}} \sqrt{\frac{s.e.h^2_1 \quad .s.e.h^2_2}{h^2_1 \cdot h^2_2}}$$

h^2 = heritability estimate,

M = number of offspring per sire,

N = number of sire groups,

$s.e.h^2$ = standard error of heritability estimate and

r^2_G = squared genetic variance.

RESULTS AND DISCUSSION

Data

Table VI contains means, standard deviations, and coefficients of variation for yearling conformation score, yearling condition score, adjusted yearling weight, estimated cutability, estimated percentage kidney fat, and fat thickness per hundredweight for the 349 bulls and steers slaughtered in this study. The data from the 131 Hereford steers were analyzed separately from the data on the 86 Angus bulls and 132 Angus steers to determine if there was a breed difference in the scoring. The magnitude of the coefficients of variation show that scores were more variable on the Hereford calves although only one sex (steers) was represented. The small variation among scores in the Angus breed, even when two sexes (bulls and steers) were represented, may reflect the inability of the scorers to effectively separate individuals in this breed by visual appraisal. The coefficients of variation for variables other than scores were similar for the two breeds.

Single measures of carcass fatness were more variable than conformation and condition scores for both breeds. The similar breeding and age and the common environment of the feedlot probably contributed to the uniform appearance of the animals and reduced the variation among scores. In addition, conformation scores represented a type of index in that extra merit for thickness of muscling might be offset by structural weaknesses or, conversly, weakness in one trait might be compensated by extra merit in another. Also, the average of several scorers tends to have fewer extremes than scores of one individual. Estimated cutability from an equation containing four variables (Murphey, 1960) was the least variable of the measures studied.

Table VII contains means, standard deviations, and coefficients of variation for yearling conformation score, yearling condition score and adjusted yearling weight for the 240 Hereford and 420 Angus bulls and steers used in this study.

The differences in breed means for conformation and condition scores are more a reflection of the relatively smaller percentage of the Hereford calves scored under the 17 point scoring system than of the Angus calves, rather than an actual breed difference in merit. All Hereford slaughter calves were scored under the fifteen point scoring system used in 1963 and 1964, where a value of 11 represented an "average choice" quality score and one point intervals represented each one-third of a grade. Angus calves however, were also slaughtered in 1965 when a numerical scale of 17 points was used and a value of 13 represented an "average choice" quality score.

TABLE VI

MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIATION FOR YEARLING MEASURES ON 131 HEREFORD AND 218 ANGUS SLAUGHTER CATTLE

Trait	Mean	Standard Deviation	C.V.(o/o)
<u>Hereford</u> <u>Steers</u>			
Yearling Conformation Score[a]	9.95	0.97	9.75
Yearling Condition Score[a]	9.49	0.89	9.38
Adjusted Yearling Weight, lb.	846.58	64.43	7.61
Single Fat Thickness, in.	0.519	0.133	25.55
Estimated Cutability, o/o	48.99	1.46	2.98
Percent Kidney Fat	3.36	0.63	18.75
Fat Thickness/cwt., in.	0.091	0.0206	22.64
<u>Angus</u> <u>Bulls</u> <u>and</u> <u>Steers</u>			
Yearling Conformation Score[a]	10.97	0.73	6.67
Yearling Condition Score[a]	11.18	0.63	5.64
Adjusted Yearling Weight, lb.	864.29	71.34	8.25
Single Fat Thickness, in.	0.543	0.121	22.36
Estimated Cutability, o/o	49.52	1.17	2.36
Percent Kidney Fat	3.27	0.49	15.06
Fat Thickness/cwt., in.	0.100	0.0213	21.30

[a]Scored by visual appraisal. The numerical scale was 15 points in 1963 and 1964, and 17 points in 1965. Values of 11 and 13 represented "average choice" quality scores for the two periods, respectively.

TABLE VII

MEANS, STANDARD DEVIATIONS AND COEFFICIENTS OF VARIATION FOR CONFORMATION SCORES, CONDITION SCORES AND ADJUSTED YEARLING WEIGHTS FOR ALL HEREFORD AND ANGUS CATTLE

Trait	Mean	Standard Deviation	C.V.(%)
Hereford			
Yearling Conformation Score[a]	10.16	0.99	9.73
Yearling Condition Score[a]	10.26	0.86	8.41
Adjusted Yearling Weight, lb.	865.86	70.87	8.18
Angus			
Yearling Conformation Score[a]	10.97	0.80	7.29
Yearling Condition Score[a]	11.22	0.67	5.95
Adjusted Yearling Weight, lb.	856.33	70.42	8.22

[a]Scored by visual appraisal. The numerical scale was 15 points in 1963 and 1964, and 17 points in 1965. Values of 11 and 13 represented "average choice" quality scores for the two periods, respectively.

Adjustments

Adjusted yearling weight is a standard measure that is corrected for differences in age of calf and age of dam. Other measures used in this study are not normally adjusted for differences due to age, birth date or age of dam. Regression analyses were used in this study to determine if birth date of calf and age of dam caused a significant portion of the variation in these yearling measures. Yearling conformation score, yearling condition score, adjusted yearling weight, single fat thickness at the twelfth rib, estimated cutability, estimated percentage kidney fat and fat thickness per hundredweight were regressed on birth date of calf and age of dam in months to determine their linear and quadractic effects. If birth date of calf or age of dam significantly ($P<.05$) affected the variation in these yearling measures, the measures were adjusted to remove the source of variation. Effects of breed, year, and sex were removed by analysis within breed, year, and sex groups.

The analyses of variance with mean squares due to birth date of calf and age of dam effects on these yearling measures are found in Table VIII. Linear effects associated with birth date of calf were significant ($P<.001$) for yearling conformation and yearling condition scores. Linear effects associated with age of dam were significant for yearling conformation scores ($P<.05$) and for yearling condition scores ($P<.01$). Quadratic effects associated with age of dam were significant for yearling conformation scores ($P<.001$), yearling condition scores ($P<.001$) and adjusted yearling weight ($P<.01$).

No significant effects for either birth date of calf or age of dam

TABLE VIII

ANALYSES OF VARIANCE SHOWING REGRESSION MEAN SQUARES FOR DATE OF BIRTH AND AGE OF DAM EFFECTS ON CERTAIN YEARLING MEASURES

Trait	Error D.F.	Birth Date β_1[a]	Birth Date β_2[b]	Age of Dam β_3[c]	Age of Dam β_4[d]	Error Mean Square
Yearling Conformation Score	541	17.121049***	0.053713	3.262987*	6.636614***	0.77598
Yearling Condition Score	541	26.218190***	0.367634	4.926548**	7.414819***	0.56469
Adjusted Yearling Weight	541	5824.7293	1204.0571	6143.1313	28541.913*	5019.9700
Single Fat Thickness	273	0.051313	0.000016	0.007824	0.017632	0.01584
Estimated Cutability	273	5.055355	0.209648	3.210601	1.338488	1.67110
Percent Kidney Fat	273	0.207216	0.047305	0.068826	0.034949	0.30934
Fat Thickness/cwt.	273	0.000041	0.000001	0.000064	0.000055	0.00044

[a] β_1 represents the mean square for linear effects from fitting β_1 after the mean,

[b] β_2 represents the mean square for quadratic effects from fitting β_2 after the mean and β_1

[c] β_3 represents the mean square for linear effects from fitting β_3 after the mean, β_1 and β_2

[d] β_4 represents the mean square for quadratic effects from fitting β_4 after the mean, β_1, β_2, and β_3.

*** ($P<.001$) ** ($P<.01$) * ($P<.05$)

were found for single fat thickness, estimated cutability, estimated percentage kidney fat or fat thickness per hundredweight. Therefore, these traits were not adjusted for birth date of calf and age of dam effects.

Yearling conformation scores, yearling condition scores and adjusted yearling weights were adjusted using regression coefficients from the least squares estimates. Table IX contains the common regression coefficients used to adjust these traits.

TABLE IX

COMMON REGRESSION COEFFICIENTS FROM LEAST SQUARES ESTIMATES DUE TO BIRTH DATE OF CALF AND AGE OF DAM EFFECTS ON YEARLING CONFORMATION SCORE, YEARLING CONDITION SCORE AND ADJUSTED YEARLING WEIGHT

Traits	Birth Date		Age of Dam	
	β_1	β_2	β_3	β_4
Yearling Conformation Score	-.00560133	-.00001537	0.03834083	-.00027953
Yearling Condition Score	-.00395927	-.00003762	0.04141987	-.00029546
Adjusted Yearling Weight	-.46882102	0.00204521	1.9475098	-.01833140

The specific adjustment formulae were:

adjusted yearling conformation score = actual yearling conformation

$$\text{score } -[\beta_1(X_{1i}-\bar{X}_1)+\beta_2(X_{1i}^2-\bar{X}_1^2)+\beta_3(X_{2i}-\bar{X}_2)+\beta_4(X_{2i}^2-\bar{X}_2^2)]$$

adjusted yearling condition score = actual yearling condition score

$$-[\beta_1(X_{1i}-\bar{X}_1)+\beta_2(X_{1i}^2-\bar{X}_1^2)+\beta_3(X_{2i}-\bar{X}_2)+\beta_4(X_{2i}^2-\bar{X}_2^2)],$$

adjusted yearling weight' = actual adjusted yearling weight

$$-[\beta_1(X_{1i}-\overline{X}_1)+\beta_2(X_{1i}^2-\overline{X}_1^2)+\beta_3(X_{2i}-\overline{X}_2)+\beta_4(X_{2i}^2-\overline{X}_2^2)]$$

where:

X_{1i} = birth date of the i'th calf,

X_1 = mean for birth date of all calves

X_{1i}^2 = squared birth date of the i'th calf,

X_1^2 = average of the squared birth dates for all calves,

X_{2i} = age of dam in months of the i'th calf,

X_2 = mean for age of dam of all calves,

X_{2i}^2 = squared age of dam for the i'th calf,

X_2^2 = average of the squared ages of dams for all calves.

The Betas were determined in fitting the original model.

The adjustments using a common regression coefficient across breeds and sexes affected the sire components of variance quite differently, tending to lower sire components of variance for Hereford calves, raise the sire component of variance for Angus slaughter calves, and leave the Angus bulls with a negative sire component of variance for scores. It was, therefore, concluded that the assumption that regressions were equal might be invalid, and separate regressions were made for each sex and breed. The regression coefficients from the separate analyses are compared to those from the common analysis in Table X. Standard errors on the regression coefficients from the separate analyses showed that birth date of calf and age of dam effects on scores and weights of Hereford steers were significantly different from the estimates of their effects from the common regression. The data were then adjusted using the regression coefficients determined by

TABLE X

COMPARISON OF REGRESSION COEFFICIENTS FOR SEX AND BREED GROUPS WITH COMMON REGRESSION COEFFICIENTS FROM LEAST SQUARES ESTIMATES DUE TO BIRTH DATE OF CALF AND AGE OF DAM EFFECTS ON YEARLING CONFORMATION SCORES, YEARLING CONDITION SCORE AND ADJUSTED YEARLING WEIGHT

	Birth Date		Age of Dam	
	β_1[a]	β_2[b]	β_3[c]	β_4[d]
Yearling Conformation Score				
Hereford Bulls	0.00921314±.0275	-.00012401±.00016	0.00965094± .0056	
Angus Bulls	-.01169430±.0117			
Hereford Steers	-.06865179±.0236[a]	0.00041510±.00015[a]		
Angus Steers	0.03221730±.0194	-.00019694±.00012	0.07391408± .0277	-.00053109±.00021
Common β	-.00560133	-.00001537	0.03834083	-.00027953
Yearling Condition Score				
Hereford Bulls	0.00716087±.0225	-.00011203±.00013	0.05923768± .0214	-.00042555±.00018
Angus Bulls	-.00053558±.0085	-.00007703±.00005	0.02984379± .0121	-.00020474±.00010
Hereford Steers	-.07251619±.0209[a]	0.00044532±.00013[a]		
Angus Steers	0.03019986±.0179	-.00020756±.00011[a]	0.05956248± .0245	-.00041271±.00019
Common β	-.00395927	-.00003762	0.04141987	-.00029546
Adjusted Yearling Weight				
Hereford Bulls	-.10319007±.4039			
Angus Bulls	-.01195972±.9088	0.00595135±.00541	0.02632685±1.289	-.02699463±.16430
Hereford Steers	0.71323130±.3465[a]			
Common β	-.46882102	0.00204521	1.94750980	-.01833140

[a] β_1 and β_3 represent mean squares associated with linear effects.

[b] β_2 and β_4 represent mean squares associated with quadratic effects.

[c] Significantly different from common β $(\beta_i \pm t = 1.96 \times S.E.\beta_i)$

fitting the model for each sex and breed group.

The separate adjustments for each sex and breed had only minor effects on scores and weights for Hereford bulls and on scores for Angus bulls. Sire components of variance for Hereford and Angus steers were raised for the traits which were adjusted. While the data were extremely variable after adjusting with the separate regression coefficients for each sex and breed, the sample size and degrees of freedom for sires for each group was quite small. The widely differing data suggested no logical reason for pooling after making the separate adjustments and, as only regression coefficients on Hereford steers were significantly different from the common regression coefficients, it was concluded that there was little or no advantage to using separate regressions when such small numbers were involved.

Heritability estimates were calculated using both methods of adjustments. A large number of negative sire components of variance were found after adjusting with the regression coefficients for each sex and breed. The negative sire components of variance associated with this method of adjustment prevented calculation of the genetic correlations, so correlations were calculated only from the data adjusted with the common regression coefficient.

Heritability Estimates

Heritability estimates obtained by the half-sib intraclass correlation method are found in Tables XI through XV. Table XI contains heritability estimates from the unadjusted data on the 131 Hereford steers and 218 Angus bulls and steers which were slaughtered. All measures on the Hereford calves appeared to be moderately to highly

TABLE XI

HERITABILITY ESTIMATES FOR UNADJUSTED DATA ON HEREFORD AND ANGUS SLAUGHTER CATTLE [a]

Trait	Degrees of Freedom For Sires	Heritability Estimate	Standard Error [b]
Hereford			
Yearling Conformation Score	17	0.43	0.35
Yearling Condition Score	17	0.67	0.43
Adjusted Yearling Weight	17	0.33	0.31
Single Fat Thickness	17	0.76	0.46
Estimated Cutability	17	0.61	0.41
Percent Kidney Fat	17	0.31	0.31
Fat Thickness/cwt.	17	0.51	0.38
Angus			
Yearling Conformation Score	48	0.13	0.23
Yearling Condition Score	48	0.10	0.22
Adjusted Yearling Weight	48	0.28	0.26
Single Fat Thickness	48	-.001	0.20
Estimated Cutability	48	0.19	0.24
Percent Kidney Fat	48	-.15	0.17
Fat Thickness/cwt.	48	0.07	0.22

[a]Variance components and k values are found in Appendix Tables XXI and XXII.

[b]Standard Error (Robertson, 1959)

heritable, although the small number of sires caused the standard errors to be large. The heritability estimates from the unadjusted data on the Angus calves were decidedly lower, although not significantly different (with the exception of single fat thickness) from the estimates on the Hereford calves. The small to negative sire component variances for carcass measures of fatness associated with the Angus calves was unexpected and caused subsequent difficulty in computing meaningful genetic correlations.

Table XII contains heritability estimates for yearling conformation score, yearling condition score, and adjusted yearling weight on the slaughter calves after adjusting these traits for birth date of calf and age of dam effects with common regression coefficients across sex and breed. The heritability estimates for yearling conformation and condition scores were lowered substantially for the Hereford calves and were raised for the Angus calves so that the two breeds had similar heritability estimates for those traits which were adjusted.

Table XIII contains the heritability estimates after adjusting for age of dam and birth date of calf effects for yearling conformation score, yearling condition score, and adjusted yearling weight with common regression coefficients on all 660 calves in this study. The low heritability estimates for the 240 Hereford calves after making the adjustments would seem to indicate that much of the variation attributed to sires before adjusting the data was in fact associated with differences in birth date of calf and age of dam. Low heritability estimates for conformation and condition scores were also found for the Angus calves. The heritability estimate for adjusted yearling weight on Angus calves increased sharply with the inclusion of the larger number

TABLE XII

HERITABILITY ESTIMATES ON HEREFORD AND ANGUS SLAUGHTER CATTLE AFTER ADJUSTING FOR AGE OF DAM AND BIRTH DATE OF CALF EFFECTS USING COMMON REGRESSION COEFFICIENTS [a]

Trait	Degrees of Freedom For Sires	Heritability Estimate	Standard Error [b]
Hereford			
Yearling Conformation Score	17	0.26	0.27
Yearling Condition Score	17	0.11	0.24
Adjusted Yearling Weight	17	0.03	0.03
Angus			
Yearling Conformation Score	48	0.28	0.26
Yearling Condition Score	48	0.19	0.22
Adjusted Yearling Weight	48	0.28	0.26

[a] Variance components and k values are found in Appendix Table XXIII.

[b] Standard Error (Robertson, 1959)

TABLE XIII

HERITABILITY ESTIMATES ON ALL HEREFORD AND ANGUS CATTLE AFTER ADJUSTING FOR AGE OF DAM AND BIRTH DATE OF CALF EFFECTS WITH COMMON REGRESSION COEFFICIENTS [a]

Trait	Degrees of Freedom For Sires	Heritability Estimate	Standard Error [b]
Hereford			
Yearling Conformation Score	25	0.21	0.20
Yearling Condition Score	25	0.06	0.16
Adjusted Yearling Weight	25	0.12	0.18
Angus			
Yearling Conformation Score	79	0.01	0.13
Yearling Condition Score	79	0.28	0.17
Adjusted Yearling Weight	79	0.66	0.24

[a]Variance components and k values are found in Appendix Table XXIV.

[b]Standard Error (Robertson, 1959)

of Angus bulls which were fed.

Based on these results, it appeared that yearling conformation and condition scores on Hereford and Angus calves were affected differently by birth date of calf and age of dam, or that there were differences in birth dates of calves and ages of dams associated with sires. Heritability estimates for adjusted yearling weight appeared to vary within breed according to sex. Therefore, the data were divided into breed and sex groups and a separate regression analysis run for each group. Separate adjustements for sex and breed groups were made where indicated. The unadjusted and the adjusted data were then analyzed within sex and breed groups, to determine if the heritability estimates did vary with sex within breed and to determine the effects of the separate adjustments.

The heritability estimates from the unadjusted data according to breed and sex groups are found in Table XIV. The Hereford calves were divided into the same groups as in the previous analysis as only Hereford steers were slaughtered. The Angus slaughter calves were divided according to sex. Heritability estimates from the unadjusted data were low to negative for all traits measured on Angus steers. Heritability estimates for all traits, with the exception of percentage kidney fat, were higher for the Angus bulls than for the Angus steers, although not significantly different as the standard errors were large.

Heritability estimates from the data after adjusting for birth date of calf and age of dam effects with separate regression coefficients are found in Table XV. The heritability estimates for scores were lowered somewhat for both Hereford and Angus bulls, while heritability estimates for adjusted yearling weight were raised in both breeds. The

TABLE XIV

HERITABILITY ESTIMATES FOR SEX AND BREED GROUPS FROM UNADJUSTED DATA ON ALL CATTLE [a]

Trait	Degrees of Freedom For Sires	Heritability Estimate	Standard Error [b]
Hereford Bulls			
Yearling Conformation Score	8	0.27	0.34
Yearling Condition Score	8	0.05	0.23
Adjusted Yearling Weight	8	0.01	0.21
Angus Bulls[c]			
Yearling Conformation Score	49	-.02	0.15
Yearling Condition Score	49	0.27	0.20
Adjusted Yearling Weight	49	0.86	0.32
Hereford Steers			
Yearling Conformation Score	17	0.43	0.35
Yearling Condition Score	17	0.67	0.43
Adjusted Yearling Weight	17	0.33	0.31
Single Fat Thickness	17	0.76	0.46
Estimated Cutability	17	0.61	0.41
Percent Kidney Fat	17	0.31	0.31
Fat Thickness/cwt.	17	0.51	0.38
Angus Steers			
Yearling Conformation Score	30	-.02	0.27
Yearling Condition Score	30	0.01	0.27
Adjusted Yearling Weight	30	-.07	0.28
Single Fat Thickness	30	-.40	0.37
Estimated Cutability	30	0.13	0.30
Percent Kidney Fat	30	-.17	0.31
Fat Thickness/cwt.	30	-.30	0.34
Angus Slaughter Bulls			
Yearling Conformation Score	18	0.36	0.44
Yearling Condition Score	18	0.25	0.40
Adjusted Yearling Weight	18	0.74	0.57
Single Fat Thickness	18	0.55	0.50
Estimated Cutability	18	0.28	0.41
Percent Kidney Fat	18	-.13	0.36
Fat Thickness/cwt.	18	0.69	0.55

[a]Variance components and k values are found in Appendix Table XXV.

[b]Standard Error (Robertson, 1959)

[c]Includes purebred and slaughter Angus bulls.

TABLE XV

HERITABILITY ESTIMATES FROM DATA ADJUSTED FOR AGE OF DAM AND BIRTH DATE OF CALF EFFECTS WITH SEPARATE REGRESSION COEFFICIENTS FOR BREED AND SEX GROUPS [a]

Trait	Degrees of Freedom For Sires	Heritability Estimate	Standard Error [b]
Hereford Bulls			
Yearling Conformation Score	8	0.05	0.23
Yearling Condition Score	8	-.03	0.22
Adjusted Yearling Weight	8	0.18	0.29
Angus Bulls[c]			
Yearling Conformation Score	49	-.05	0.16
Yearling Condition Score	49	0.25	0.20
Adjusted Yearling Weight	49	1.53	0.46
Hereford Steers			
Yearling Conformation Score	17	0.75	0.46
Yearling Condition Score	17	1.19	0.61
Adjusted Yearling Weight	17	0.51	0.38
Angus Steers			
Yearling Conformation Score	30	1.17	0.57
Yearling Condition Score	30	0.80	0.47
Adjusted Yearling Weight	30	-.07	0.28
Angus Slaughter Bulls			
Yearling Conformation Score	18	0.33	0.43
Yearling Condition Score	18	0.07	0.34
Adjusted Yearling Weight	18	0.72	0.56

[a]Variance components and k values are found in Appendix Table XXVI.

[b]Standard Error (Robertson, 1959)

[c]Includes purebred and slaughter Angus bulls.

high heritability estimate ($h^2 = 1.53$) for adjusted yearling weight in Angus bulls indicates that there was a source of variation unaccounted for in the analysis and may have been due in part to error associated with the regression coefficients used to adjust the data. The small numbers of sires and offspring per sire associated with sex and breed groups may have let chance contribute to unreliable estimates of regression coefficients for adjusting the data. If the heritability estimates for Angus bulls are unreliable after adjusting with the separate regression coefficients, then the estimates for the other groups adjusted in the same manner should also be viewed with caution as they have fewer sires and smaller total numbers than the Angus bulls.

Heritability estimates for conformation and condition scores on Hereford and Angus steers were high after adjusting with the separate regression coefficients, especially when compared to heritability estimates for the same traits measured on bulls. These differences were not significant due to the size of the standard errors but the estimates on the Angus steers seem particularly questionable due to the large effects of the adjustment. The regression coefficients used to adjust the data on Hereford steers were significantly different from the common regression coefficients and therefore, separate regressions may be indicated if numbers are large enough to obtain reliable estimates. However, the dams of the Hereford steers were involved in feeding trials and, although sires were allotted at random across all treatments, effects due to treatment of dams may have increased the variation between sire means for the Hereford calves and increased the heritability estimates.

A comparison of heritability estimates for breeds indicated that heritability estimates for adjusted yearling weight were significantly higher for Angus bulls than for Hereford bulls both before and after adjustment of the data. The higher heritability estimates for adjusted yearling weight for Angus bulls may have been due in part to greater variation among sires for the Angus calves. Heritability estimates for all measures of carcass fatness were higher for Hereford steers than for Angus steers, and were significantly higher for single fat thickness and fat thickness per hundredweight.

The only meaningful comparison between sexes within breed was between the steers and bulls from the Angus slaughter calves. The Angus slaughter calves represented groups of half-sibs of which a random half were castrated in 1964 and 1965. Heritability estimates from these unadjusted data were higher for all traits measured on the Angus bulls than for the same traits measured on the Angus steers, although both sexes had small negative heritability estimates for estimated percentage kidney fat. However, the only significant difference in heritability estimates between sexes within breed, was for adjusted yearling weight, where bulls had significantly higher heritability estimates than steers.

The heritability estimates differed widely after adjusting the data with separate regression coefficients for each sex and breed. The separate populations from which the estimates were calculated were small, and the standard errors on the regression coefficients showed that only the coefficients for Hereford steers were significantly different from the common regression coefficients. It therefore was concluded that the data were not sufficient to obtain reliable estimates for separate regression coefficients, and correlations were calculated only from the data adjusted with common regression coefficients.

Comparison of the heritability estimates from the data adjusted with common regression coefficients with reports obtained from the literature show that the heritability estimates for yearling conformation score of 0.21 and 0.01 for all Herefords and all Angus, respectively, are somewhat lower than the estimates of 0.27 and 0.33 reported by Knapp and Clark (1951) and Koch and Clark (1955). However, estimates from the unadjusted data in this study ranged from -.02 for Angus steers to 0.43 for Hereford steers. After adjusting for birth date of calf and age of dam effects, heritability estimates of 0.26 and 0.28 were found for Hereford and Angus slaughter calves, respectively. These estimates are in close agreement with the reports from the literature. Few previous reports in the literature have suggested adjustments for scores, but this study indicates that heritability estimates for scores may be influenced by birth date of calf and age of dam.

Heritability estimates for yearling condition score ranges from 0.01 for Angus steers to 0.67 for Hereford steers from the unadjusted data. The heritability estimates for yearling condition score on all calves after adjusting the data with the common regression coefficients were 0.06 and 0.28 for Herefords and Angus, respectively. While the heritability estimate of 0.06 for the Hereford calves is quite low, the estimate of 0.28 for the Angus calves is in close agreement with the estimate of 0.29 reported by Turner (1966).

The heritability estimates of 0.01 to 0.33 for adjusted yearling weight from the unadjusted data, and 0.03 to 0.12 from the Hereford data adjusted with the common regression coefficients are lower than those reported in the literature. The estimates from unadjusted data for Angus calves ranged from -.07 on Angus steers to 0.74 on Angus slaughter bulls. The heritability estimates from the adjusted data of 0.28 for Angus slaughter calves (steers and bulls) and 0.66 for all Angus calves are in general agreement with reports in the literature. Heritability estimates for adjusted yearling weight ranging from 0.34 to 0.86 have been reported by Knapp and Clark (1955), Koch and Clark (1955), Swiger (1961), Brinks et al. (1962), Brinks et al. (1964) and Turner (1966).

Heritability estimates for measures of carcass fatness from Hereford steers and Angus bulls were somewhat higher than those reported in the literature, while estimates for the same traits in Angus steers were consistantly lower than those reported in the literature. No apparent reason for the low heritability estimates from Angus steers was found. Heritability estimates of 0.76, 0.55, and -.40 for single fat thickness were obtained for Hereford steers, Angus bulls, and Angus steers respectively. Estimates ranging from 0.24 to 0.43 have been reported by Shelby et al. (1955), Christians (1962), Shelby et al. (1963), and Cundiff (1966).

The heritability estimates of 0.61, 0.28, and 0.13 for estimated cutability from data on Hereford steers, Angus bulls, and Angus steers, respectively, ranged on both sides of the estimate of 0.40 reported by Cundiff (1966). No reported estimates of heritability for estimated percentage kidney fat or fat thickness per hundredweight in beef cattle were obtained from the literature. However, Munson (1966), using lamb data, reported a heritability estimate of 1.01 for percentage kidney fat obtained by physical separation and weight.

Collectively, these heritability estimates suggest that birth date of calf and age of dam may be important sources of variation in heritability estimates for conformation and condition scores, and that standard adjustments for age of calf and age of dam may not be adequate when adjusting yearling weight. Linear and quadratic effects for birth date of calf and age of dam may vary between the Hereford and Angus breeds or between sexes within a breed, and separate estimates of their effects by sex and breed should be considered when adjusting the data if numbers are sufficiently large to obtain reliable estimates. Further studies with larger numbers of individuals and sires will be necessary to determine whether there is a significant difference in heritability estimates of carcass fatness for the two breeds or for sexes within breeds.

The low heritability estimates for scores after adjusting for birth date of calf and age of dam indicate that such scores under the present system of scoring have only limited value in a breeding program.

Correlations

Phenotypic correlations are gross correlations and include both the genetic and environmental correlations. A genetic correlation between traits is the result of genes responsible for the expression of one trait also influencing the expression of another trait.

Phenotypic and genetic correlations found in this study from the unadjusted data and data adjusted by the common regression coefficients are presented in Tables XVI through XX. Table XVI contains correlations among traits from data which were not adjusted for birth date of calf or age of dam effects for the 131 Hereford calves which were slaughtered. The phenotypic and genetic correlations between yearling

TABLE XVI

PHENOTYPIC AND GENETIC CORRELATIONS AMONG TRAITS FROM UNADJUSTED DATA ON HEREFORD SLAUGHTER CATTLE

Traits	r_P	r_G
Yearling Conformation Score and:		
Yearling Condition Score	0.79[a]	0.85±.14[b]
Adjusted Yearling Weight	0.66	0.07±.62
Single Fat Thickness	0.31	0.18±.48
Estimated Cutability	-.25	-.28±.48
Percent Kidney Fat	0.21	0.38±.54
Fat Thickness/cwt.	0.15	-.16±.54
Yearling Condition Score and:		
Adjusted Yearling Weight	0.74	0.09±.54
Single Fat Thickness	0.50	0.72±.21
Estimated Cutability	-.49	-.82±.15
Percent Kidney Fat	0.36	0.78±.22
Fat Thickness/cwt.	0.32	0.17±.48

[a]Error degrees of freedom = 112, ($r_P > 0.19$ significant at $P < .05$)

[b]Standard error (Robertson, 1959)

conformation score and yearling condition score were high and positive and suggest a close environmental and genetic relationship between these variables. Conformation and condition scores both showed high phenotypic correlations with adjusted yearling weight and low genetic correlations with the same trait. In the unadjusted data, yearling conformation scores had low phenotypic and genetic correlations with measures of carcass fatness, (-.25 to 0.38) indicating that conformation scores and measures of carcass fatness were not closely related. With the exception of fat thickness per hundredweight, yearling condition scores were moderately to highly correlated to measures of carcass fatness and had higher genetic than phenotypic correlations. In the unadjusted data, yearling condition scores accounted for a significant portion of the variation in carcass fatness as determined by these measures.

The phenotypic and genetic correlations among traits from the unadjusted data on the 218 Angus bulls and steers which were slaughtered are found in Table XVII. Yearling conformation and condition scores were closely related phenotypically, ($r_P = 0.73$) but were negatively related genetically ($r_G = -.24$). Although the standard error of 1.32 on the genetic correlation between yearling conformation score and yearling condition score was large enough that the difference between breeds was not significant, it is suggested that a difference may exist between the breeds in this relationship. Yearling conformation and condition scores showed only low to moderate phenotypic correlations with adjusted yearling weight. Yearling conformation and condition scores had negative correlations with adjusted yearling weight although the standard errors were large enough that the correlations

TABLE XVII

PHENOTYPIC AND GENETIC CORRELATIONS AMONG TRAITS FROM UNADJUSTED DATA ON ANGUS SLAUGHTER CATTLE

Traits	r_P	r_G
Yearling Conformation Score and:		
Yearling Condition Score	0.73[a]	-.24±1.32[b]
Adjusted Yearling Weight	0.33	-.63± .55
Single Fat Thickness	0.22	xxx
Estimated Cutability	-.14	0.64± .62
Percent Kidney Fat	0.18	xxx
Fat Thickness/cwt.	0.05	0.62±1.03
Yearling Condition Score and:		
Adjusted Yearling Weight	0.27	-.28± .92
Single Fat Thickness	0.28	xxx
Estimated Cutability	-.22	0.22±1.12
Percent Kidney Fat	0.23	xxx
Fat Thickness/cwt.	0.12	1.15± .59

[a]Error degrees of freedom = 165, (r_P>0.15 significant at P<.05)

[b]Standard error (Robertson, 1959)

[xxx]Correlation undefined (negative sire component of variance)

were not significantly different from zero.

All phenotypic correlations among yearling conformation and condition scores and measures of carcass fatness in the unadjusted Angus data were small. Genetic correlations between yearling conformation score and estimated cutability (r_G = 0.64) and yearling condition score and estimated cutability (r_G = 0.22) were both positive, while the same traits had negative correlations in the Hereford data. Fat thickness per hundredweight was more closely related genetically to yearling condition score (r_G = 1.15) than to yearling conformation score (r_G = 0.62). Although these correlations suggest that yearling condition scores were more closely related to measures of carcass fatness than yearling conformation scores were, no trend was clearly established. Negative sire components of variance when scores were paired with single fat thickness and percentage kidney fat prevented estimation of genetic correlations among these traits. However, if the small sire components of variance for measures of carcass fatness on the Angus calves are estimating zero, then some negative sire components of variance are to be expected.

Phenotypic and genetic correlations among traits on Hereford slaughter cattle after adjusting yearling conformation score, yearling condition score, and adjusted yearling weight for birth date of calf and age of dam effects are found in Table XVIII. Relationships between yearling conformation and condition scores were not changed appreciably by the adjustments. The phenotypic correlations between yearling conformation and condition scores were considerably lower after adjusting the variables for birth date of calf and age of dam effect, and the genetic correlations between the same traits were increased

TABLE XVIII

PHENOTYPIC AND GENETIC CORRELATIONS AMONG TRAITS ON HEREFORD SLAUGHTER CATTLE AFTER ADJUSTING FOR AGE OF DAM AND BIRTH DATE OF CALF EFFECTS

Traits	r_P	r_G
Yearling Conformation Score and:		
Yearling Condition Score	0.78[a]	$0.77\pm.44$[b]
Adjusted Yearling Weight	0.38	$0.27\pm.67$
Single Fat Thickness	0.23	$-.49\pm.43$
Estimated Cutability	-.18	$0.16\pm.58$
Percent Kidney Fat	0.17	$-.08\pm.72$
Fat Thickness/cwt.	0.11	$-.69\pm.32$
Yearling Condition Score and:		
Adjusted Yearling Weight	0.47	$0.58\pm.69$
Single Fat Thickness	0.41	$0.60\pm.52$
Estimated Cutability	-.41	$-.91\pm.15$
Percent Kidney Fat	0.32	$0.83\pm.32$
Fat Thickness/cwt.	0.28	$0.34\pm.79$

[a]Error degrees of freedom = 112, ($r_P > 0.19$ significant at $P < .05$)

[b]Standard error (Robertson, 1959)

considerably. Phenotypic correlations between yearling conformation score and measures of carcass fatness were lowered somewhat by the adjustments. All genetic correlations between yearling conformation score and measures of carcass fatness were small or negative, indicating that conformation could be improved without increasing fatness. With the exception of single fat thickness, the genetic correlations between yearling condition score and measures of carcass fatness were increased by the adjustments.

Phenotypic and genetic correlations among traits on Angus slaughter cattle after adjusting for birth date of calf and age of dam effects are found in Table XIX. The phenotypic correlation between conformation and condition scores was not changed by the adjustments, but the genetic correlation between the same two traits changed from a negative ($r_G = -.24$) to positive ($r_G = 0.50$) relationship. Phenotypic correlations between yearling conformation and condition scores and adjusted yearling weight were changed only slightly by the adjustments. The negative genetic correlation between yearling conformation score and adjusted yearling weight dropped from -.63 to -.32. Genetic correlations between yearling conformation and yearling condition scores and measures of carcass fatness showed no consistent pattern of change due to the adjustments. Genetic correlations between scores and fat thickness per hundredweight decreased, while genetic correlations between scores and estimated cutability increased after the adjustments were made. The negative sire components of variance found in the unadjusted data when scores were summed with single fat thickness and estimated percentage kidney fat were not removed by the adjustments.

The inconsistent relationships between yearling conformation and

TABLE XIX

PHENOTYPIC AND GENETIC CORRELATIONS AMONG TRAITS ON ANGUS SLAUGHTER CATTLE AFTER ADJUSTING FOR AGE OF DAM AND BIRTH DATE OF CALF EFFECTS

Traits	r_P	r_G
Yearling Conformation Score and:		
Yearling Condition Score	0.73[a]	0.50± .55[b]
Adjusted Yearling Weight	0.35	-.32± .59
Single Fat Thickness	0.17	xxx
Estimated Cutability	-.07	1.05±.08
Percent Kidney Fat	0.15	xxx
Fat Thickness/cwt.	0.06	0.35±1.06
Yearling Condition Score and:		
Adjusted Yearling Weight	0.30	-.32± .66
Single Fat Thickness	0.22	xxx
Estimated Cutability	-.16	0.38± .73
Percent Kidney Fat	0.19	xxx
Fat Thickness/cwt.	0.14	0.73± .63

[a]Error degrees of freedom = 165, (r_P>0.15 significant at P<.05)

[b]Standard error (Robertson, 1959)

[xxx]Correlation undefined (negative sire component of variance)

condition scores and measures of carcass fatness in the Angus data and their differing relationships from those found in the Hereford data among the same variables may be due in part to the small sire component variances associated with these variables and loss of precision due to rounding error. However, the differing results of the adjustments on the genetic correlations for other traits and difference in size and direction of the correlations suggest that there may be an actual breed difference in genetic relationships in these populations.

Phenotypic and genetic correlations among live animal measures on all Hereford and Angus calves in the study, after adjusting the traits for birth date of calf and age of dam effects, are found in Table XX. Phenotypic correlations in the Hereford breed were changed only slightly by the addition of data from the feeding trials for purebred bulls. The genetic correlation between yearling conformation score and yearling condition score increased from $0.77 \pm .44$ to $0.99 \pm .01$. The genetic correlation ($r_G = 0.99 \pm .01$) between yearling conformation and yearling condition scores appeared to be a chance high correlation with the standard error forced down by the method of computation. However, the two traits probably are closely related with condition an important part of conformation under the scoring system used. Also, the scores for conformation and condition may have varied among sires more on the bull calves than on the steer calves. The small negative genetic correlation ($r_G = -.10$) between yearling conformation score and adjusted yearling weight was not significantly different from zero, and did not indicate much, if any, antagonism between conformation and weight in the Hereford data. The high positive genetic correlation ($r_G = 0.99 \pm .01$) between yearling condition score and adjusted yearling

TABLE XX

PHENOTYPIC AND GENETIC CORRELATIONS AMONG TRAITS ON ALL HEREFORD AND ANGUS CATTLE AFTER ADJUSTING FOR AGE OF DAM AND BIRTH DATE OF CALF EFFECTS

Traits	r_P	r_G
Hereford		
Yearling Conformation Score and:		
Yearling Condition Score	0.72[a]	0.99 ± .01[b]
Adjusted Yearling Weight	0.43	-.10 ± .84
Yearling Condition Score and:		
Adjusted Yearling Weight	0.47	0.99 ± .01
Angus		
Yearling Conformation Score and:		
Yearling Condition Score	0.67[c]	-.52 ± 1.32
Adjusted Yearling Weight	0.38	-2.24 ± 1.74
Yearling Condition Score and:		
Adjusted Yearling Weight	0.28	-.70 ± .17

[a]Error degrees of freedom = 210, ($r_P > 0.14$ significant at $P < .05$)

[b]Standard error (Robertson, 1959)

[c]Error degrees of freedom = 335, ($r_P > 0.11$ significant at $P < .05$)

weight should be viewed with caution. The summing of the variables with widely differing means and variances when one variable has a sire variance close to zero, may allow error in the estimate of covariance which can have a large effect on the genetic correlation.

Phenotypic correlations among yearling conformation score, yearling condition score and adjusted yearling weight in the Angus data were similar to those found in the Hereford data. Genetic correlations were widely different for the two breeds. The negative genetic correlation between yearling conformation score and yearling condition score (r_G = -.52) from the Angus data is in direct contrast to the positive correlation (r_G = 0.99) found in the Hereford data and the positive correlation (r_G = 0.50) between the same two traits in the adjusted data from the Angus slaughter calves. The negative genetic correlation between these traits may be due to a negative estimate of sire variance from the data on the purebred Angus bulls. The large negative genetic correlation ($r_G = -2.24 \pm 1.74$) between yearling conformation score and adjusted yearling weight in the Angus data is not significantly different from zero due to the large standard error. However, a correlation of this magnitude suggests an error in the estimate of the covariance between the traits and may be due to the small estimate of sire variance for yearling conformation score. Estimates of covariance and genetic correlations appeared to be unreliable when sire variance for either of the variables was very small.

The genetic correlations between adjusted yearling weight and yearling conformation score ranging from -2.24 to 0.27 found in this study are generally lower than those reported in the literature. Blackwell *et al*. (1962) reported a small positive genetic correlation of 0.11, but other estimates by Knapp and Clark (1951), Woodward et al. (1954), Koch and Clark (1955), Woodward et al. (1959), Swiger et al. (1963) and Shelby et al. (1963) were all positive and of greater magnitude. These differences may have been associated with differences in the scoring system used in this study or to failure of the scorers to detect actual differences in the Angus calves. Scores used in this study represented an average of several scorers and were based on thickness of muscling and structural soundness. Generally, the thickest muscled calves were not the largest. Coefficients of variation for the Angus calves indicated that Angus calves were less variable than the Hereford calves or that the scorers failed to detect the differences, and sire variance estimates were small to negative for the Angus calves.

Collectively, these correlations indicate that although an attempt was made to separate conformation and condition when scoring, the attempt was at best only partially successful. However, condition scores did appear to be more closely related to measures of carcass fatness than conformation scores both phenotypically and genetically. Correlations between variables were consistently higher for Hereford calves than for Angus calves, although generally not significantly different. Genetic correlations with single fat thickness and estimated percentage kidney fat from the Angus data were undefined due to negative estimates for sire variance. Changes in genetic correlations due to adjustment of the variables for birth date of calf and age of dam showed no definite pattern as some genetic correlations increased while others decreased after the adjustments. Covariance estimates and genetic correlations appeared to be unreliable when estimates of sire components of variance were close to zero.

Because of differences in correlation estimates for Hereford and Angus calves, the differing effects of the adjustements, the negative estimates of sire variances for some traits in Angus calves, and the small numbers of calves and sires in each breed, these data did not appear to be sufficient to clearly establish the phenotypic and genetic relationships between yearling conformation and condition scores and their relationships with weight and carcass fatness. However, phenotypic correlations were more consistent than genetic correlations, and were similar across breeds and sexes. Genetic correlations varied from high negative to high positive estimates and appeared to vary with breed and sex.

SUMMARY

The data used in this study were three liveweight measures from 660 bull and steer calves and four carcass measures from 349 of the calves. Data were collected over a three year period from 1963 through 1965 and included data from Angus and Hereford herds. A total of 61 Angus and 30 Hereford sires were represented.

All calves were born in the spring. The calves were group-fed in sex and breeding groups for a period of 168 days. Liveweight measures were taken at the conclusion of the feeding test. Then, calves from the commercial Hereford herd (steers) and from the Angus progeny test herd (bulls and steers) were slaughtered and carcass measures obtained.

Yearling conformation scores, yearling condition scores, adjusted yearling weight, single fat thickness, estimated cutability, estimated percentage kidney fat, and fat thickness per hundredweight were regressed on birth date of calf and age of dam in months to determine their linear and quadratic associations. Effects of breed, sex, and year were removed by analysis within breed, sex, and year groups. Yearling conformation scores, yearling condition scores, and adjusted yearling weights were adjusted using regression coefficients from the least squares estimates. The unadjusted data were compared to data adjusted with common regression coefficients across breed and sex and with data adjusted with separate regression coefficients for each breed and sex. The data varied widely after adjusting sex and breed groups with separate regression coefficients and since only regression coefficients for

Hereford steers were significantly different from the common regression coefficients, it was concluded that these data were insufficient to obtain realiable estimates for separate regression coefficients. Therefore, correlations were obtained from the data adjusted with common regression coefficients.

An hierarchal analysis of variance was employed for estimation of genetic and environmental variances and covariances. The variances and covariances were used to estimate heritabilities of the traits and correlations among the traits.

Birth date of calf and age of dam appeared to be important sources of variation in heritability estimates for conformation score, condition score, and adjusted yearling weight, although estimates of their effects varied with sex and breed. Hereford calves had higher heritability estimates for measures of carcass fatness than Angus calves, but the differences were generally not significant. Heritability estimates for scores were low, ranging from 0.01 to 0.28 after adjusting the data for birth date of calf and age of dam effects.

Correlations between variables were consistently higher for Hereford calves than for Angus calves, although generally not significantly different. Changes in genetic correlations due to adjustment of the variables for birth date of calf and age of dam showed no definite pattern as some correlations increased while others decreased after the adjustments. Covariance estimates and genetic correlations appeared to be unreliable when estimates of sire components of variance were close to zero.

These data did not appear to be sufficient to clearly establish the phenotypic and genetic relationships between yearling conformation and condition scores and their relationships with weight and carcass fatness. However, phenotypic correlations were more consistent than genetic correlations, and were similar across breeds and sexes.

Yearling condition score did appear to be more closely related to measures of carcass fatness than yearling conformation score, both phenotypically and genetically. Yearling condition score accounted for a significant portion of the phenotypic variation in conformation score, although neither score accounted for a significant portion of the phenotypic variation in measures of carcass fatness. Genetic correlations varied from high negative to high positive estimates and appeared to vary with breed and sex.

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APPENDIX

TABLE XXI

COMPONENTS OF VARIANCE FROM HIERARCHAL ANALYSES OF VARIANCE FOR UNADJUSTED DATA ON 131 HEREFORD SLAUGHTER CALVES

Variable	$\hat{\sigma}^{2}_{s}$ [a]	$\hat{\sigma}^{2}_{w}$ [b]
Single Variables		
Yearling Conformation Score	0.11554161	0.97136900
Yearling Condition Score	0.16019405	0.79104505
Adjusted Yearling Weight	361.604980	4128.750000
Single Fat Thickness	0.00415616	0.01759409
Estimated Cutability	0.38539965	2.14383370
Percent Kidney Fat	0.03337251	0.40272018
Fat Thickness/cwt.	0.00006246	0.00042427
Sums of Variables		
Yearling Conformation Score plus:		
Yearling Condition Score	0.50790059	3.14278737
Adjusted Yearling Weight	362.60667	4175.553528
Single Fat Thickness	0.12371902	1.08006613
Estimated Cutability	0.38300122	2.41067940
Percent Kidney Fat	0.19676421	1.62106758
Fat Thickness/cwt.	0.11471219	0.97982897
Yearling Condition Score plus:		
Adjusted Yearling Weight	363.20068	4178.848206
Single Fat Thickness	0.20148675	0.91454424
Estimated Cutability	0.13753780	1.83607700
Percent Kidney Fat	0.30842849	1.54998560
Fat Thickness/cwt.	0.16348148	0.80198233

[a] $\hat{\sigma}^{2}_{s}$ = (among sires mean square - within sires mean square)/k

$k = 6.832$

[b] $\hat{\sigma}^{2}_{w}$ = within sires mean square.

TABLE XXII

COMPONENTS OF VARIANCE FROM HIERARCHAL ANALYSES OF VARIANCE FOR UNADJUSTED DATA ON 218 ANGUS SLAUGHTER CALVES

Variable	$\hat{\sigma}^2_s$ [a]	$\hat{\sigma}^2_w$ [b]
Single Variables		
Yearling Conformation Score	0.01744025	0.53833008
Yearling Condition Score	0.00978227	0.40188358
Adjusted Yearling Weight	393.199212	5135.224182
Single Fat Thickness	-.00000500	0.01473589
Estimated Cutability	0.06707850	1.36884469
Percent Kidney Fat	-.00884425	0.24253688
Fat Thickness/cwt.	0.00000801	0.00045364
Sums of Variables		
Yearling Conformation Score plus:		
Yearling Condition Score	0.0209913	1.64274384
Adjusted Yearling Weight	389.834141	5175.418152
Single Fat Thickness	0.01643809	0.59431818
Estimated Cutability	0.12860391	1.62078598
Percent Kidney Fat	-.00553098	0.92737038
Fat Thickness/cwt.	-.01790926	0.53979196
Yearling Condition Score plus:		
Adjusted Yearling Weight	391.215676	5163.757568
Single Fat Thickness	0.01227505	0.45867513
Estimated Cutability	0.8860416	1.42807764
Percent Kidney Fat	0.00503928	0.78040069
Fat Thickness/cwt.	0.01043247	0.40495383

[a] $\hat{\sigma}^2_s$ = (among sires mean square - within sires mean square)/k

k = 4.008

[b] $\hat{\sigma}^2_w$ = within sires mean square.

TABLE XXIII

COMPONENTS OF VARIANCE FROM HIERARCHAL ANALYSES OF VARIANCE FOR HEREFORD AND ANGUS SLAUGHTER CALVES AFTER ADJUSTING THE DATA WITH COMMON REGRESSION COEFFICIENTS

Variable	$\hat{\sigma}^2_s$ [a]	$\hat{\sigma}^2_w$ [b]
Single Variables (Herefords)		
Yearling Conformation Score	0.06540761	0.94691249
Yearling Condition Score	0.2274962	0.79945155
Adjusted Yearling Weight	340.053075	4151.875000
Sums of Variables (Herefords)		
Yearling Conformation Score plus:		
Yearling Condition Score	0.14716947	3.10580879
Adjusted Yearling Weight	342.698349	4202.214233
Single Fat Thickness	0.05339111	1.04955292
Estimated Cutability	0.52242876	2.45696148
Percent Kidney Fat	0.09150974	1.58203778
Fat Thickness/cwt.	0.06266945	0.95517185
Yearling Condition Score plus:		
Adjusted Yearling Weight	343.274449	4207.160751
Single Fat Thickness	0.03855721	0.91594151
Estimated Cutability	0.23847409	1.92543247
Percent Kidney Fat	0.10210105	1.54210553
Fat Thickness/cwt.	0.02361534	0.81014578
Single Variables (Angus)		
Yearling Conformation Score	0.04072268	0.53614464
Yearling Condition Score	0.01961222	0.30907905
Adjusted Yearling Weight	384.117370	5090.290894
Sums of Variables (Angus)		
Yearling Conformation Score plus:		
Yearling Condition Score	0.08845907	1.63049242
Adjusted Yearling Weight	381.597598	5132.848450
Single Fat Thickness	0.3753537	0.58571851
Estimated Cutability	0.21767176	1.67864582
Percent Kidney Fat	0.01634102	0.90716145
Fat Thickness/cwt.	0.04112852	0.53819542
Yearling Condition Score plus:		
Adjusted Yearling Weight	382.354233	5121.357544
Single Fat Thickness	0.01956778	0.44801580
Estimated Cutability	0.11404452	1.49928977
Percent Kidney Fat	0.01362511	0.75664950
Fat Thickness/cwt.	0.02020085	0.40277728

[a] $\hat{\sigma}^2_s$ = (among sires mean square - within sires mean square)/k
k = 6.832 (Herefords), k = 4.008 (Angus)

[b] $\hat{\sigma}^2_w$ = within sires square.

TABLE XXIV

COMPONENTS OF VARIANCE FROM HIERARCHAL ANALYSES OF VARIANCE FOR ALL HEREFORD AND ANGUS CALVES AFTER ADJUSTING THE DATA WITH COMMON REGRESSION COEFFICIENTS

Variable	$\hat{\sigma}^2_s$ [a]	$\hat{\sigma}^2_w$ [b]
Single Variables (Herefords)		
Yearling Conformation Score	0.05309275	0.97842029
Yearling Condition Score	0.01195601	0.74477422
Adjusted Yearling Weight	152.383396	5022.26663
Sums of Variables (Herefords)		
Yearling Conformation Score plus:		
Yearling Condition Score	0.11512848	2.94226190
Adjusted Yearling Weight	151.881002	5085.933289
Yearling Condition Score plus:		
Adjusted Yearling Weight	155.070552	5078.971375
Single Variables (Angus)		
Yearling Conformation Score	0.00192795	0.63979856
Yearling Condition Score	0.0330404	0.44502536
Adjusted Yearling Weight	983.355379	4958.459656
Sums of Variables (Angus)		
Yearling Conformation Score plus:		
Yearling Condition Score	0.02668890	1.85706623
Adjusted Yearling Weight	977.198871	5012.656677
Yearling Condition Score plus:		
Adjusted Yearling Weight	976.443073	4997.098450

[a] $\hat{\sigma}^2_s$ = (among sires mean square - within sires mean square)/k

k = 7.776 (Herefords), k = 4,872 (Angus)

[b] $\hat{\sigma}^2_w$ = within sires mean square.

TABLE XXV

COMPONENTS OF VARIANCE FROM HIERARCHAL ANALYSES OF VARIANCE FOR UNADJUSTED DATA ON ALL HEREFORD AND ANGUS CALVES BY SEX AND BREED GROUPS

Variable	$\hat{\sigma}^2_s$ [a]	$\hat{\sigma}^2_w$ [b]
Hereford Bulls		
Yearling Conformation Score	0.07957665	1.09046905
Yearling Condition Score	0.00990825	0.79878826
Adjusted Yearling Weight	15.772508	5954.744873
Angus Bulls		
Yearling Conformation Score	-.00425944	0.74567788
Yearling Condition Score	0.3974850	0.55293299
Adjusted Yearling Weight	1402.881532	5087.516907
Hereford Steers		
Yearling Conformation Score	0.11554161	0.97136900
Yearling Condition Score	0.16019405	0.79104505
Adjusted Yearling Weight	361.604980	4128.750000
Single Fat Thickness	0.00415616	0.01759409
Estimated Cutability	0.38539965	2.14383370
Percent Kidney Fat	0.03337251	0.40272018
Fat Thickness/cwt.	0.00006246	0.00042427
Angus Steers		
Yearling Conformation Score	-.00319848	0.55797230
Yearling Condition Score	0.00155203	0.47523699
Adjusted Yearling Weight	-93.011429	5160.434326
Single Fat Thickness	-.00142056	0.01543728
Estimated Cutability	0.04299015	1.32196969
Percent Kidney Fat	-.01175246	0.28219435
Fat Thickness/cwt.	-.00003635	0.00051652
Angus Slaughter Bulls		
Yearling Conformation Score	0.04892250	0.50888523
Yearling Condition Score	0.01971257	0.29187566
Adjusted Yearling Weight	1152.445540	5097.454529
Single Fat Thickness	0.00218020	0.01368387
Estimated Cutability	0.10643897	1.43971945
Percent Kidney Fat	-.00588402	0.18305021
Fat Thickness/cwt.	0.00007485	0.00035932

[a] $\hat{\sigma}^2_s$ = (among sire mean square - within sire mean square)/k
k = 9.780 (Hereford Bulls), k = 5.461 (Angus Bulls),
k = 6.832 (Hereford Steers), k = 3.911 (Angus Steers),
k = 4.169 (Angus Slaughter Bulls).

[b] $\hat{\sigma}^2_w$ = within sires mean square.

TABLE XXVI

COMPONENTS OF VARIANCE FROM HIERARCHAL ANALYSES OF VARIANCE FOR ALL HEREFORD AND ANGUS CALVES AFTER ADJUSTING THE DATA WITH SEPARATE REGRESSION COEFFICIENTS FOR SEX AND BREED GROUPS

Variance	$\hat{\sigma}^2_s$ [a]	$\hat{\sigma}^2_w$ [b]
Hereford Bulls		
Yearling Conformation Score	0.01444131	1.04305968
Yearling Condition Score	-.00502215	0.67345443
Adjusted Yearling Weight	258.827368	5568.418335
Angus Bulls		
Yearling Conformation Score	-.00885952	0.65880313
Yearling Condition Score	0.02802210	0.42536538
Adjusted Yearling Weight	4526.118660	7288.906738
Hereford Steers		
Yearling Conformation Score	0.20949486	0.90051160
Yearling Condition Score	0.30514104	0.71237400
Adjusted Yearling Weight	581.359595	3972.857117
Angus Steers		
Yearling Conformation Score	0.211024707	0.51234513
Yearling Condition Score	0.10721539	0.43703638
Adjusted Yearling Weight	-93.011429	5160.434326
Angus Slaughter Bulls		
Yearling Conformation Score	0.04199471	0.46358236
Yearling Condition Score	0.00523928	0.29560805
Adjusting Yearling Weight	1652.200817	7487.363586

[a] $\hat{\sigma}^2_s$ = (among sires mean square - within sires mean square)/k
k = 9.780 Hereford Bulls, k = 4.561 Angus Bulls,
k = 6.832 Hereford Steers, k = 3.911 Angus Steers
k - 4.169 Angus Slaughter Bulls.

[b] $\hat{\sigma}^2_w$ = within sires mean square.

VITA

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