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Relationship of body measurements, weight, age and fatness to size and performance in beef cattle

John Robert McCurley

To the Graduate Council:

I am submitting herewith a dissertation written by John Robert McCurley entitled "Relationship of body measurements, weight, age and fatness to size and performance in beef cattle." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

J.B. McLaren, Major Professor

We have read this dissertation and recommend its acceptance:

W.T. Butts Jr, J.H. Philpor, D.O. Richardson, R.R. Shrode

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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J. B. McLaren, Major Professor

We have read this dissertation and recommend its acceptance:

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RELATIONSHIP OF BODY MEASUREMENTS, WEIGHT, AGE AND FATNESS TO SIZE AND PERFORMANCE IN BEEF CATTLE

A Dissertation

Presented for the

Doctor of Philosophy

Degree

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John Robert McCurley

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ABSTRACT

The objectives of this study were to determine effects of cow weight, cow wither height, cow body volume, cow fat thickness, calf fat thickness, and cow size and shape indexes on 205-day weaning weight, adjusted wither height, approximate body volume, and size and shape indexes of calves. Indexes of size and shape were the result of principal-component analysis.

The data consisted of weight, body measurements and fat thickness measurements of 318 Hereford and 516 Angus cows and their progeny maintained at the Alcoa Farm, The University of Tennessee, Knoxville. Body measurements collected were wither height, body length, body depth and body width. Weaning weight and all body measurements collected on calves were statistically adjusted to a 205-day age basis and were adjusted for sex of calf effects with least-squares estimates of regression obtained directly from these data.

Principal-component analysis, a multivariate technique, was studied as a method to define animal size and shape. The first component for both cows and calves contrasted animals according to general size. It accounted for 56.2 and 46.9 percent of the total variation in cows and calves, respectively. The second component contrasted animals according to body shape. Total variation explained by the first two principal components was 72.5 and 67.2 percent for cows and calves, respectively.

All correlations among cow body measurements and measures of size, and among calf body measurements and measures of size were highly significant (P<.01). Adjusted 205-day weight and calf wither height were highly correlated (P<.01) with the cow measurements and measures of size. Calf volume was significantly (P<.01) correlated with the cow variables. Principal component indexes for size and shape of calves were generally highly correlated (P<.01) with the cow variables. Calf fat thickness was correlated (P<.01) with all cow variables except cow fat thickness, however the correlations were not as large as those with indicators of calf size.

Stepwise multiple regression analysis indicated that calf fat thickness and cow weight controlled the most variation in 205-day weaning weight. Effects of year, breed and cow age also were included in the model as discrete variables, as they were in all regression equations. Independent variables exhibiting the most pronounced effects on calf wither height were calf fat thickness and cow wither height. Calf fat thickness was indicated as the only significant effect on calf volume. Coefficients of determination (R^2) of calf weight, wither height, and volume ranged from 39.7 to 42.9 percent. Independent variables with the greatest effects on calf size index were calf fat thickness, cow weight and cow shape index. Calf fat thickness and cow height were the first effects to enter the equation describing the regression of calf shape index on the cow variables. Coefficients of determination from analyses of calf size and shape indexes were 55.7 and 67.0 percent, respectively.

These analyses indicated that cow weight, cow wither height and calf fat thickness had the most pronounced effects on the measures of calf size and performance.

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CHAPTER I

INTRODUCTION

The usual product of Southeast beef cattle enterprises is a weaned feeder calf ready for movement to a feedlot or stocker operation. For this reason, the primary objective of cattle producers in this region has been to maximize weaning weights of calves. Secondary importance has been assigned to body shape or conformation. In general, bulls have been the only component of the breeding unit to be subjected to intense selection, and the necessity for sire selection has been stated in several reports. Selection of females to enter the breeding unit has generally been limited to pressure on weaning and yearling weight. The result has been an increase in mature cow size. An accurate method of defining cow size is needed, and the relationships among cow size and calf performance need further study.

Cow weight alone or cow weight adjusted for condition have been popular indicators of cow size. Cow weight adjusted for condition has been reported more accurate in defining cow size than weight alone, but condition scores are subjective and considerable error is likely. Skeletal development has been postulated as an indicator of skeletal size (Jeffery and Berg, 1972). These authors concluded that body height was a good measure of skeletal size. Crickenberger and Black (1975) stated that frame size of feeder calves has become more important to cattle feeders. Large framed cattle had higher daily gains and better conversion of feed to gain. Combinations of body measurements may improve the accuracy of defining body size. Approximate body volume was calculated in the present study for this purpose. The multivariate technique of principal-component analysis also was investigated as a method of combining weight, body measurements and fat thickness into indexes to define body size and shape.

The objectives of this study were:

(1) To determine the relationships of cow measurements and measures of size with calf performance.

(2) To determine the effect of cow weight on calf performance.

(3) To determine the effect of cow condition on calf performance.

(4) To determine the effect of cow size indicators: wither height, volume, and size and shape index, on calf performance.

CHAPTER II

REVIEW OF LITERATURE

I. EFFECT OF DAM'S WEIGHT ON PROGENY WEANING WEIGHT

Several research studies have been conducted to quantify the relationship between the dam's body weight and the weaning weight of her progeny. The interest in this area increased during the 1950's when performance testing was accepted as an important tool in beef management. Gregory *et al.* (1950) reported a significant ($P<.05$) coefficient of correlation between calf weaning weight and cow weight at weaning ($r=0.20$) from data collected at one station, and a nonsignificant coefficient ($r=-0.11$) from another station. The difference in these estimates was attributed to different management regimens on the two stations. Also, differences due to sex with respect to gain and weaning weight were not significant. These workers concluded that culling cows on first-calf performance should increase calf weaning weight since cows tended to repeat previous performances with respect to gain of their calves from birth to weaning.

From a study involving Holstein dairy cattle, Blackmore *et al.* (1958) calculated a phenotypic correlation of 0.07 between six month calf weight and dam weight. A much higher estimate of correlation ($r=0.51$) between cow weight and 180-day adjusted weaning weight was reported by O'Mary *et al.* (1959). However, this estimate was calculated from only 20 Angus cow-calf pairs. Brinks *et al.* (1962) calculated a coefficient of correlation between fall cow weight and calf weaning weight of 0.09 from data including 9797 cow-calf records. A 7-lb increase in weaning weight for each 100-lb increase in cow weight was reported by Neville (1962), but he concluded that this estimate was low since variation due to difference in milk production had been statistically removed.

Several other workers reported estimates of the relationship between cow weight and progeny weaning weight and growth rate from birth to weaning during the 1960's. From Oregon, Sawyer *et al.* (1963) studied 230 cow-calf records and determined that there was a fairly low relationship between cow weights and calf performance, but the coefficients of correlation and regression indicated that heavier cows tend to produce calves that gain more rapidly and were heavier from birth through 18 months of age. A similar study utilizing creep-fed calves resulted in a low relationship between fall cow weight and calf weight when age-of-cow effect had been removed (Meiske *et al.*, 1964). However, these workers reported that models containing effects due to year of birth, age of cow, sex, breed and body weight of cow explained 57 percent of the variation in calf weaning weight.

Hawkins *et al.* (1965) determined that average mature cow weight did not significantly affect cow productivity measured as the number of calves born per 100 cows bred, calves weaned per 100 cows bred and 205-day calf weight. A simple correlation between

180-day calf weight and cow weight of 0.34 was reported by Tanner *et al.* (1965). This estimate was calculated from 72 cow-calf pairs, and cow weight was taken at calving, which may have led to a higher value than reported by others.

Vaccaro and Dillard (1966) reported that cows which were heavier at 90 days before calving tended to produce heavier calves at 180 days of age. Nelson and Cartwright (1967) indicated that heavier dams produced calves with higher pre-weaning average daily gain, the relationship being more curvilinear in Herefords than Angus. Heavier dams tended to wean heavier calves, also, in a study including 878 progeny records in Texas (Smith and Fitzhugh, 1968). Singh *et al.* (1969) determined that cow weight did not significantly affect weaning weight of calves; however, heavier cows tended to wean heavier calves.

In the more recent studies involving the effect of cow weight on progeny weight, the results have generally followed those reported from earlier studies. Godley *et al.* (1970) reported that the weight of Hereford dams was positively correlated with calf weight per day of age at 210 days of age, but weight of Angus dams did not significantly affect weight per day of age of their calves. An estimate of correlation of 0.21 was calculated between cow weight and 205-day weaning weight by Urick *et al.* (1971). They also determined that an increase of 45.4 kg in cow weight resulted in a 1.93-kg increase in 205-day weaning weight. Carpenter *et al.* (1972) concluded that variation in size of mature Hereford cows did not significantly affect preweaning gain or 205-day weight. From a Canadian study, Jeffery and Berg(1972) reported that across breed and age of dam, a 10-kg increase in cow weight resulted in a 0.7 kg increase in calf weaning weight. Miguel *et al.* (1972) concluded that heavier cows had slightly heavier calves. They reported significant coefficients of regression of weaning weight on cow weight for male and female progeny of four- to five-year-old cows and for males of cows over ten years of age.

Murphey (1972) determined that cow weight had a positive, nonsignificant effect on weaning weight. A 100-lb increase in cow weight resulted in a 7.3- to 12.2-lb increase in calf weaning weight. From 394 progeny of Angus-Holstein cows bred to Polled Hereford sires, Simpson *et al.* (1972) reported a correlation of 0.22 between metabolic weight of the cow and 205-day weaning weight. Benyshek and Marlowe (1973) calculated adjustments on cow weights and 205-day weaning weights designed to adjust for known environmental influences. The results were only slightly affected by the different correction factors used. Coefficients of regression of weaning weight on adjusted cow weight were 0.08 to 0.10 kg per kg of cow weight. The results indicated a highly significant positive linear relationship between calf growth rate and adjusted cow weight. A significant linear regression of 0.04 kg of weaning weight on dam weight was reported by Edwards and Bailey (1975).

Studies that have been conducted to assess the relationship of cow weight and calf weaning weight have indicated a general trend for heavier cows to produce heavier calves. This has been demonstrated by estimates of regression and correlation, many of which were statistically significant.

II. EFFECT OF DAM'S BODY MEASUREMENTS ON PROGENY WEANING WEIGHT

Various cow body measurements have been used with body weight to define cow size. The effect of these measures on calf weaning weight has also been studied. From a study involving Holstein cows and their daughters, Blackmore *et al.* (1958) reported phenotypic correlations of cow height, cow depth and cow length with six-month daughter weight of 0.12, 0.08 and 0.05, respectively. O'Mary *et al.* (1959) determined correlations of 180-day adjusted calf weaning weight with cow height, cow body length and chest depth of 0.25, 0.33 and 0.27, respectively. However, these estimates were not significant, since they were calculated from only 20 Angus cow-calf pairs. From data collected on 72 Hereford cows and calves, Tanner *et al.* (1965) calculated estimates of correlation of 180-day calf weights with cow wither height and body length of 0.45 in both instances. They reported also a multiple correlation of 0.50 for calf weight with cow wither height and back length.

Jeffery and Berg (1972) determined an increase of 1.82 kg in weaning weight for every cm increase in cow height utilizing Hereford and Angus-Galloway cross cows. Cow measurements generally did not have a significant effect on progeny weaning weight, as reported by Murphey (1972). Cow depth was the only measure that significantly affected weaning weight, and it influenced only heifer calves. Simpson *et al.* (1972) calculated coefficients of partial correlation between progeny weaning weight and cow body measurements. Correlations of weaning weight with height, length and body depth were 0.22, 0.19 and 0.20, respectively.

III. EFFECT OF DAM'S CONDITION ON PROGENY PERFORMANCE

Neel (1966) utilized Angus cows to study the effect of different energy intake levels during the winter on subsequent body weight changes, condition and calf performance. Cows were scored with respect to their condition before and after winter and at the time their calves were weaned. Thin cows produced the heaviest calves at 240 days of age. Cow condition at weaning had a negative effect on calf adjusted average daily gain, but condition scores taken before or after winter had no significant effect on average daily gain of calves. Godley *et al.* (1970) reported that cow condition, scored at breeding, was positively correlated with 90- and 120-day weight per day of age of Angus calves, while condition of Hereford cows was positively correlated with 120-, 180- and 210-day weight per day of age of their calves. A change in cow condition from April to weaning of her calf was negatively correlated with calf weight per day of age.

Cow fat thickness had a negative effect on weaning weight of calves in a study conducted by Murphey (1972). However, the effect was significant only in male calves of the Angus and Hereford cows, but the trend existed in the heifer calves also. The among-sex differences were attributed to different management practices imposed on the cows and their progeny which were grouped according to sex of calf. Simpson *et al.* (1972) calculated a nonsignificant correlation between cow conditions and 205-day calf weight; however, the trend was negative. These workers reported also that cow condition generally did not affect calf body measurements except for a negative ($P<.05$) relationship between cow condition and calf wither height.

IV. RELATIONSHIP OF DAM'S BODY MEASUREMENTS WITH BODY MEASUREMENTS OF PROGENY

Touchberry (1951) calculated intra-sire correlations between body measurements of Holstein cows and measurements of their female progeny. All measures were taken when the animals were three years of age, and all estimates were highly significant ($P<.01$). Dam wither height was positively correlated with progeny wither height, chest depth and body length (r=0.36, 0.32 and 0.28, respectively). Cow chest depth was related to the same progeny characteristics (r=0.30, 0.40 and 0.27, respectively), and they were correlated (r=0.24, 0.25 and 0.29, respectively) with cow body length.

Several correlations among cow body measures and body measurements of progeny were reported by Blackmore *et al.* (1958). Coefficients of correlation of cow height with calf height, depth and length were 0.17, 0.15 and 0.12, respectively. Those of cow depth with calf height, depth and length were 0.04, 0.13 and 0.04, respectively. Estimates of correlation of cow length with the three calf variables were 0.06, 0.06 and 0.09, respectively. Murphey (1972) reported that cow wither height significantly (P<.05) affected the wither height of Hereford and Angus heifers only; however, the positive trend was evident also in the bull calves. Cow body length did not significantly affect any calf body measure. Cow depth significantly (P<.05) influenced wither height of Hereford heifers, but the positive trend was apparent also in Angus heifers and male calves of both breeds.

A partial correlation between cow depth and calf wither height of 0.11 (P<.05) was calculated by Simpson *et al.* (1972). The estimate for cow height with calf height was 0.14 (P<.01). Cow body length was not significantly related to any of the calf measures. Although only a few significant correlations have been reported between cow measures and calf measures, these relationships may be important in a selection program to maintain a desirable conformation as weaning weight increases.

V. RELATIONSHIP OF SIZE AND SHAPE INDEXES IN COWS AND CALVES CALCULATED FROM PRINCIPAL-COMPONENT ANALYSIS

One of the early attempts to relate principal components (PC) with the concepts of size and shape was reported by Jolicoeur and Mosimann (1960) using the painted turtle. Length, width and height of the shell were measured. The equation of the major axis corresponded to a simultaneous increase or decrease of all variables. Therefore, PC1 was interpreted as a growth trend or general size variable, and it accounted for most of the total variation. The direction cosines of the second axis differed in sign corresponding to an increase in one measure and decreases in the others. It was concluded that PC2 was a trend of shape variation with a general contrast of length versus width measures. Carpenter (1971) utilized chest depth, hook width, body length and weight of 38 Hereford cows to perform a principal-component analysis. Coefficients for PC1 ranged from 0.42 to 0.54 defining a size trend and accounted for 75 percent of the total variation. PC2 included both positive and negative coefficients, and thus was interpreted as defining a shape factor, mostly contrasting height and body length. The first two principal components accounted for 90 percent of the generalized variance. Eller (1972) calculated principal component analyses on three different data sets, which included weight, fat thickness or condition score and all available skeletal size scores or measurements. The first two principal components were similar for all three data sets. PC1 contrasted bulls of different sizes since coefficients for all variables were positive, and they accounted for 48 to 68 percent of the total variance. The second principal component accounted for 23 to 36 percent of the variation in the dependence structure. PC2 contrasted bulls of different body shape and, in general, arrayed bulls from those which were fat, wide and small-framed to those which were thinner, narrow and larger-framed.

Brown *et al.* (1973a, 1973b) reported an extensive study of 267 Hereford and 283 Angus bulls utilizing principal component analysis. Nine skeletal measures and body weight were the variables included. As in previously reported studies, PC1 was comprised of positive coefficients, defining a size trend. PC2 again defined shape variation by assigning positive coefficients to shoulder and hip width, and negative values to height and length. Other measures, including weight, received little emphasis in PC2. Separate analyses were performed on measures taken at four and eight months of age. More components were required at the later age to explain the same amount of variation in the dependence structure. They suggested that condition may have a larger effect on the dependence structure among the variates at eight months than at four months. This indicates that the inclusion of a condition score or fat-thickness measure in the analysis may increase the amount of variation each component can explain. The second paper of this series reported genetic and phenotypic correlations of the principal components calculated in the first paper with postweaning feedlot performance. Positive correlation estimates of nine of the measures taken at eight months of age with preweaning gain also were reported. These measures all had positive coefficients for PC1, indicating that PC1 was positively correlated with gain to weaning, as would be expected because PC1 defined a size trend. PC2 was negatively related to all postweaning performance traits, and would be expected to have a similar relationship with preweaning gain, since animals with high values for PC2 were wide, low and short-bodied.

Principal-component analyses of weight, body measures and estimates of fatness, collected at weaning, were calculated by Hammack (1973). Separate analyses were conducted for the Angus and Polled Hereford breeds, and sexes were analyzed individually within breed. The first and second components were generally the same for all four sets of data. PC1 contrasted animals according to overall size and fatness and accounted for 65 to 70 percent of the total variation. The remaining components contrasted animals according to body shape. Stepwise multiple regression analyses were used to predict birth to yearling gain, weaning to yearling gain and yearling condition. PC1 generally entered the equation after age at time of measure and was followed by PC2. This indicated that longer-bodied animals with less condition at a given age and weight tend to have larger gains and smaller yearling condition scores.

These studies indicate that principal-component analysis can be used to combine body weight, measurements and condition into components defining body size and shape. It appears that indexes calculated using the coefficients from this analysis may be useful in selection programs to improve weaning weight while maintaining an acceptable conformation and condition.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. SOURCE OF DATA

The data for this study were collected from the purebred Hereford and Angus cows and calves maintained at The University of Tennessee Alcoa Farm. Calving occurred from January through April, followed by the breeding season beginning in April through July. Following the breeding season, cows and calves were grouped according to age and sex of the calves and pastured in these groups for the remainder of the grazing season.

Grazing of *Dactylis glomerata*, aerial pt, fresh, IRN 2-03-451 (orchardgrass) or *Festuca elatior*, meadow, aerial pt, fresh, IRN 2-01-920 (fescue) began in mid-March through November. Some of these pastures contained also *Medicago sativa*, aerial pt, fresh, IRN 2-00-196 (alfalfa) or *Trifolium repens*, aerial pt, fresh, IRN 2-01-383 (Ladino clover). During winter confinement, the cows were fed a ration consisting of urea-limestone treated *Zea mays*, aerial pt, ensiled, mature, well-eared, mn 30 mx 50 dry matter, IRN 3-08-153 (corn silage) according to N.R.C. (1970) recommendations for mature dry cows.

Newborn calves nursed their dams without supplemental feed until weaning. At the end of the breeding season in early July, the calves and their dams were grouped according to age and sex of calves.

January and February bull calves and their dams were assigned the best pasture available, which generally consisted of an orchard-grass-legume combination. The younger bulls were grouped on orchard-grass pastures with less legume or fescue-clover pastures. Orchard-grass or fescue pastures with little legume were utilized for heifer calves. Older bull calves were weaned in mid-September and all remaining calves were weaned in late October.

II. DESCRIPTION OF DATA

These data were collected from 1969 through 1975. Complete records were available on 318 Hereford and 516 Angus cows and their progeny. The calves were weighed and measured at the time of weaning, and the cows were measured in November or December. In addition to body weight, the following measurements were taken:

(1) Body height--distance from ground to top of withers.

(2) Body length--distance on dorsal midline from the midpoint of the *scapula* (top of shoulder) to a line connecting the prominences of the *ilium* (pins).

(3) Body depth--depth at the heart girth posterior to the *olecranon* (elbow).

(4) Body width--distance between the distal points of the *humerus* (shoulder).

(5) Fat thickness--single measure of subcutaneous fat thickness taken over the *longissimus dorsi* muscle between the 12th and 13th ribs.

The body length measure was taken with a flexible steel tape calibrated in centimeters. Height, depth and width measures were taken with calipers calibrated in centimeters. Touchberry and Lush (1950) concluded that single body measurements yielded acceptable accuracy; therefore, a single measure of each variable of each animal was utilized in this study. Fat thickness was measured ultrasonically with a Branson Model 12 Sonoray over the *longissimus dorsi* muscle between the 12th and 13th ribs, about three-fourths of the distance between the dorsal midline and the distal edge of the *l. dorsi* muscle (Watkins, 1967; Backus, 1968; McReynolds and Arthaud, 1970).

III. ADJUSTMENTS OF CALF MEASUREMENTS

Body weight and all measurements collected from calves were statistically corrected to a 205-day age basis and were adjusted for sex of calf. The mean age of measurement of all the calves was 248 days. Regression analyses of calf age and sex on calf weight and body measures were calculated to obtain estimates of regression coefficients. These b-values were used to adjust the data for variation in age and sex of calf. Analysis of variance was performed on adjusted data to evaluate the effectiveness of the adjustments. The data were not adjusted for age of dam to allow further study of that effect on calf performance. Cow age was included as a discrete effect in all subsequent statistical models.

IV. CALCULATION OF BODY VOLUME VARIABLE

One of the objectives of this study was to examine the ability of certain measures and combinations of measures to accurately define animal size. An estimate of body volume was calculated from body width, depth and length measures and evaluated as a measure of size. It was assumed that the cross section of a *Bovine* approximates an elipse. The width and depth measures were used to calculate the area of the elipse and that area was multiplied by body length to obtain the estimate of body volume. The equation used to calculate the variable was:

$$\text{Body Volume} = \pi\left(\frac{\text{Width}}{2} \times \frac{\text{Depth}}{2}\right)\text{Length}$$

V. PRINCIPAL-COMPONENT ANALYSIS

A further attempt to define cow and calf size involved a multivariate technique known as principal-component analysis. The use of this technique in analyzing biological measurement data has been reported by Jolicoeur and Mossimann (1960), Carpenter (1971), Eller (1972), Brown *et al.* (1973a) and Hammack (1973). The purpose of this analysis was to simultaneously study the effect of all body measurements on performance rather than examining each one singly. Weight and body measures, taken individually, are correlated indicators of body size which can be statistically combined to yield an overall expression of size through a principal-component index.

The technique of principal-component analysis involves making linear combinations of the available variables into factors or components. Each component explains a portion of the variation in the total dependence structure, and each is orthogonal, or independent, of the others. The procedure reduces a covariance or correlation matrix into a set of orthogonal axes or components. The major axis or component explains the largest amount of variation in the variance-covariance structure, and minimizes the residual correlation among the variables. Each successive component will explain the largest possible portion of the remaining variation while satisfying the requirement that each component be orthogonal of the others. When the number of components equals the number of original variables, 100 percent of the variation in the total structure will have been explained. For a more detailed discussion of principal-component analysis, the reader is directed to the texts of Morrison (1967) and Hope (1968).

The principal-component analysis for this study was calculated from a correlation matrix, consisting of unities as the diagonal elements and the correlation estimates between the members of specific pairs of variables as the off-diagonal elements. It was determined in this study that only the first two principal components would be included in the regression analysis. These components were used to classify animals according to body size and shape, as was done by Brown *et al.* (1973a) and Eller (1972). An index for each animal was calculated from the weights derived for each component. The procedure involved multiplying the factor coefficient for a variable by the standarized measure for that variable, and summing the products across variables. The range in these index scores allowed the ranking of animals within each principal component. The result of this type of analysis offered a means of distinguishing between animals according to body size and shape.

Preliminary principal-component analysis utilized weight, fat thickness and the four body measures. However, body width was not available in 1969 through 1971 data. It was decided to drop body width from the analysis so that those animals could be included in the analysis. Thus, all reported principal-component indexes were calculated from analysis of weight, fat thickness, body height, length and depth.

VI. STATISTICAL ANALYSIS

Multiple regression equations were constructed with selected variables and in a stepwise manner. Equations were fitted to predict adjusted 205-day weaning weight, adjusted calf height, calf volume, calf size index (PC1) and calf shape index (PC2). Independent variables were cow weight, cow wither height, cow size index, cow shape index, cow fat thickness and calf fat thickness. Calf fat was included as an indicator of maternal influence. Cow volume was an additional independent variable when predicting calf volume. Cow fat was included as a linear and quadratic term in the selected variable equations. Coefficients of multiple determination (R^2) were utilized to study the value of a particular combination of independent variables to predict a dependent variable.

Stepwise regression equations were constructed using the Maximum R^2 Improvement technique (Barr *et al.*, 1976). This method selected the single variable which formed the best one-variable model, the two variables that formed the best two-variable model, and so forth. Maximum R^2 was used as the criterion to select the variables which comprised the best combination. Therefore, a variable may be present in one model and be dropped from the next. This method eventually included all available variables in the equation, regardless of whether the R^2 improvement was significant. A description of stepwise regression analysis was presented by Draper and Smith (1966).

Preliminary least-squares analyses indicated homogeneous variances among years and breeds. Therefore, data from individual years and breeds were pooled for regression analysis. Year, breed and cow age were included as discrete variables in the regression equations. Interactions among year, breed and cow age were pooled in an overall lack-of-fit term according to Brown *et al.* (1972). In fitting regression equations, sire differences were ignored because the main purpose of this study was to investigate relationships between cow and calf characteristics, and previous progeny records were not available for the younger sires. Brown and Shrode (1971) discussed reasons for ignoring sire effects in a similar analysis.

CHAPTER IV

RESULTS AND DISCUSSION

I. MEASURES OF COW SIZE

Body Weight

Cow weight has been utilized as an indicator of size and has been related to calf performance in several studies (Gregory *et al.*, 1950; Brinks *et al.*, 1962; Urick *et al.*, 1971; Edwards and Bailey, 1975). Therefore, weight was the initial characteristic used to define cow size in this study, and its relationship with calf performance was analyzed. Means and standard deviations of cow weight are presented in Table I. Hereford cows were heavier than Angus cows. Weight ranged from 469 kg for Angus cows with female calves to 521 kg for Hereford cows with male calves. Within breeds, cows with bull calves were slightly heavier than cows with heifer calves, probably a result of preferential treatment of cows with male calves who were grazed on the best quality pastures. Analysis of variance indicated that year and breed significantly ($P<.01$) affected cow weight.

Body Height

Means and standard deviations of body height are presented in Table I. There was little difference in mean height, which ranged from 117 to 122 cm. However, year and breed effects on body height were significant ($P<.01$). This characteristic was analyzed in an

TABLE I

MEANS AND STANDARD DEVIATIONS OF COW TRAITS BY CALF SEX AND BREED

Variable	Hereford Bulls		Hereford Heifers		Angus Bulls		Angus Heifers	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (yr)	6.73	3.21	6.68	3.11	5.54	3.00	5.77	3.06
Weight (kg)	521.33	67.75	517.64	63.05	484.23	55.78	469.02	58.35
Height (cm)	121.75	5.42	119.89	5.73	118.61	4.71	117.40	6.13
Length (cm)	135.11	6.07	135.81	5.85	127.62	6.07	128.00	6.50
Depth (cm)	66.83	3.33	65.39	3.80	65.51	3.46	64.24	4.04
Width (cm)	47.01	4.16	46.00	3.86	45.74	3.66	44.43	3.57
Fat thickness (mm)	9.80	5.11	9.83	4.82	9.19	3.97	8.37	4.31
Volume (l)	670.08	103.53	647.98	87.90	602.48	87.61	584.55	88.31

attempt to find an easy-to-measure character that was a good indicator of cow size and had a relationship to calf performance. Wither height can be easily measured, even when scales are not available, or it can be used in combination with body weight to quantify size. Body height could be an indicator of frame size and be as accurate as a subjective frame score in a selection program, especially when the observer is an inexperienced grader.

Body Volume

Approximate body volume was calculated from width, depth and length measures as an indicator of body size. Means and standard deviations are presented in Table I. The greatest volume was 670 liters for Hereford cows with male calves, and the lowest was 584.5 for Angus with female calves. Herefords possessed the larger values, following the same trend as observed with other size indicators. Year and breed effects on body volume were significant ($P<.01$).

Principal-Component Indexes

A principal component analysis of data collected from 1972 through 1975 was conducted. Variables included were weight, height, length, depth, width and fat thickness. A similar analysis with the width measure deleted also was conducted. The results of the two analyses were similar enough to justify eliminating body width from the analysis, which allowed the inclusion of the 1969 through 1971 data, which did not include width.

Principal-component analyses were conducted also within each breed, and the results were similar. Means and standard deviations of the five characteristics included in the analysis are presented in Table I. The breed means for each characteristic were similar, causing the similar within-breed components. The similarities among the principal components from different data sets agree with results of Eller (1972) and Hammack (1973). From these preliminary analyses, it was decided to combine the two breeds into one data set, and to utilize weight, height, length, depth and fat thickness in the principal-component analysis.

Results of the principal component analysis are presented in Table II. The coefficients for PC1 were all positive, indicating that the first component contrasted animals according to overall size. PC1 accounted for 56.2 percent of the total variance. PC2 was comprised of positive coefficients for body length and fat thickness, and negative coefficients for height and depth. This component was interpreted as contrasting body shape, arraying animals from those which were tall and thin with a tendency to be short- and deep-bodied to those which were short in stature, fat, longer-bodied and shallow. Weight received little emphasis in PC2, and 16.3 percent of the remaining variation was explained. Thus, 72.5 percent of the total variation was explained by the first two components. These components generally agree with those reported by Carpenter *et al.* (1971), calculated from 38 mature Hereford cows. However, the coefficients calculated in the present study were smaller, possibly because of the difference in cow numbers between the two studies.

TABLE II

COEFFICIENTS AND INTERPRETATIONS OF THE PRINCIPAL COMPONENTS OBTAINED FROM COW MEASUREMENTS

Variable	Coefficients for principal component number			Principal Component	Description of cows having large positive component index values
	1	2	3		
Weight	.3273	.1773	-.0705	1	Large-framed and heavy
Height	.2333	-.7873	.1994	2	Short in stature and fat with a tendency to be long and shallow
Length	.2477	.3781	-.7983		
Depth	.2882	-.3289	-.0280		
Fat thickness	.2237	.5667	.8154	3	Short-bodied and fat
% Total variance	56.2	16.3	14.8		

Correlations Among Cow Measures

Estimates of correlation among cow measurements and measures of cow size are presented in Table III. All estimates were highly significant ($P<.01$) except for the 0.0 correlation between the two principal-component indexes, the result of the orthogonality requirement.

Cow body weight was highly related to the four body measurements and fat thickness, the estimates ranging from 0.48 to 0.74. These results are similar to those reported by Touchberry (1951). The relationships of weight with PC1 and PC2 were 0.92 and 0.15, respectively. Since PC1 was interpreted as a size index and PC2 as a shape index, with little emphasis on weight, these correlation estimates were as expected. Carpenter *et al.* (1971) reported a correlation of 0.93 between body weight and PC1.

The estimates of correlation among the body measures and fat thickness ranged from 0.22 to 0.64. Wither height was most highly correlated with body depth, indicating that the taller animals in this study were deeper and also tended to be longer, wider and fatter. Long-bodied cows were deeper and wider and tended to be fat. These results followed the trend of the estimates calculated from Holstein cows by Touchberry (1951), but were generally smaller. They were also smaller than those reported by Simpson *et al.* (1972), calculated from progeny of Angus-Holstein cows and Polled Hereford sires. The relationship between body depth and width, 0.64, was the highest among body measures. Wide animals had a strong tendency to

TABLE III

ESTIMATES OF CORRELATION AMONG COW MEASUREMENTS AND MEASURES OF COW SIZE[1,2]

Variable	2	3	4	5	6	7	8	9
1 Weight	.48	.65	.67	.74	.56	.88	.92	.15
2 Height		.25	.52	.22	.23	.37	.66	-.64
3 Length			.41	.46	.26	---	.70	.31
4 Depth				.64	.34	---	.81	-.27
5 Width					.51	---	.70	.34
6 Fat thickness						.47	.63	.46
7 Volume							.90	.27
8 PC1								.00
9 PC2								

[1]The cow measurements were not adjusted for age effects.

[2]All estimates were significant ($P<.01$) except between PC1 and PC2.

be fat (0.51), which indicated that body width is a function of body condition.

An estimate of 0.49 indicated that cows with greater body volume tended to be fat. Volume exhibited a strong relationship with PC1, the size index. A much smaller correlation between volume and PC2 indicated that a large body volume can be the result of several shapes.

The estimates of correlation of PC1 with the body measurements, 0.66 to 0.81, indicated that animals with large size indexes were larger in all dimensions, a result of the positive coefficients for all measurements in PC1. Animals with high index values for PC2 were short in height and fatter, with a tendency to be longer-bodied, wider and shallow. These results are the same as those from the principal-component analysis.

Effect of Cow Age on Measures of Size

Means and standard deviation of cow ages are presented in Table I. The breed mean ages were very similar; however, the Hereford cows were approximately one year older than the Angus cows. Cow ages were divided into seven classes for all analysis as follows: two, three, four, five through nine, ten, eleven, and twelve and thirteen years of age.

A plot of cow weight versus cow age is presented in Figure 1. Hereford cows were slightly heavier than Angus cows at all ages. The largest differences occurred after maturity, with differences at two, three and four years being the smallest. Cow height versus cow age

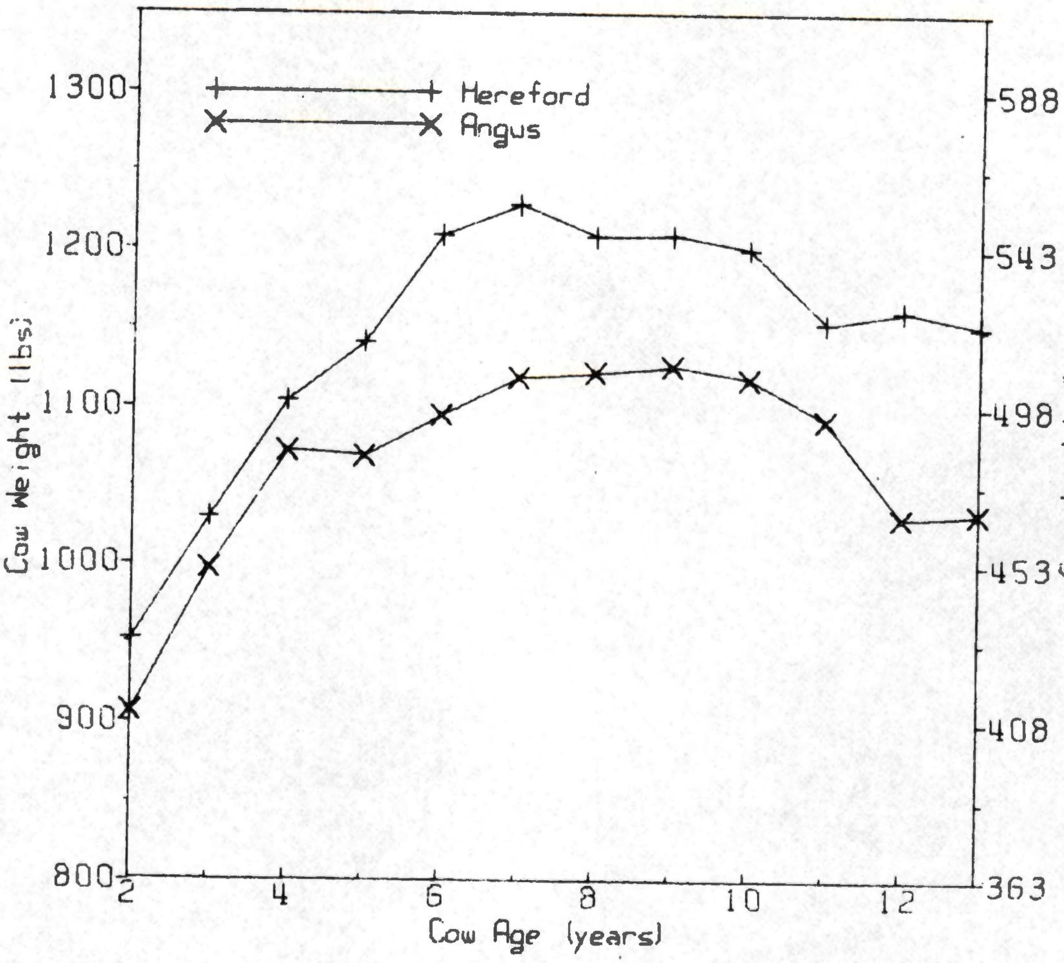

Figure 1. Cow weight plotted against cow age.

is shown in Figure 2. Herefords were taller than Angus at all ages except four years, where they appeared to be similar. The divergent trend of the older cows was caused by the small numbers in those age classes. There were only small breed differences in the three-through-nine year age classes, which contained the majority of the cows. Figure 3 indicated that there was no breed difference in fat thickness. Also, analysis of variance indicated no breed effect on fat thickness.

Cow size index (PC1) versus cow age is presented in Figure 4. This plot is generally the same as that of weight versus age (Figure 1), expected due to the high correlation between weight and PC1. Herefords had larger average size index scores at all ages. Figure 5 is a plot of cow shape index (PC2) versus cow age. Neglecting those of ages eleven, twelve and thirteen years because of small numbers, the indexes of the two breeds are very similar. Herefords tended to have higher scores than Angus, especially in ages four through nine years. It should be remembered that a high score for PC2 is probably undesirable, since it indicated an animal short in stature and fat.

II. MEASURES OF CALF SIZE AND PERFORMANCE

Adjusted Weaning Weight

Weaning weight was adjusted to an age-constant basis (205 days) and then corrected for sex effect. Multiplicative correction factors for sex were 0.93 for bull calves and 1.07 for heifers.

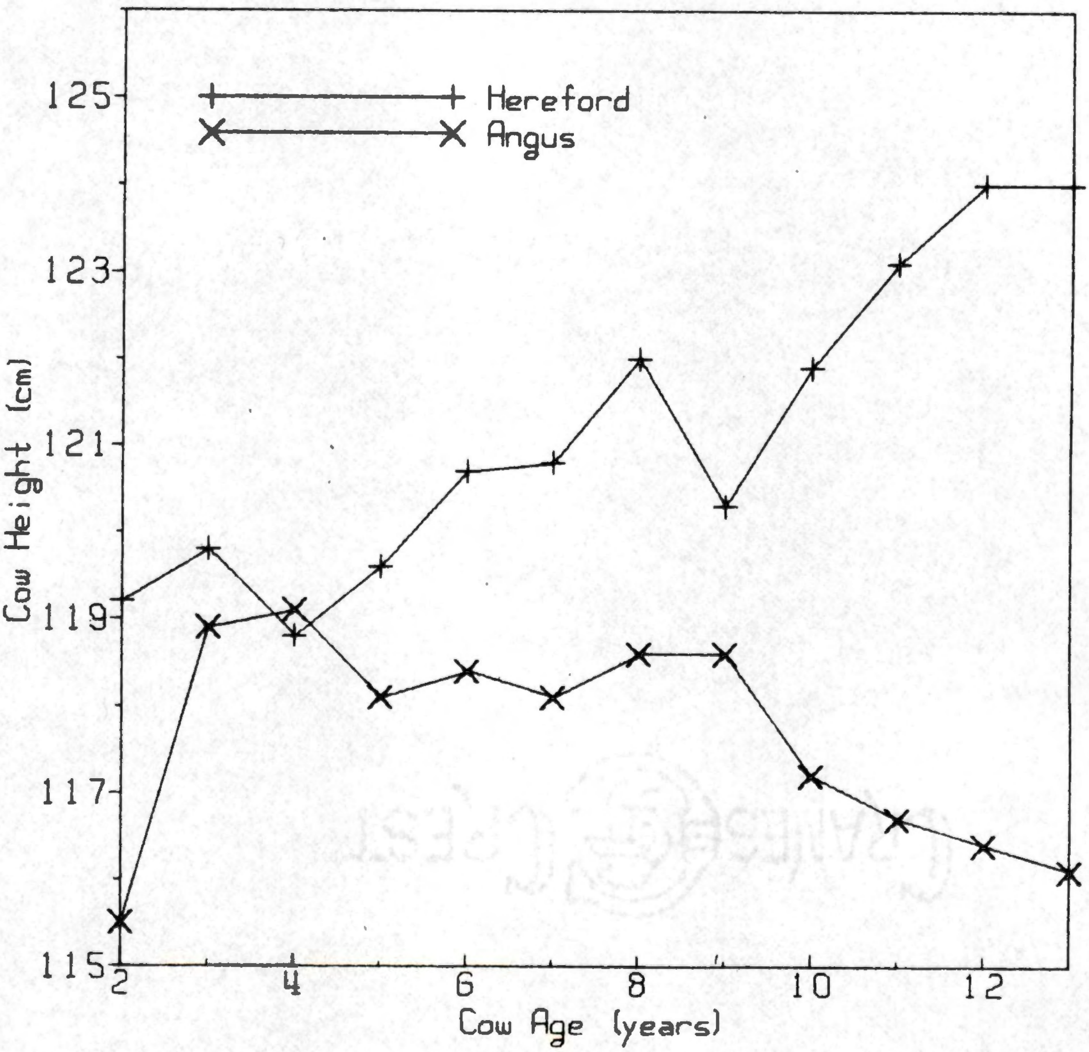

Figure 2. Cow wither height plotted against cow age.

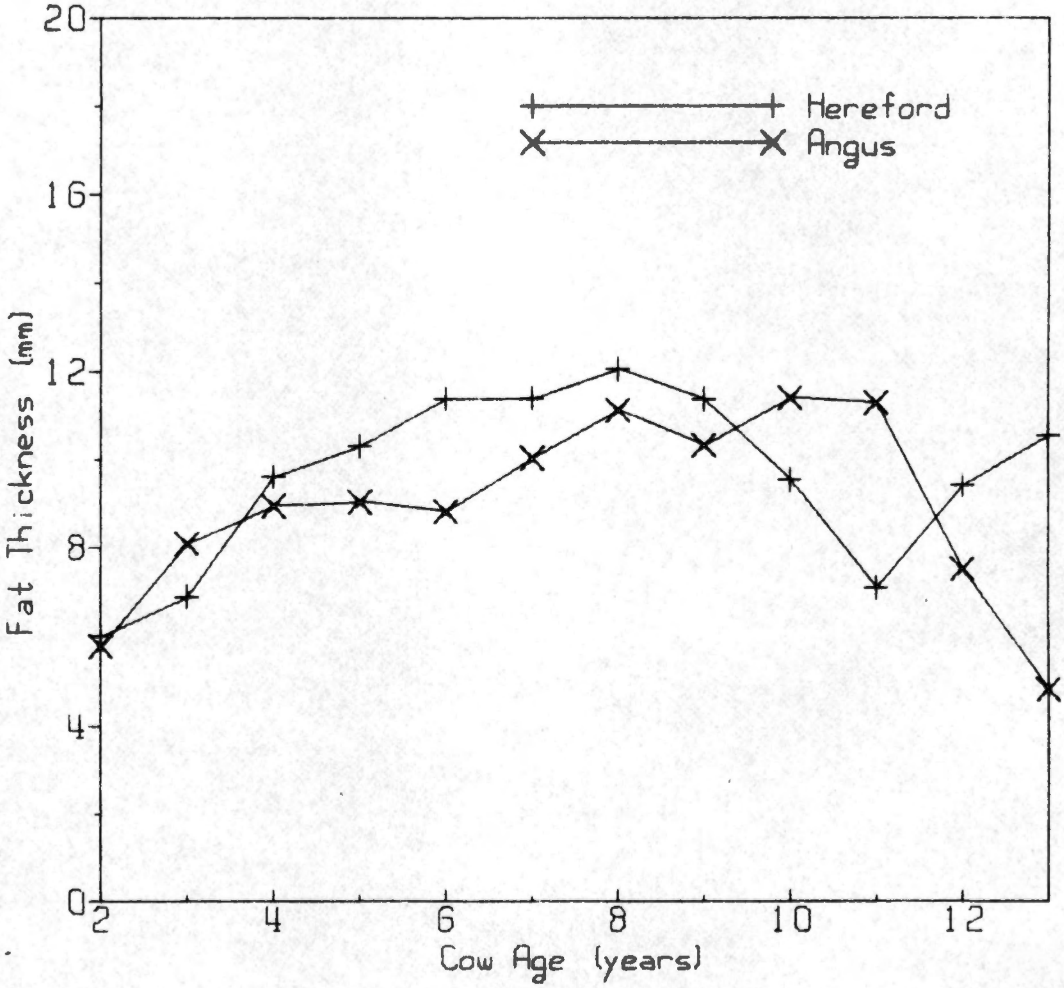

Figure 3. Cow fat thickness plotted against cow age.

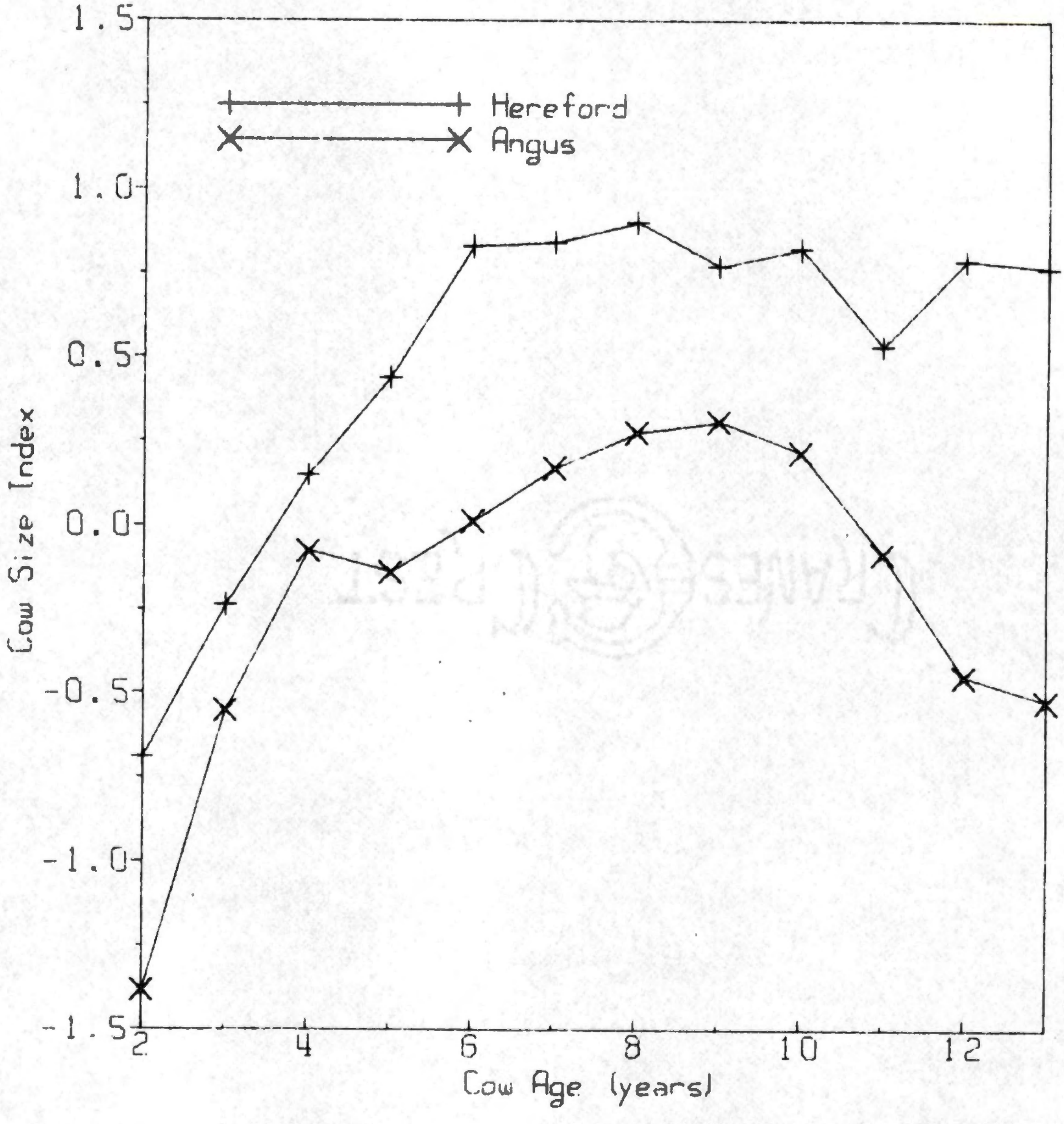

Figure 4. Cow size index (PC1) plotted against cow age.

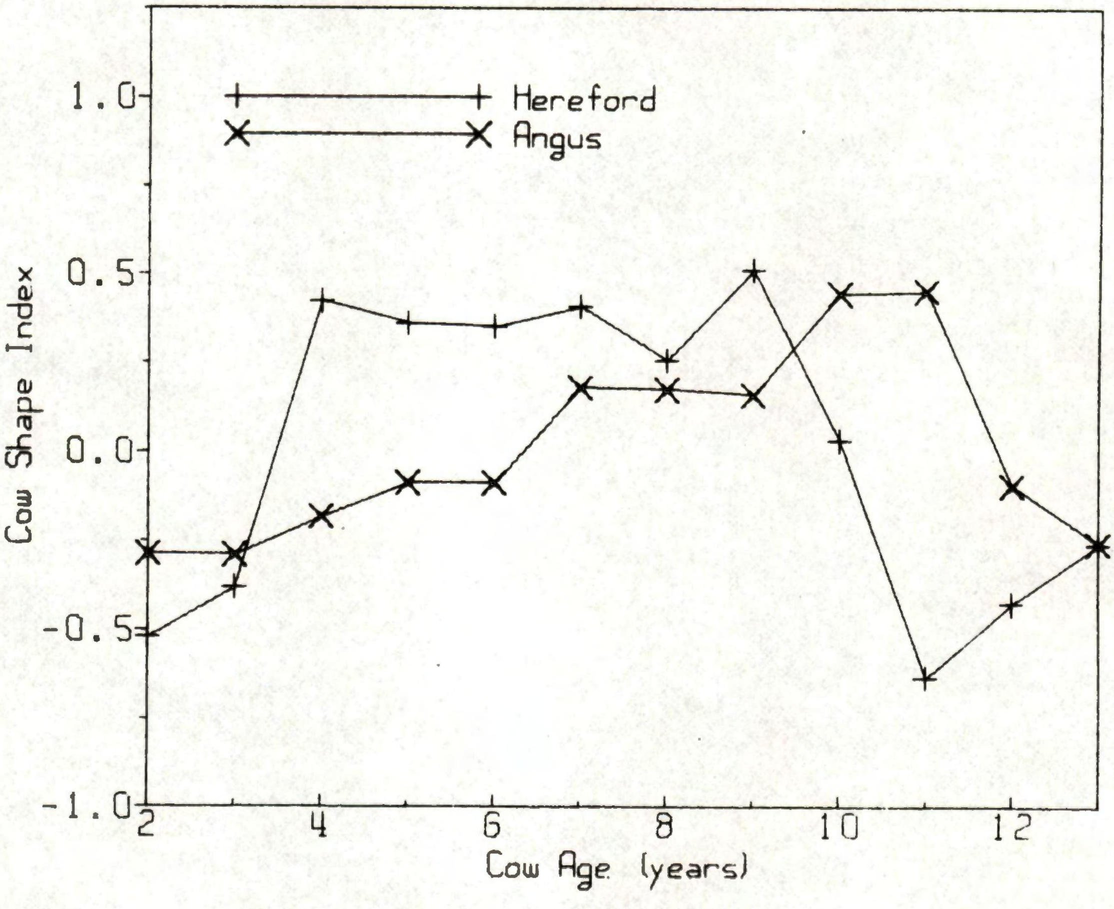

Figure 5. Cow shape index (PC2) plotted against cow age.

Analysis of variance of adjusted 205-day weaning weight indicated no effect of age or sex. Means and standard deviation of adjusted weaning weight are presented in Table IV. Mean weights ranged from 221 kg for Hereford heifers to 241 kg for Angus bulls. Weaning weight was significantly influenced by year and breed ($P<.01$).

Adjusted Height

Wither height was analyzed as a possible indicator of calf size. This measure was also adjusted for weaning age and for sex effects. Sex adjustment factors calculated from the data were 0.99 for male calves and 1.01 for females. Means and standard deviations of adjusted height are presented in Table IV. Breed and sex mean heights were similar, ranging from 99.7 cm to 100.6 cm. However, the effects of year and breed were significant ($P<.01$).

Body Volume

Body volume was calculated for calves by the same method used for cows. Means and standard deviations of the variable are presented in Table IV. Similar statistics are listed also for the body measurements used in the calculation: body length, depth and width. Analysis of variance indicated that these variables were significantly ($P<.01$) affected by year and breed. Means of the volume variable ranged from 233.9 to 239.8 liters.

Principal Component Indexes

Indexes of size and shape were calculated for calves utilizing principal-component analysis similar to that conducted on cow data.

TABLE IV

MEANS AND STANDARD DEVIATIONS OF ADJUSTED CALF TRAITS
BY CALF SEX AND BREED

Variable	Hereford Bulls		Hereford Heifers		Angus Bulls		Angus Heifers	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (days)	228.73	18.67	256.83	24.65	232.04	15.57	267.83	23.54
Weight (kg)	228.94	35.39	220.97	34.94	240.55	35.26	225.77	31.62
Height (cm)	100.60	4.56	100.44	5.31	99.71	4.37	100.62	5.46
Length (cm)	100.84	5.72	101.46	6.84	98.73	5.56	98.88	6.23
Depth (cm)	50.67	3.99	49.85	4.13	50.45	3.57	50.16	3.77
Width (cm)	35.05	4.18	33.47	3.18	36.74	3.48	34.50	2.82
Fat thickness (mm)	2.23	1.00	2.96	1.47	2.27	1.00	3.28	1.32
Volume (1)	233.93	47.56	237.46	42.31	239.76	40.86	233.86	32.84

Variables included were adjusted weaning weight, height, length, depth and fat thickness. All variables were adjusted for age and sex. Means and standard deviations of these calf measurements are presented in Table IV.

Coefficients from the principal-component analysis are presented in Table V. PC1 was comprised of positive coefficients and was interpreted as a size factor. It contrasted large-framed and heavy calves with those that were small and light and accounted for 46.9 percent of the total variation. PC2 contained positive coefficients for weight and height and negative ones for length, depth and fat thickness. Calves with large index scores for PC2 were tall and thin with a tendency to be short-bodied, shallow and heavy. This component was interpreted as defining shape trends, although body weight received more emphasis in these young animals than in cows.

The emphasis on weight in PC2 was not reported by Brown *et al.* (1973a) or Hammack (1973) from analysis on weaning data. Preferential treatment of the older male calves in the present study is one possible cause of this difference in results. PC2 accounted for 20.3 percent of the remaining variation; the first two components together explained 67.2 percent of the variation. Generally, PC1 explained less variation than those reported previously; however, PC2 accounted for a greater portion than the second component reported by Brown *et al.* (1973a), and the same as that reported by Hammack (1973).

TABLE V

COEFFICIENTS AND INTERPRETATIONS OF THE PRINCIPAL COMPONENTS OBTAINED FROM CALF MEASUREMENTS

Variable	Coefficients for principal component number			Principal Component	Description of calves having large positive component index values
	1	2	3		
Weight	.3381	.3352	-.0839	1	Large-framed and heavy
Height	.2451	.7172	.2051	2	Tall in stature with little fat and a tendency to be short-bodied, shallow and heavy
Length	.2930	-.2905	-.8294		
Depth	.3123	-.2878	.0279		
Fat thickness	.2624	-.4348	.8094		
% Total variance	46.9	20.3	14.4	3	Short-bodied and fat

Correlations Among Calf Measurements

Estimates of correlation among adjusted calf measurements and measures of calf size are presented in Table VI. Adjusted weaning weight was correlated with the body measurements (0.36 to 0.63). Weaning weight and weaning fat thickness were related (0.33), indicating that even the heavier calves had deposited little fat by this age. PC1 and weaning weight were highly correlated, and the emphasis on weight in PC2 was apparent in their correlation, 0.34.

Estimates of correlation among the body measurements and fat thickness ranged from 0.12 to 0.64. Correlations of body depth with width, length and fat thickness were 0.64, 0.44 and 0.41, respectively. A strong correlation of 0.52 was calculated between wither height and volume, volume having been calculated from the other three body measurements. The estimates of correlation of weight with body measurements from the present study indicated the same relationships, but they were smaller than those calculated by Blackmore *et al.* (1958) from six-month-old Holstein heifers.

PC1 was highly correlated with weaning weight, body measurements and fat thickness, indicating its relationship to size. The high correlation (0.86) between PC1 and volume demonstrated the relationship of volume and size. However, the low correlation (0.17) between volume and PC2 suggested that volume was not related to body shape. Correlations between PC2 and body measurements conformed to the results of the principal-component analysis.

TABLE VI

ESTIMATES OF CORRELATION AMONG ADJUSTED CALF MEASUREMENTS AND MEASURE OF CALF SIZE[1]

Variable	2	3	4	5	6	7	8	9
1 Weight	.54	.46	.36	.63	.33	.80	.79	.34
2 Height		.18	.28	.36	.12	.52	.57	.73
3 Length			.44	.32	.28	---	.69	-.30
4 Depth				.64	.41	---	.73	-.29
5 Width					.33	---	.65	.13
6 Fat thickness						.36	.62	-.44
7 Volume							.86	.17
8 PC1								0.0
9 PC2								

[1]All estimates were significant (P<.01) except between PC1 and PC2.

III. ESTIMATES OF CORRELATION AMONG COW AND CALF CHARACTERS

Coefficients of correlation were calculated to study the relationships of cow measurements and measures of cow size with calf measurements and measures of calf size. Cow measurements were used mainly as indicators of cow size and shape. Calf measurements also were used as indicators of size and shape, but were of primary interest to define overall calf performance. The return realized from a weaned feeder calf is dependent primarily on weight with some emphasis on condition and conformation. Therefore, a combination of weaning weight, fat thickness and body measurements should be a better indicator of calf performance than weight alone. Estimates of correlation among cow characters and calf characters are presented in Table VII.

Correlations Among Cow Weight and Calf Characters

Cow weight was highly correlated ($P<.01$) with all calf characters. The highest estimate, 0.38, was between cow weight and 205-day weaning weight. This estimate was higher than most that have been reported, probably a result of the selection pressure applied to weaning weight in this particular herd. However, this correlation was similar to those calculated by Gregory *et al.* (1950), O'Mary *et al.* (1959), Tanner *et al.* (1965), Urick *et al.* (1971), and Simpson *et al.* (1972). Calf body measurements were correlated with cow weight from 0.10 to 0.32. The highest estimate, that between cow weight and calf wither height, was probably a result of the importance given height in the selection process.

TABLE VII

ESTIMATES OF CORRELATION AMONG COW AND CALF MEASUREMENTS AND MEASURES OF SIZE[1,2]

Calf Variables	Cow Variables								
	Weight	Height	Length	Depth	Width	Fat Thickness	Volume	PC1	PC2
Weight	.38	.12	.20	.23	.28	.21	.32	.31	.09
Height	.32	.48	.14	.38	.18	.18	.26	.40	-.29
Length	.16	-.17	.33	$.02^{ns}$	.19	$.00^{ns}$	.26	.10	.28
Depth	.10	$-.06^{ns}$	.12	.32	.21	$-.01^{ns}$	.25	.14	$.01^{ns}$
Width	.16	$-.04^{ns}$	.13	.19	.19	.11	.20	.16	.14
Fat thickness	.11	-.14	.13	.11	.15	$.00^{ns}$	.18	.17*	.14
Volume	.27	$.03^{ns}$	.20	.29	.24	.15	.28	.26	.13
PC1	.31	$.05^{ns}$	.28	.31	.29	.10	.36	.29	.07*
PC2	.24	.54	$-.03^{ns}$	.21	.09*	.20	.12	.31	-.35

[1]Calf measures were adjusted for sex of calf and age of calf, but not for age of cow.

[2]All estimates were significant ($P<.01$) except as noted.

*$P<.05$.

A tendency for heavier cows to produce calves with greater fat thickness was indicated. Heavier cows produced calves which also had greater body volume. This was expected due to the positive correlations between cow weight and body measurements of the calves. Estimates of correlation between cow weight and the principal-component indexes of the calves also indicated the tendency for heavy cows to produce heavier and larger calves. Cow weight and calf PC2 were correlated (r=0.24), indicating a tendency for heavier cows to produce taller calves with less fat thickness.

These estimates of correlation between cow weight and calf characters indicated that heavy cows are desirable when these particular calf characters are considered. Calves from heavy cows should be heavier, have a more desirable conformation and not be excessively fat. The result should be heavier feeder calves that have more desirable feeder grades.

Correlations Among Cow Body Measurements and Calf Characters

Cow wither height was significantly correlated (P<.01) with calf height and calf shape index, PC2 (0.48 and 0.54, respectively). These strong relationships indicated that taller cows produced calves with a more desirable conformation in which height was an important component. Calves from taller cows tended also to be heavier, shorter-bodied and less fat. These results indicated that height may be an important trait in a selection program, especially to improve conformation. Cow body length appeared to be a useful character, particularly because of its relationship with calf length (r=0.33). Selection of heavier and taller cows should slightly decrease calf length or leave it unchanged. Selection of longer cows should increase calf length. Increases in body length of cows also resulted in increases in all other calf characters except shape index (PC2).

Cow body depth was correlated with calf wither height and body depth (r=0.38 and 0.32, respectively). Body depth of cows was related to calf weight, volume and size index (PC1) (r=0.23, 0.29 and 0.31, respectively). Selection of deeper-bodied cows should increase all of the calf characters studied except body length. Cow body width was highly correlated ($P<.01$) with all calf characters except shape index (PC2). However, other cow characters exhibited similar or higher correlations with the calf characters, an additional indicator that eliminating body width from the principal-component analysis was acceptable.

The estimates of correlation between cow body measurements and adjusted weaning weight calculated in the present study generally agreed with those reported by O'Mary *et al.* (1959) and Simpson *et al.* (1972). They appeared to be higher than those calculated from Holstein cows and their daughters by Blackmore *et al.* (1958) and those reported by Murphey (1972). Touchberry (1951) calculated correlations between cow body measurements and calf measurements from Holstein cows and their female progeny. Cow wither height was correlated with calf height (r=0.36). Estimates of 0.30 and 0.40 were calculated for cow body depth with calf height and depth, respectively. Other reported estimates were in general agreement with the estimates from the present study. The few estimates not in agreement were considered a result of the differences in beef and dairy conformation. Estimates reported by Blackmore *et al.* (1958), also from Holsteins, were generally lower than those from the present study. Coefficients of correlation reported here were higher also than those reported by Murphey (1972) and Simpson *et al.* (1972).

Correlations Among Cow Fat Thickness and Calf Characters

Cow fat thickness was not as highly correlated with the calf characters as were other cow characters. Cows with greater fat thickness produced heavier and taller calves with a more desirable shape index (PC2). A tendency for calves to be wider with greater volume and higher size index (PC1) also was present. Fat thickness of cows did not affect calf fat thickness, body length or depth. Godley *et al.* (1970) reported that cow condition was positively correlated with calf weight per day of age. Murphey (1972) and Simpson *et al.* (1972) reported a negative trend between cow condition and calf weaning weight. Simpson *et al.* (1972) reported that cow condition did not generally affect calf body measurements except for a negative relationship with wither height.

Correlations Among Cow Body Volume and Calf Characters

Approximate cow body volume was highly correlated ($P<.01$) with all calf characters studied. Cow volume was most highly correlated with 205-day weight and size index (PC1), r=0.32 and 0.36, respectively. This fact was further substantiated by the high coefficients of correlation of cow volume with calf body measurements and volume. Calves from cows with greater volume tended to be fatter. In comparison with the other estimates of correlation, cow volume and calf shape index (PC2) were not highly correlated (r=0.12). Selecting cows with greater volume would probably not improve calf conformation and would not increase the number of calves with more desirable feeder grades. Since a large body volume could be the result of several body shapes, volume would not be a useful trait in a selection program where calf conformation is an important economic trait.

Correlations of Cow Size (PC1) and Shape (PC2) Indexes with Calf Characters

Cow size index (PC1) was positively correlated (P<.01) with all calf characters except fat thickness (P<.05). Cows with higher size index scores produced calves that were heavier and taller, with a tendency to be larger in the other body measurements. Calf fat thickness exhibited only a slight tendency to increase when size index was high. Calves with greater body volume and higher size and shape index scores tended to be those from cows with higher scores for PC1.

Strong negative coefficients of correlations, -0.29 and -0.35, were calculated for cow shape index with calf wither height and shape index, respectively. High shape index scores for cows were probably undesirable because they were typical of animals short in stature and fat. However, high shape index scores for calves were desirable since they described tall animals with little fat. These facts led to the negative correlations of cow shape index with calf height and shape index.

The estimates of correlation calculated in the present study indicate that breeding animals can be selected for desirable size and shape indexes, and the result should be heavier calves with more desirable shape or conformation.

IV. REGRESSION OF CALF MEASURES ON COW MEASURES

Estimates of regression of measures of calf size on cow measurements and on measures of cow size were calculated to investigate the usefulness of the cow variables to predict calf performance. Since cow and calf measurements were collected during the same year, the regression estimates could not validly be used as predictors of subsequent calf performance. However, they were used to study the importance of various cow variables in a selection program.

The first step in the regression procedure was to force year, breed and cow age into the equation individually as discrete variables. The Maximum R^2 Improvement method of stepwise regression was then allowed to include the other cow variables into the equation according to its criterion. One reason for using this method was that it eventually included all of the available variables into the equation regardless of whether they significantly improved R^2. Calf fat thickness was included with the cow characters as an indicator of maternal effect, especially milking ability. Neel (1973) reported a highly significant (P<.01) correlation of dam's daily milk production with calf weaning fat thickness (r=0.46).

Regression of 205-Day Weight On Cow Measures

Results of the regression analysis of 205-day weight on cow measures are presented in Table VIII. Effects due to year and breed together explained 10 percent of the variation in adjusted weaning weight. Cow age explained an additional 22 percent of the variation when it entered the equation. The first variable to enter the equation after year, breed and cow age was calf fat thickness. The coefficient of regression (b=16.2) indicated that a calf was 16 lb heavier at weaning for every additional mm of fat. Inclusion of calf fat thickness increased R^2 to 41 percent.

The second continuous variable entering the equation was cow weight. It significantly (P<.01) influenced 205-day weight throughout the analysis, and resulted in an additional increase in R^2 of 1.6 percent. The last significant (P<.05) effect on weaning weight was cow fat thickness. However, cow fat became a nonsignificant effect when additional variables were added to the equation. The negative b-value for cow fat indicated a negative effect on calf weaning weight when effects due to year, breed, cow age, calf fat thickness and cow weight had been removed. The addition of cow fat thickness increased R^2 to 42.7 percent. The remaining cow variables entered the regression equation, in order, size index (PC1),

TABLE VIII

STEPWISE REGRESSION OF ADJUSTED WEANING WEIGHT ON COW MEASURES[1]

Intercept	Year[2]	Breed[2]	Cow Age[2]	Weight	Height	PC1	PC2	Cow Fat	Calf Fat	R^2
448.17	+									.098
447.97	+	+								.099
443.42	+	+	+							.322
405.54	+	+	+						16.207**	.406
333.77	+	+	+	.067**					15.908**	.422
322.46	+	+	+	.086**				-1.031*	15.893**	.427
279.30	+	+	+	.123**		-6.911		-.739	15.837**	.428
258.03	+	+	+	.137**		-10.884*	-3.973		15.788**	.429
259.74	+	+	+	.136**		-10.548	-3.746	-0.64	15.792**	.429
255.41	+	+	+	.136**	.036	-10.671	-3.588	-0.76	15.790**	.429

[1]Calculated from 818 cow-calf pairs.

[2]Year, breed and cow age were included as discrete variables.

*P<.05.

**P<.01.

shape index (PC2) and wither height. The highest R^2 attained was 42.9 percent.

These results indicated that cow weight and fat thickness are important characters when selecting for increased weaning weight. Calf fat thickness had a significant effect on weaning weight and should be used when selecting cows that have produced calves. Year effects and cow age were also important influences and should be considered in a selection program.

Regression of Adjusted Calf Height on Cow Measures

Results of the regression of adjusted calf wither height on cow measures are presented in Table IX. This measurement has been considered an indicator of frame size (Jeffery and Berg, 1972) and was studied in that respect. Year and breed effects together explained nearly 28 percent of the variation in calf wither height. Cow age added an additional 7 percent to R^2. Calf fat thickness was the first variable to enter after the discrete variables. It remained significant ($P<.01$) throughout the analysis, and explained an additional 3.5 percent of the variation in calf height. The tendency observed was for calves with greater fat thickness to be taller.

Cow wither height was the only additional significant ($P<.01$) effect to enter the equation. R^2 increased to 40.8 percent when cow height entered the equation. Cow fat thickness, weight, shape index and size index then entered the equation, respectively. The maximum

TABLE IX

STEPWISE REGRESSION OF ADJUSTED CALF HEIGHT ON COW MEASURES[1]

Intercept	Year[2]	Breed[2]	Cow Age[2]	Weight	Height	PCI	PC2	Cow Fat	Calf Fat	R^2
96.48	+									.250
96.63	+	+								.276
96.58	+	+	+							.344
94.59	+	+	+						.849**	.379
71.37	+	+	+		.198**				.822**	.408
71.21	+	+	+		.200**			-.018	.823**	.408
71.82	+	+	+	.001	.185**			-.031	.820**	.409
73.18	+	+	+	.001	.172*		-.102	-.019	.821**	.409
73.72	+	+	+	.001	.169*	0.43	-.104	-.021	.821**	.409

[1]Calculated from 818 cow-calf pairs.

[2]Year, breed and cow age were included as discrete variables.

*P<.05.

**P<.01.

R^2 indicated that 40.9 percent of the variation in calf wither height was explained by all of the cow variables.

Cow height, year, breed and cow age should all be considered when selecting for increased calf height. Calf fat thickness should be utilized also if calf records are available.

Regression of Calf Body Volume On Cow Measures

The results of the stepwise regression procedure of calf volume on cow characters are presented in Table X. Year and breed effects together explained nearly 18 percent of the variation in calf volume. R^2 increased to 34.3 percent after cow age was included. Calf fat thickness was the first continuous variable to enter the equation. It exhibited a highly significant ($P<.01$) effect on calf volume throughout the analysis. Cow weight had the only other significant ($P<.05$) effect on calf volume. The effect occurred only when year, breed, cow age, calf fat and cow fat were in the equation. R^2 indicated that 39.7 percent of the variation in calf volume could be explained by the available cow variables. The remaining cow variables in the order they entered the equation were weight, fat, wither height, shape index, volume and size index.

These results indicated that calf body volume is not predictable from the cow characters available in the present study. Body volume of cows or calves is probably not useful in a selection program because a large volume indicates a large animal, but expresses nothing about the shape or conformation of that animal.

TABLE X

STEPWISE REGRESSION OF CALF VOLUME ON COW MEASURES[1]

Inter-cept	Year[2]	Breed[2]	Age[2]	Weight	Height	Volume	PC1	PC2	Cow Fat	Calf Fat	R^2
271.96	+										.177
272.08	+	+									.177
272.17	+	+	+								.343
244.77	+	+	+							9.315**	.390
220.25	+	+	+	.021						9.247**	.394
212.86	+	+	+	.032*					-.589	9.265**	.397
220.49	+	+	+	.029	.127				-.569	9.271**	.397
173.19	+	+	+	.027	.397			2.028	-.811	9.258**	.397
172.33	+	+	+	.029	.409	-.004		2.079	-.812	9.253**	.397
165.23	+	+	+	.031	.446	-.003	-.547	2.133	-.795	9.254**	.397

[1]Calculated from 581 cow-calf pairs.

[2]Year, breed and cow age were included as discrete variables.

*P<.05.

**P<.01.

Regression of Calf Size Index (PC1) On Cow Measures

Results of stepwise regression of calf size index on cow measures are presented in Table XI. Effects due to year and breed together accounted for 10 percent of the variation in calf size index. An additional 19 percent was explained when cow age was added. Calf fat thickness was the most important continuous variable and entered the regression equation first. It exhibited a highly significant (P<.01) effect on calf size index, and increased R^2 to 54 percent, an addition of 25 percent. Cow weight was the next variable to be included in the equation. It had a highly significant (P<.01) effect on calf size index at that point, but was reduced to a significant (P<.05) effect after cow shape index and size index were included. Cow weight explained only an additional percent of the variation in calf size index, but it appeared more valuable than cow size index in that respect.

Cow shape index entered the equation after cow weight as a highly significant (P<.01) variable. However, it increased R^2 only 0.6 percent, and became nonsignificant after additional variables were included. The remaining cow variables entered the equation, in order, size index, wither height and fat thickness. The maximum amount of variation in calf size index explained by the available cow characters was 55.7 percent.

It appeared that cow weight had an important effect on calf size index, after year and cow age differences were accounted for. Calf fat thickness measurements, if available, also should be considered in a selection program for calf size.

TABLE XI

STEPWISE REGRESSION OF CALF SIZE INDEX (PC1) ON COW MEASURES[1]

Intercept	Year[2]	Breed[2]	Cow Age[2]	Weight	Height	PC1	PC2	Cow Fat	Calf Fat	R^2
.093	+									.097
.104	+	+								.100
.035	+	+	+							.290
-1.129	+	+	+						.498**	.540
-2.153	+	+	+	.001**					.494**	.551
-2.227	+	+	+	.001**			-.109**		.494**	.557
-2.419	+	+	+	.001*		-.029	-.109**		.493**	.557
-3.052	+	+	+	.001*	.005	-.054	-.093		.493**	.557
-3.010	+	+	+	.001*	.004	-.058	-.101	.001	.493**	.557

[1]Calculated from 818 cow-calf pairs.

[2]Year, breed and cow age were included as discrete variables.

*P<.05.

**P<.01.

Regression of Calf Shape Index (PC2) On Cow Measures

Results of the regression of calf shape index on cow variables are presented in Table XII. Year effect alone explained nearly 56 percent of the variation in that variable. Breed and cow age added an additional 2.3 percent to R^2. The first continuous variable to enter the equation was calf fat thickness. It had a highly significant ($P<.01$) effect throughout the analysis and increased R^2 to nearly 66 percent. Cow wither height was included in the regression equation next ($P<.01$), and increased the amount of explained variation to 67 percent.

Cow weight, size index, fat thickness and shape index, respectively, then entered the equation. The available cow characters accounted for 67 percent of the variation in calf shape index.

The most useful cow characters for explaining variation in calf shape index were measurements taken directly from the animals. Cow wither height was more important than either of the principal-component indexes. Effects due to year, breed and cow age should be accounted for, and calf fat thickness should be considered if available.

Summary of Regression Analyses

Results of the regression analyses established trends in the importance of some cow characters in explaining variation in calf characters. Yearly differences appeared to have a substantial effect on calf variation. Breed effects were probably not as important. Cow age variation was significant and should be removed from

TABLE XII

STEPWISE REGRESSION OF CALF SHAPE INDEX (PC2) ON COW MEASURES[1]

Intercept	Year[2]	Breed[2]	Cow Age[2]	Weight	Height	PC1	PC2	Cow Fat	Calf Fat	R^2
-.229	+									.558
-.208	+	+								.568
-.195	+	+	+							.581
.442	+	+	+						-.273**	.657
-2.871	+	+	+		.028**				-.277**	.669
-2.714	+	+	+	.0003	.024**				-.277**	.670
-3.629	+	+	+	.0007	.028**	-.078			-.278**	.670
-3.355	+	+	+	.0006	.027**	-.056		-.003	-.278**	.670
-3.813	+	+	+	.0006	.031*	-.058	.032	-.006	-.278**	.670

[1]Calculated from 818 cow-calf pairs.

[2]Year, breed and cow age were included as discrete variables.

*P<.05.

**P<.01.

data used in a selection program. In attempting to explain variation in calf size and shape or conformation, cow weight and wither height appeared to be the most valuable variables. Some importance might be given also to cow fat thickness. If the selection was a culling process utilizing records of calves already produced, calf fat thickness also should be considered since it was the most important continuous variable in explaining calf variation in all analyses.

CHAPTER V

SUMMARY

The objectives of this study were to determine effects of cow weight, cow wither height, cow body volume, cow fat thickness, calf fat thickness, and cow size and shape indexes on 205-day weaning weight, adjusted wither height, approximate body volume, and size and shape indexes of calves. Indexes of size and shape were the result of principal-component analysis.

The data consisted of weight, body measurements and fat thickness measurements on 318 Hereford and 516 Angus cows and their progeny maintained at the Alcoa Farm, The University of Tennessee, Knoxville. Body measurements collected were wither height, body length, body depth and body width. Weaning weight and all body measurements collected on calves were statistically adjusted to a 205-day age basis and were adjusted for sex of calf effects utilizing least-squares estimates of regression obtained directly from these data.

Principal-component analysis, a multivariate technique, was studied as a method to define animal size and shape. The first component for both cows and calves contrasted animals according to general size. It accounted for 56.2 and 46.9 percent of the total variation in cows and calves, respectively. The second component contrasted animals according to body shape. Total variation explained

by the first two principal components was 72.5 and 67.2 percent for cows and calves, respectively.

All correlations among cow body measurements and measures of size, and among calf body measurements and measures of size were highly significant (P<.01). Adjusted 205-day weight and calf wither height were highly correlated (P<.01) with the cow measurements and measures of size. Calf volume was significantly (P<.01) correlated with the cow variables. Principal-component indexes of size and shape of calves were generally highly correlated (P<.01) with the cow variables. Calf fat thickness was correlated (P<.01) with all cow variables except cow fat thickness; however, the relationships were not as large as those with indicators of calf size.

Stepwise multiple regression analysis indicated that calf fat thickness and cow weight were the most important effects on 205-day weaning weight. Effects of year, breed and cow age also were included in the model as discrete variables, as they were in all regression equations. Independent variables exhibiting the most important effects on calf wither height were calf fat thickness and cow wither height. Calf fat thickness was indicated as the only significant effect on calf volume. Coefficients of determination (R^2) of calf weight, wither height and volume ranged from 39.7 to 42.9 percent. Independent variables with the greatest effects on calf size index were calf fat thickness, cow weight and cow shape index. Calf fat thickness and cow height were the significant effects to enter the equation describing the regression of calf shape index on the cow variables. Coefficients of determination from analyses of calf size and shape indexes were 55.7 and 67.0 percent, respectively.

These analyses indicated that cow weight, cow wither height and calf fat thickness had the greatest effects on measures of calf size and performance.

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APPENDIX

TABLE XIII

REGRESSION OF ADJUSTED WEANING WEIGHT ON COW MEASURES[1,2]

Intercept	Weight	Height	PC1	PC2	Cow Fat	$(\text{Cow Fat})^2$	Cow Age[3]	Calf Fat	R^2
442.64									.099
449.61							+		.322
266.98	.165**								.241
370.96	.073**						+		.342
358.18	.093**				-1.11	.003	+		.346
405.70					.869	-.033	+	15.999**	.403
326.38	.087**				-1.515	.020	+	15.912**	.427
223.96		1.848**							.116
240.37		1.417**			5.953**	-.177**			.147
316.60		1.116**					+		.329
291.06		.984**			.390	-.021	+	16.056**	.411
339.44	.090**	-.135			-1.553	.021	+	15.919**	.427
447.30			21.492**						.213
458.91			25.812**		-1.326*				.219
450.15			7.122**				+		.331
418.61			10.221**		-1.160	.004		16.092**	.417
252.76	.179**		.259		.274	-.047	+		.245
284.12	.124**		6.897		-1.212	.020	+	15.856**	.428
444.06				7.348**					.109
403.14				-1.840	6.626**	-.187**			.137
448.50				-2.582			+		.324
401.04				-4.677	1.108	-.022	+	16.130**	.408
325.56	.086**			-.472	-1.450	.020	+	15.910**	.427

[1]Calculated from 818 cow-calf pairs. [2]Year and breed effects were included in all models.
[3]Cow age was included as a discrete variable. *P<.05. **P<.01.

TABLE XIV

REGRESSION OF ADJUSTED CALF HEIGHT ON COW MEASURES[1,2]

Intercept	Weight	Height	PC1	PC2	Cow Fat	(Cow Fat)^2	Cow Age[3]	Calf Fat	R^2
96.61									.276
97.45							+		.344
94.74					.138	-.006	+	.842**	.380
87.88	.008**								.329
92.55	.005**						+		.355
90.01	.005**				.010	-.003	+	.827**	.391
68.73		.236**							.319
72.87		.207**			-.016				.376
73.03		.205**					+		.376
71.43		.199**			.083	-.004	+	.818**	.409
71.95	.001	.187**			.062	-.004	+	.817**	.409
96.88			1.255**						.335
97.96			1.659**		-.124**				.343
97.51			.753**				+		.358
96.02			1.081**		-.054	-.002	+	.834**	.399
100.00	-.002		1.358**		-.027	-.004	+		.366
98.82	-.003		1.438**		-.053	-.003	+	.839**	.399
96.58				-.186					.277
93.32				-1.093**	.493**	-.011**			.309
97.17				-.650**			+		.354
93.35				-1.204**	.253*	-.004	+	.830**	.400
90.41	.003*			-1.038**	.152	-.003	+	.822**	.405

[1]Calculated from 818 cow-calf pairs. [2]Year and breed effects were included in all models.
[3]Cow age was included as a discrete variable. *P<.05. **P<.01.

TABLE XV

REGRESSION OF CALF SIZE INDEX (PC1) ON COW MEASURES[1,2]

Inter-cept	Weight	Height	PC1	PC2	Cow Fat	(Cow Fat)^2	Cow Age[3]	Calf Fat	R^2
-.337									.100
-.134							+		.289
-3.17	.003**								.217
-1.36	.001**						+		.305
-.305					.038	-.002	+		.292
-1.47					.023	-.001	+	.495**	.539
-2.59	.001**				-.010	-.0002	+	.494**	.554
-5.23		.041**							.128
-5.01		.034**			.108**	-.003**			.155
-3.66		.030**					+		.304
-4.46		.026**			.014	-.001	+	.494**	.551
-3.97	.001**	.014*			-.016	-.0003	+	.493**	.556
-.257			.366**						.205
-.038			.447**		-.025**				.212
-.124			.137**				+		.300
-1.24			.188**		-.013	-.0003	+	.496**	.553
-1.43	.001*		.026		.001	-.0008	+		.309
-2.15	.001		.072		-.013	-.0002	+	.494**	.554
-.322				.073					.103
-1.15				-.119	.132**	-.004**			.141
-.173				-.091*			+		.294
-1.64				-.157**	.036	-.001	+	.496**	.548
-2.55	.001**			-.106*	.005	-.0002	+	.493**	.557

[1]Calculated from 818 cow-calf pairs. [2]Year and breed effects were included in all models.
[3]Cow age was included as a discrete variable. *P<.05. **P<.01.

TABLE XIV

REGRESSION OF CALF SHAPE INDEX (PC2) ON COW MEASURES[1,2]

Intercept	Weight	Height	PC1	PC2	Cow Fat	(Cow Fat)^2	Cow Age[3]	Calf Fat	R^2
.140									.570
.207							+		.583
-.811	.001**								.583
-.480	.001**						+		.587
.172					.007	-.0002			.583
.815					.015	-.001		-.274**	.658
-.013	.001**				-.007	-.0001		-.276**	.664
-3.26		.029**							.583
-2.89		.026**					+		.593
-2.50		.028**			.008	-.0004	+	-.277**	.669
-2.30	.0004	.024**			-.0003	-.0002	+	-.278**	.670
.170			.137**						.584
.315			.191**		-.017*				.587
.215			.102**				+		.588
1.01			.163**		-.014	-.0001	+	-.275**	.666
.514	-.0001		.177*		-.021	.0002	+		.590
.911	.0001		.151*		-.014	-.0001	+	-.275**	.666
.134				-.034					.570
-.091				-.136**	.026**				.577
-.161				-.134**	.041*	-.001			.577
.175				-.076*			+		.586
.636				-.155**	.030	-.0004	+	-.275**	.664
.032	.001**			-.121**	.010	-.0001	+	-.277**	.688

[1]Calculated from 818 cow-calf pairs. [2]Year and breed effects were included in all models.
[3]Cow age was included as a discrete variable. *P<.05. **P<.01.

VITA

John Robert McCurley was born July 14, 1950 in Rochester, Pennsylvania. He was raised on a beef farm in western Pennsylvania and was active in 4-H beef and horse clubs, and in FFA projects and activities. He received his elementary and secondary education near New Castle, Pennsylvania and graduated from Mohawk Area High School in June, 1968.

In September of 1968, he entered The Pennsylvania State University and was graduated with a B.S. degree in Animal Science in June, 1972. He subsequently was admitted to The Pennsylvania State University in September, 1972 as a graduate student in Animal Industry. He held a graduate assistantship from March, 1973 to May, 1974 and received the M.S. degree in August, 1974.

In September, 1974 he entered The University of Tennessee to work on the Ph.D. degree in Animal Science. He held a graduate research assistantship during his study at The University of Tennessee. He is a member of Gamma Sigma Delta.