PRODUCTIVITY OF BEEF COWS AS APPRAISED BY CALF WEIGHTS AT 112 AND 210 DAYS OF AGE

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INTRODUCTION

Cattlemen recently have recognized a need for a more accurate appraisal of the mothering ability of the brood cow. Interest has been aroused in production testing programs which are based upon the keeping of an orderly set of records on each cow. Weights and grades of the calves at weaning are the usual criteria upon which these production tests are based. The records usually are adjusted for the major temporary sources of variation by the use of correction factors which may or may not have been calculated from the data to which they are applied. The purpose of these corrections is to make selection for mothering ability more effective by standardizing the records of all cows to a common basis for appraisal.

Many traits of economic importance in beef cattle vary in expression from time to time in the same animal due largely to temporary environmental influences. To improve the efficiency of phenotypic selection, the variation due to these environmental peculiarities must be reduced. Correction factors are applied to production records in an effort to standardize them to what they might have been if the environmental conditions had been constant. It is impossible to measure accurately all of the effects of environment. The use of standard correction factors is not likely to make the most appropriate adjustment for each individual record. However, their proper use does remove the average effects of certain extraneous factors which permits more effective selection. It is usually worthwhile to correct for the most important sources of variation only.

Production in range beef cattle may be measured by weight, rate of gain, appraised value, conformation score, or any combination of these traits. At a given age, these traits occur only once in the life of an individual. It is only when these traits are considered as characteristics of the sire or dam that repeated records become available for predicting the producing ability of the parents.

An estimate of the producing ability of the beef cow must be obtained early in her productive life if it is to be of much value in selection. The repeatability of the trait which predicts production must be known in order to determine the number of records necessary to make selection effective early in the cow's life and to compare more accurately cows with varying numbers of records.

Repeatability is the correlation between recurrent expressions of a trait by the same animal. Therefore, the repeatability of a cow's producing ability as measured by the adjusted weights of her calves is obtained by correlating the weights of two or more offspring produced by that cow. It is that fraction of the total variance among corrected records which is due to permanent differences between cows. This fraction includes that portion of the variance due to additive genetic effects and the effects of dominance and epistasis. In addition, it includes any environmental influences which permanently affect the performance of an individual. Since some of this permanent difference between cows may be non-transmissible, repeatability should be as great as, and usually greater, than heritability. The repeatability of a trait may be determined by three methods: (1) the correlation of different records by the same cow, (2) the regression of subsequent records on earlier records by the same cow, and (3) the intraclass correlation obtained from an analysis of variance.

The present study was undertaken to determine the value of using the weights of calves at 112 days of age to estimate the productive ability of range beef cows and to predict 210-day weaning weights of the same calves. An attempt also was made to evaluate some of the factors which cause variations in calf weights at both 112 days and 210 days of age. Correction terms obtained for these effects at the two ages were compared to determine the relative importance of the influence of these variables on weights at the two ages.

The weaning age of 210 days was selected for study since this is the average age at which a large portion of the calves are weaned in Oklahoma and adjoining areas. There were several reasons for studying the weights of calves at 112 days of age as a possible selection criterion for cow productivity. It was thought that the milking ability of the cow might be more apparent at the earlier age of her calf than at weaning time. Calves which suckle their dams on pasture eat more grass as they become older. Calves produced by cows which are poor milkers might be expected to eat more grass than those calves produced by good milking cows. Some breeders creep feed their calves during the suckling period. There is some evidence that the effects of creep feeding do not manifest themselves in the weights of the calves until they are over four months of age. Weights at 112 days of age might be of more value than later weights to estimate the mothering ability of the cows if the practice of creep feeding is followed.

Bull calves often are castrated between two and four months of age. It was thought that the use of weights at 112 days of age might minimize the differences in weights between those male calves kept for bulls and those which were castrated. It is known that differences in climatic conditions which occur within the same year in Oklahoma influence differently the weights of calves dropped at various times in the calving season. It was thought that weights obtained at the earlier age might be influenced less by seasonal variations than weights at 210 days of age.

It may be to the advantage of the breeder to handle the cows which he intends to cull from the herd differently from those which are to be retained. If he could estimate reliably the producing ability of his cows earlier in the summer, the poor producing cows and their calves could be sorted from the herd and placed on supplemental pasture to get them in a more favorable condition for market. It sometimes becomes necessary to reduce the size of the breeding herd during the summer. Occasionally, conditions arise which produce a favorable market for slaughter cows during the summer. An earlier evaluation of productivity would allow the breeder to cull poor producers from the herd to his economic advantage. Purebred breeders, who prefer not to register calves by cows which will be culled from the herd, and breeders who produce calves to be marketed as veal, could make practical use of an earlier weight in appraising cow productivity.

It was recognized that, if variation in persistency of lactation is great among beef cows, the weights of calves at 112 days of age might not be a reliable indication of weaning weight.

In the current study, repeatability estimates of 112-day and 210-day weights were calculated by two methods to determine their relative value in selecting cows on the basis of their first calves' weights at the two ages. Correlation coefficients were obtained between 112-day and 210-day weights to indicate the degree of accuracy in predicting weaning weights from the earlier weights.

REVIEW OF LITERATURE

Rollins and Guilbert (1954) reported the results of a study on repeatability of growth rate of beef calves from birth to four months of age and of 240-day weights of the same calves. The study included weights of 159 purebred Hereford calves from 57 dams obtained during the period from 1944 through 1951. The herd was maintained as a single unit on irrigated pasture during the summer and was wintered on a meadow range. Spring-dropped calves received no supplement during the suckling period, while calves suckling during the winter were creep-fed alfalfa hay. Birth weights were not obtained and the first weight was taken at an age somewhere between birth and one month of age for all calves. Successive monthly weights were taken throughout the suckling period, and the calves were weaned as a group as near 240 days of age as possible.

Adjustments for differences in ages of calves, sex, year and season of birth, and ages of dam reduced the variance of individual rates of gain 31 per cent and the variance of individual weaning weights 55 per cent. The intraclass correlation of corrected records by the same cow, as obtained by the ratio of variances method, provided the repeatability estimate of .34 for rate of growth from birth to four months of age and the estimate of .48 for 240-day weaning weight. Upper and lower limits of the 95 per cent confidence interval for the two traits were .51 and .16, and .63 and .30, respectively. The correlation between the two adjusted traits was .91 when calculated on a between-dams basis. The magnitude of this correlation and the size of the repeatability estimates for the two traits suggested that the maternal influence of the dam was expressed throughout the entire suckling period.

The data from 25 cows with three or more records provided a correlation of .48 between growth from birth to four months of a cow's first calf and the average 240-day weight of her second and third calves. According to this estimate, 23 per cent of the variance of the average weaning weight of a cow's second and third calves was explained by the rate of growth from birth to four months of the first calf. On the basis of four months' gain of their first calves, the five cows with the lowest records were considered as culled, and the remaining twenty cows were considered as selected for herd replacements. The selected cows' second and third calves averaged 23 pounds heavier at 240 days of age than those of the "culled" cows. The authors concluded that some culling of first calf heifers on the basis of their calves' weights early in the suckling period would be effective.

Krasnov and Pak (1939) reported a correlation of .50 between birth weight and weight at four months of age. The correlations between birth weight and adult weight were .56 for males and .41 for females.

Knapp et al. (1942) reported that their study on the effects of various factors on birth weights and weaning weights indicated that sex of the calf, sire, and age of dam had significant effects on both traits. The data analyzed included records on 770 calves produced by 112 cows. Analysis of the data indicated that about 19 per cent of the variance in birth weights was accounted for by differences in cows, while 20 per cent of the variance in weaning weights was due to cow influences. The study included a select population of cows, all of which were capable of producing large calves. The authors concluded that more than 20 per cent of the variance in calf weights in a random-selected population could be attributed to differences between cows.

Koger and Knox (1947) reported the results of a study of the repeatability of yearly production in range beef cows. The records included weaning data on about 900 calves dropped during the period 1935 to 1945, including only those from cows that produced their first calf at three years of age and yearly thereafter as long as their calf records were included. The study included 77 cows with five-year-records, 96 with four-year-records, 121 with three-year-records, and 142 with two-year-records. Comparisons were made within groups of cows that came into production in the same year. The relatively constant environment of each group might tend to give higher estimates than would be expected under different conditions.

Weights were adjusted to a standard age of 205 days, and corrections were made for the effects of sex of calf, age of dam, and years. Correlation and regression coefficients for various combinations of weaning weights and grades of calves were determined for adjacent records by the same cow. All correlation coefficients were highly significant. The average correlation between the weaning weights of all adjacent calves was .49. The correlation between weaning weights of first calves and second calves was .66. When the weight of the first calf was compared with the averages of various combinations of subsequent weights, correlations varied from .51 to .53. The averages of the first two calf weights compared with various combinations of subsequent weights provided correlations varying from .54 to .59. The inclusion of the second record did not increase materially the correlations. Cow differences accounted for 51 per cent of the variance in calf weights, based on cows with five records.

The average score of three judges determined the grades of the calves. The correlation between grades of the first and second calves by the same cow was .24. The inclusion of the second record with the first materially increased the correlation with subsequent records. Analysis of variance indicated that differences in cows accounted for about 33 per cent of the variance in calf grades. It was concluded that differences in maternal ability were expressed more freely in weaning weight than in grade, since all cows seemingly gave sufficient milk for the calf to reach the grade allowed by its conformation.

Gregory and coworkers (1950) described a similar study in which repeatability estimates were obtained for birth weight, weaning weight, and gain from birth to weaning. The data were obtained from two sources and were treated separately in all analyses because of differing environmental conditions. Some of the cows calved first as two-year-olds, and the remainder calved first at three years of age. The ages of the dams and years of calving were completely confounded. The data were analyzed on an intra-year, intra-lot basis, and sex correction was necessary only for birth weight. Sire differences were not significant either for gains to weaning or for weaning weights, as determined by a few progeny in each sire group. Birth and weaning weights were collected at the North Platte Station, Nebraska, in 1936 for 33 calves. Birth weights for 248 calves and weaning weights for 237 calves were obtained from 1944 through 1947 at that station. These calves were dropped in March and April and were weaned near 200 days of age. Seventy-four birth weights and sixty-nine weaning weights were obtained from the Valentine Station during 1935 and 1936. These calves were dropped in May and June and were weaned near 150 days of age.

Correlations between first and second records made by the same cow were higher than those for any other combination of records in all three traits studied. Correlation coefficients for various combinations ranged from -.12 to .24 for birth weight, from .35 to .50 for weaning weight, and from .38 to .57 for gain from birth to weaning. The correlations between birth weight and weaning weight were .27 at North Platte and .60 at Valentine. The correlations between birth weight and gain to weaning were .07 and .44 at North Platte and Valentine, respectively. Correlation and regression coefficients for various cow-calf weight relationships were presented. Heritability estimates as obtained by paternal half-sib correlations were .45 and 1.00 for birth weight, .00 and .45 for gain from birth to weaning, and .26 and .52 for weaning weight, from the North Platte and Valentine data, respectively.

Koch (1951) analyzed weaning weight data obtained from 745 calves produced by 180 cows. The calves were dropped in April and May and were weaned in October. Weights were adjusted for differences in ages of calves, sex, year, age of dam, inbreeding of calves, and inbreeding of cows. The repeatability estimate of weaning weight, determined by means of a ratio of variances, was .52, with upper and lower limits at the 95 per cent level of confidence of .60 and .44, respectively. The average uncorrected weight of all calves was 393 pounds. The standard deviation of adjusted weights was 27 pounds. The average age at weaning was 176 days.

The average inbreeding of all cows was 5.9 per cent, while that for all calves was 12.4 per cent. The regression of calf weight on inbreeding of the dam was -2.54 pounds for each 1 per cent of inbreeding, while the regression of weight on the calf's own inbreeding was -.48 of a pound for each 1 per cent of inbreeding.

Botkin and Whatley (1953) reported the results of a study of repeatability of production in range beef cows. The data included birth weights and weaning weights of calves produced in herds at two locations. Birth weights were available for 620 calves and weaning weights for 603 calves produced by 151 cows at the Stillwater Station from 1944 through 1951. Birth weights and weaning weights were available for 98 calves produced by 49 cows at the Fort Reno Station during 1950 and 1951. The cows in the Stillwater herd calved first at three years of age, while the group at Fort Reno calved first as two-year-olds. The calves were dropped largely in February, March, and April, with a few coming in January and May. The calves were weaned as a group in October each year. The calves were with their dams on range throughout the suckling period without access to a creep, with the exception of one group of 26 calves which was creep-fed during the summer of 1951.

Birth weights were corrected for the effects of sex of the calf, age of dam, and year. Weaning weights were adjusted to a standard age of 210 days by use of the age intercept method, and corrections were made for sex of calf, age of dam, and year. Repeatabilities of birth weight, weaning weight, and gain from birth to weaning were determined by two methods: (1) the intraclass correlation between calves by the same cow and (2) the regression of subsequent records on earlier records by the same cow. The repeatability estimate for weaning weight, calculated as the ratio of variance between cows to the total variance, was .43, with upper and lower limits at the 95 per cent confidence level of .55 and .29, respectively. The estimate obtained from the regression of second records on first records was .51, while the regression of all subsequent records on the first gave an estimate of .49. The repeatability estimates of birth weight were .18, based on the intraclass correlation of records by the same cow, and .14 as determined by the regression of all subsequent records on the first. The estimate obtained for the portion of the variance due to permanent differences between cows for gain from birth to weaning was .38 by both methods. The authors concluded that the very low producers could be culled on the basis of their first calves' weaning weights with little danger of culling the average or above average cows and that birth weight was not nearly as useful as weaning weight in measuring cow productivity.

Koch and Clark (1955a) reported estimates of heritability and repeatability and genetic and environmental relationships for several traits of economic importance in beef cattle. The data were collected from the registered and grade Hereford herds at the U. S. Range Livestock Experiment Station, Miles City, Montana, during the period 1926 through 1951 and included records from 4,553 calves by 137 different sires. Weaning weights were standardized to 182 days of age. Adjustments were made for the effects of sex, age of dam, year, line of breeding, inbreeding among lines, and sire. Repeatability estimates, as determined by maternal half-sib correlations from the pooled data of all lines, were as follows: .26 for birth weight; .34 for weaning weight; .34 for gain from birth to weaning; and .20 for fall yearling weight. Heritability estimates were computed from paternal half-sib analyses. The estimates obtained for birth weight, weaning weight, gain from birth to weaning, and yearling weight were .35, .24, .21, and .47, respectively. The genetic correlation between birth weight and gain from birth to weaning was .46, indicating that many of the same genes affected prenatal and postnatal growth to weaning. The genetic correlation between yearling gain and gain from birth to weaning was -.05, indicating almost complete genetic independence of gain for the two periods.

Rollins and Wagnon (1956) analyzed weaning weights of 577 calves to estimate repeatability and heritability of weaning weight in herds subjected to diverse environmental conditions. One herd of grade cows received supplemental feed during the late summer, fall, and winter, while the other herd received no supplemental feed. The two herds were maintained under conditions otherwise similar.

Repeatability estimates were .51 and .34 in the herds subjected to high and low nutritional regimes, respectively. Heritability estimates, as determined by paternal half-sib correlations, were .09 for weaning weight of the calves in the herd on the high level of nutrition and .54 for calves produced in the herd that received no supplemental feed. The 95 per cent confidence intervals determined for both repeatability and heritability estimates covered the two estimates for both traits. The authors concluded that the two levels of nutrition had no significant effect on estimates of repeatability and heritability.

Knapp and Nordskog (1946) reported heritability estimates for birth weight and weaning weight as determined by two methods. Data analyzed were weight records from 177 steer calves by 23 sires. Estimates obtained from paternal half-sib correlations were .23 for birth weight and .12 for weaning weight, while those obtained from the regression of offspring on sire were .34 for birth weight and .30 for weaning weight.

Knapp and Clark (1950) reported heritability estimates of weight at several ages from an intra-year, intra-station analysis, based on paternal half-sib correlations. From the progeny of 110 Hereford sires, the estimate obtained for birth weight was .53, while that for weaning weight was .28. The estimates obtained for growth after weaning were of a greater magnitude, the highest being .86 for final feedlot weight at 15 months of age. By the similar analysis of comparable data, Shelby et al. (1955), reported heritability estimates of .72 for birth weight and .23 for weaning weight.

Koch and Clark (1955b) reported heritability estimates for several traits in beef cattle, as determined by the regression of offspring on dam and the regression of progeny average on sire. From the analysis of records on 4,234 calves from 1,231 dams, estimates for birth weight were .44 and .35, and for weaning weight, .11 and .25, as determined by the offspring-dam regression and the progeny-sire regression, respectively. Koch and Clark (1955c) reported the results of a study aimed at evaluating the maternal influence of cows in the phenotypic expression of traits in their calves other than that from genes transmitted to the calves by their dams. Heritability estimates for various traits were determined with maternal environment taken into account. Estimates obtained for birth weight, weaning weight, and gain to weaning were .42, .19, and .12, respectively.

Several workers have estimated the permanent difference between dairy cows in milk and butterfat production. Others have studied the importance and nature of persistency of lactation in dairy cattle.

Lush and Arnold (1937) compared lifetime averages of 676 daughters and their dams to obtain an estimate of the actual variation between records that could be attributed to permanent differences between cows and to ascertain what share of these permanent differences were transmissible. Cows mated to the same sire were divided into high and low lines on the basis of their fat production in the first lactation tested. The regression of later records toward the herd average measured the extent to which differences in the first records were due to temporary environmental influences. The differences between the average records of the daughters of the two groups of cows, when doubled and divided by the average difference between the first records of their dams, measured the degree to which variations in single records were inherited and the amount of gain which could be obtained in the first generation of selection. The estimate obtained for repeatability of milk production was 0.43, and that for the inherited portion of the variation was 0.28. This left 15 per cent of the variation due to permanent, but non-transmissible, differences between cows.

Dickerson (1940) analyzed the data of 1,574 lactations from 274 Holstein cows to determine what adjustments for environmental influences were advisable when comparing cows in their butterfat producing ability. The average within-herd correlation between records by the same cow was the criterion used in evaluating these adjustments and in comparing five kinds of adjusted records. Repeatability estimates were obtained on the unadjusted production records at 240 days, 305 days, 365 days, and total lactation. These estimates ranged from 0.23 for 240-day records to 0.26 for total lactation. Adjusting the records for age of the cow significantly raised the repeatability estimates of all five kinds of records, the increase being greater for 240-day and 305-day records than for longer lactation records. Similarly, correction for calving interval to a 365-day basis significantly increased the repeatability estimate by reducing the variation among records by the same cow and increasing the variation between cow means.

Berry (1945) analyzed data obtained from H.I.R. Yearbooks to obtain gross and intra-herd correlations on butterfat production between different records by the same cow and between parent and offspring. Correlations of various combinations of records were determined by the use of path coefficients. The analyses of records of 454 Holstein cows gave gross repeatabilities for butterfat production of 0.41 for six-record-cows and 0.38 for seven-record-cows. The correlations obtained between single records and various combinations of records by the same cow were in close agreement with the expected values. The major increase in the reliability of estimating later production from early records came from the addition of the second record to the first. Inclusion of records beyond the third contributed little additional information.

Madden et al. (1955) studied the effectiveness of using partial records in selection for increased milk and fat production. The data consisted of 599 production records by 253 Holstein cows compiled from 1940 through 1952. Heritability estimates were obtained for monthly and cumulative milk and butterfat production by the intra-sire regression of daughter's production on dam's production. Heritability estimates for single month milk and fat production and for cumulative month milk and fat production were .15, .09, .25, and .19, respectively. Repeatability estimates for the same traits, in that order, as determined by intraclass correlations were .41, .32, .57, and .51, respectively. Both repeatability and heritability estimates decreased for later single months. The authors concluded that this was an indication of increased effects of temporary environmental influences on production in the latter stage of lactation which suggested that persistency of lactation was determined primarily by extraneous environmental sources rather than by inherent qualities of the cow.

Ludwick and others (1943) studied the genetic aspects of persistency of lactation in several breeds of dairy cattle. The first lactation was more persistent than later ones, and younger cows were more persistent than older cows. Persistency values for the second and all subsequent lactations were about 10 per cent less than each preceding one. The three most important sources of variation in persistency were age of the cow, frequency of milking, and length of the calving interval. The authors postulated that a major portion of the variation in persistency is probably the result of the "inheritance of factors or genes which govern the development and rate of function of various endocrine glands, the interaction and interdependence of such glands, or the inherited or acquired ability of various tissues to respond to various glandular secretions. The mode of inheritance is undoubtedly complex."

Mahadevan (1951) studied persistency of lactation from 5,000 lactation records of Ayrshire cattle in Scotland. Numerical expressions of persistency were obtained by the use of the formula

$$\text{persistency} = \frac{A-B}{B},$$

in which A represented the milk yield during the first 180 days and B was the initial milk yield during the first ten weeks of lactation. The data were corrected for the variance due to age of dam, first calvers having a higher persistency than older cows. The repeatability estimate for persistency, based on the intra-cow correlation within herds, was .24. The estimates obtained for heritability indicated that only about 10 to 15 per cent of the total variance was attributable to additive genetic differences in persistency. The authors concluded that the improvement of management practices would be the most advisable method of making immediate improvement in persistency of lactation.

Sidwell and Grandstaff (1949) analyzed the weaning weights of 1,506 lambs from 414 Navajo ewes. Six environmental factors were found to have significant effects on weaning weights. Analysis of variance of weights adjusted for the effects of year of birth, age of ewes, breeding of sire, type of birth, sex, and age of the lamb allowed the computation of the repeatability estimate of .22 for weaning weight.

Hazel and Terrill (1945) estimated the heritability of weaning weight in range Rambouillet lambs. The average of four estimates obtained by paternal half-sib correlations was .27, while the average of the four estimates obtained by the intra-sire regression of offspring on dam was .34. In a later report, Hazel and Terrill (1946) estimated the heritability of weaning weight from data gathered from three flocks of Columbia, Corriedale, and Targhee ewes. Estimates obtained by means of paternal half-sib correlations and offspring-dam regressions gave estimates ranging from -.01 to .45. The average estimate for all three breeds combined was .17.

Nelson and Venkatachalam (1949) reported heritability estimates for birth weight and weaning weight of lambs from weight records of five breeds gathered during 1945 through 1948. Significant portions of the variation in these weights were due to differences in sex, single or multiple birth, and age of dam. On the average, female lambs weighed 5 per cent less than males at birth and 6 per cent less at weaning. Lambs from mature ewes were 10 per cent heavier than those from two-year-olds at birth and 5 per cent heavier at weaning. Single lambs were 22 per cent heavier than twins at birth and 17 per cent heavier at weaning.

Weights were adjusted for each of these effects before heritability estimates were calculated. Estimates were obtained for each breed separately and were then combined by weighting each estimate by the reciprocal of its squared standard error. Weighted averages of the heritability estimates obtained by two methods were .61 for birth weight and .33 for weaning weight.

The results of several studies of repeatability and heritability of weights at different ages in swine have been reported. Bywaters (1937) analyzed the variance in 60-day weaning weights of 1,633 Poland-China pigs in 271 litters to determine the relative importance of heredity and environment in causing weight variations. The heredity of the pig accounted for 18 per cent of the total variation, while only 4 per cent was due to the additive genetic effect. Environment common to litter mates made up 40 per cent of the total variance, leaving 42 per cent attributable to environment not common to litter mates. Sixteen per cent of the total variance was accounted for by age of dam and season of farrowing, while that portion attributable to permanent differences between dams was estimated to be 10 per cent.

Lush and Molln (1942) reported the results of an extensive study in which repeatability estimates were obtained for the number of pigs farrowed, the number of pigs weaned, and the weaning weight of the litter. The data were collected from experiment stations and college herds of eight states and in herds maintained by the United States

Bureau of Animal Industry. Three estimates of repeatability were obtained for each trait and were as follows: .15, .13, and .17 for number farrowed; .16, .13, and .17 for number weaned; and .13, .12, and .18 for weaning weight of the litter.

Whatley (1942) analyzed the weight data of 1,394 Poland-China pigs in 267 litters to determine the influence of heredity and environment on 180-day weights. The simple correlation between 60-day weight and 180-day weight was .55. The sex difference in 180-day weight was significant with gilts weighing 4 per cent less than barrows and boars. The influence of age of dam was not significant on 180-day weight. Heritability estimates for 180-day weight, as determined by several different methods, ranged from .20 to .62. The author concluded from the results that at least 30 per cent, and perhaps more than 40 per cent, of the variance in 180-day weight was due to the additive effect of genes.

Baker et al. (1943) observed the relative importance of heredity and environment on rate of gain and weight from birth to 168 days of age. They reported that the heredity of the pig played an increasingly important role in development from birth to 112 days, during which time the genetic variance increased from 7 per cent to 31 per cent, and the environmental influence decreased from 51 per cent to 34 per cent. After 112 days of age, the importance of heredity decreased while that of environment increased.

Hazel et al. (1943) calculated genetic and environmental correlations between gains in three 56-day periods from birth to 168 days of age in swine. The genetic variance constituted 15, 28, and 17 per cent of the observed variance in each of the three periods. The authors concluded that genes with persistent effects were responsible for a large portion of the genetic variation and that heredity had a less important, but a more constant, influence upon growth rate than did environment.

Nordskog and others (1944) reported heritability estimates for weight at several ages from the analysis of variance of data on 2,396 pigs and from the offspring-dam regression of 312 dam-litter comparisons. The effects of age of dam accounted for 22 per cent of the total intra-line, intra-year variance of weight at weaning. Environmental variance common to each litter was greatest at 21 days, accounting for 37 per cent of the total variance at that age. It decreased to 7 per cent at 168 days of age. The highest heritability estimate obtained was .45 for gain from 56 days to 168 days of age. Heritability of 168-day weight was .27.

Cummings et al. (1947) obtained heritability estimates of total litter weaning weight from 532 daughter-dam comparisons. Heritability was estimated to be 59 per cent, with the effects of inbreeding, size of the litter at birth, and survival number held constant. It was suggested that this figure might approximate closely the heritability of milk production in the sows.

Shrode (1950) analyzed the data from a large number of litters to determine how well the 154-day weight of a future litter could be predicted from three-week and eight-week data on an earlier litter and how much information would be sacrificed if only the more useful data were used in a production index. Analyses of litter records indicated that the eight-week data were slightly more useful and reliable as an indication of sow productivity than the corresponding three-week data, except for the repeatability of litter weights, in which case the repeatability estimate for three-week litter weight (.14) was slightly higher than that for eight-week litter weight (.08).

The author concluded that sow productivity could be predicted as accurately from an index composed of either three-week or eight-week litter data as it could be from an index composed of the data at both ages.

Blunn et al. (1954) studied the interrelationships of weights of 1,894 pigs at birth, 56 days, and 154 days of age. The highest average within-litter correlation was .63 between 56-day and 154-day weight. The correlation between birth weight and weaning weight was .53. The coefficients of determination indicated that only 28 per cent and 40 per cent of the variance in 154-day weights could be accounted for by a knowledge of birth weights and 56-day weights, respectively.

Lerner and Cruden (1948) obtained estimates of heritability of accumulative monthly and annual egg production in a flock of White Leghorn hens and studied the effectiveness of using a partial laying record as an early indication of total egg production. The heritability of accumulative egg production was found to be nearly constant throughout the year and was approximately 33 per cent. Genetic correlations between partial and full production were found to be high. A genetic correlation of .82 was reported between accumulated production through the fourth month and total annual production. With the addition of each successive month's production, the correlation was raised only slightly. The authors concluded that there was a possibility of efficient selection for increased egg production on the basis of partial records more economically than on the basis of annual production, partly because of the decreased interval between generations allowed by an earlier evaluation.

The Effect of Age of Calf

The method of weighing calves at a constant age to eliminate variation in weight due to age differences is impractical under most conditions. Since the ages at which weights are taken vary considerably, some method must be used to standardize calf weights to a common age.

For the unadjusted data analyzed by Rollins and Guilbert (1954), the average rate of growth from birth to four months of age was 1.91 pounds per day with a standard deviation of .31 of a pound. The average 240-day weaning weight was 534 pounds with a standard deviation of 70 pounds. Each calf's weight was standardized to 120 days and 240 days of age with its own successive monthly weights used for a linear interpolation.

Koger and Knox (1945b) obtained an average intraclass regression of weight on age of 1.33 pounds per day, based on the analysis of over 800 calf weights that were classified by year, sex, and age of dam. This regression coefficient was used in a modification of the age intercept method to obtain correction factors for standardizing calf weights to 205 days of age. These factors were used to design a nomograph for convenience in adjusting weights to a common age.

Sawyer et al. (1948) reported that the regression of weight on age was 1.28 pounds per day. Growth was uniform from 25 to 35 weeks of age for the beef calves studied.

Johnson and Dinkel (1951) studied monthly weights of 297 grade and purebred Hereford calves to obtain the growth curves from birth to weaning and to calculate correction factors for adjusting weights of range calves to standard ages of 155 days and 190 days. Most of the calves were dropped in April and May, and all were weaned on the same day as near November 1 as possible. The calves ran with their dams on range pasture and received no creep feed. The average weaning age was 185 days with an average weight of 380 pounds. Monthly weights made it possible to plot a growth curve which indicated almost linear growth from birth to 155 days of age. Growth then slowed down, but it was essentially linear from 155 to 225 days of age. The regression of weight on age to 155 days was 1.85, while the regression for the period from 155 to 225 days was .85 of a pound per day. Correction factors were obtained for the two periods by use of the age intercept which assumes that the rate of gain was constant throughout the period. Another set of corrections was obtained for standardizing weights to 190 days of age by use of a quadratic equation, based on the assumption that the decrease in the rate of growth was constant throughout the period. The accuracy of the two sets of correction factors was compared by studying the weights of 70 calves which had a weight at or near 190 days and weights near 30 days prior to and following the standard age. The results indicated that corrections by either method were accurate enough to be useful, but the factors obtained by the linear equation were more accurate and were recommended over those obtained from the quadratic equation. Caution was advised in applying a given set of correction factors to calves raised under varying climatic and management conditions or to weights which varied beyond 30 days preceding or following the standard age.

Koch (1951) obtained a regression of weight on age of 2.27 pounds per day which was used to adjust weights to a standard age. The average weight of the calves was 393 pounds at an average age of 176 days.

Botkin and Whatley (1953) reported an intraclass regression of weight on age of 1.46. Ages at which the calves were weaned varied from 120 days to 260 days, the average age being 217 days. The weights were adjusted to a standard age of 210 days by the age intercept method. Growth curves were plotted for five groups of calves produced in 1948, 1950, and 1951, for which monthly weights were available. Growth was essentially linear during the portion of the curve to which corrections were applied. In the same study, Botkin (1952) further checked the linearity of growth by adjusting weights by the use of the regression coefficient and on the basis of average daily gain. The correlation between weights corrected by the two methods was .98. Differences between weights corrected by the two methods were noticeable only for calves 50 days or more younger than the average.

In 1954, Burgess et al. reported the regression of weight on age to be 1.67, which was used to standardize the weaning weights of calves to 210 days. Koch and Clark (1955a) found growth to be essentially linear from birth to weaning. All weights were standardized to 182 days of age by the use of the actual rate of gain for each calf. Evans et al. (1955) analyzed weaning weights of 1,737 purebred and grade Hereford calves. The regression coefficients of weight on age at weaning for the purebred and grade calves were .91 and 1.08, respectively. A modification of the age intercept method was used to standardize weights to 210 days of age. Rollins and Wagnon (1956) adjusted each calf's weaning weight to 240 days of age by making a linear interpolation or extrapolation based on its weaning weight and its previous weight taken about one month before weaning.

From a study of the growth curves of 255 pigs, Taylor and Hazel (1955) found linear growth from 134 to 174 days of age. Six methods of adjusting weights to 154 days of age were compared. The two most accurate and convenient methods were the age intercept method and the correction by linear interpolation when two weights bracketed the standard age.

The Effect of Sex of Calf

At birth, bull calves generally have been found to be four to five pounds heavier than heifers. (Dawson et al., 1947; Gregory and others, 1950; Burris and Blunn, 1952; and Botkin and Whatley, 1953).

Rollins and Guilbert (1954) reported that bull calves gained .13 of a pound more per day than heifers from birth to four months of age. At 240 days of age, bull calves were 68 pounds heavier than heifers. Lush et al. (1930) observed the growth of beef cattle under range conditions for a number of years and found that steers consistently grew at a faster rate than heifers. Knapp and coworkers (1942) reported an average difference of 22 pounds between steers and heifers at weaning.

Koger and Knox (1945a) found that steer calves averaged 32 pounds heavier than heifer calves at 205 days of age. Woolfolk and Knapp (1949) found steers to have a 28 pound advantage over heifers at weaning. Gregory et al. (1950) found no significant difference between the sexes for gain from birth to weaning, or for weaning weight, after weights had been adjusted to a standard age. The sex difference at birth was significant with bull calves outweighing heifers by about 5 pounds.

Koch (1951) found that bulls and steers were 44 pounds and 13 pounds heavier, respectively, than heifers at 176 days of age. The weighted difference between male and female calves was 23 pounds. The authors concluded that the large difference between bulls and steers might have been due to the selection of heavier or faster gaining calves for bulls. The steers also might not have had sufficient time to overcome the setback caused by castration.

Botkin and Whatley (1953) reported that the average difference between males and females at weaning was 24.6 pounds. The weights were corrected to a steer equivalent by adding 25 pounds to the age corrected weights of all females. Burgess et al. (1954) found that steers weighed only slightly more than heifer calves, but bull calves were significantly heavier than either steers or heifers at weaning. Evans and coworkers (1955) found bull calves to be

22 pounds heavier than heifers at weaning, while steers were 17 pounds heavier.

Hitchcock et al. (1955) found that age corrected yearling weights averaged 43 pounds greater for steers than for heifers, based on data of 722 grade Hereford yearlings. From the analysis of data on 5,952 Hereford calves, Koch and Clark (1955d) reported that steer calves averaged 26.2 pounds heavier than heifers at weaning. Rollins and Wagnon (1956) found that steer calves weighed 31 pounds more than females in the herd maintained at an optimum nutritional level. The corresponding sex difference for calves raised in the herd on the lower nutritional level was 18 pounds.

The Effect of Age of Dam

Lush and Shrode (1950) stated, "It is well known that milk production increased with age at an ever-decreasing rate until maximum production is reached at around six to eight years of age. Production then declines with advancing age." From the analysis of a large number of production records from the files of the Holstein-Friesian Association of America, multiplicative age correction factors were determined for cows from two to fifteen years of age.

Gifford (1953) reported that milk production of the Hereford cows which he studied reached its peak at six years of age. The gross correlation between total milk production and gain of the calf to six months of age was .65. Knapp and Black (1941) reported that milk consumption of Shorthorn calves was the most important influence found on gain during the suckling period with a correlation of .52 between quantity of milk consumed and gain from birth to weaning.

Rollins and Guilbert (1954) reported that young cows and old cows produced calves that grew more slowly to four months of age and were lighter at weaning than calves produced by cows of intermediate ages. Calves from first-calf heifers and second-calf cows grew slightly faster than calves from older cows during the period four months to eight months of age. The authors concluded that this was evidence of greater persistency of lactation in the younger cows.

Knapp et al. (1942) found that maximum weaning weights were from calves produced by six-year-old cows, with a gradual increase from two to six years of age and a more rapid decrease from six to eleven years.

Knox and Koger (1945) studied the effect of the age of the cow on her production under range conditions. The calves were dropped in March, April, and May and were weaned in October and November at an average age of 205 days. The average weight of the cows from three to ten years of age and the average weight of their calves were plotted. The cows attained the greatest weight and produced the heaviest calves between six and eight years of age with a peak at seven years. A high correlation between the weight of the cow and her calf indicated that highest production occurred when the cow was in the period of greatest physical vigor.

In 1947, Dawson et al. reported an increase of .20 of a pound in birth weight for each month increase up to six years in age of the Shorthorn cows studied. The correlation between birth weight and age of the dam was .45 for male calves and .36 for females. According to Sawyer et al. (1948), two-year-old cows produced calves which were 75 pounds lighter at 30 weeks of age than those produced by mature cows. Their data indicated that weaning weights increased with the age of the dam through eight years of age. After that age, weaning weights declined with the increased age of the dam.

Botkin and Whatley (1953) found that cows five through thirteen years of age performed similarly, based on the weaning weights of their calves. Botkin (1952) divided these cows into age groups within each year and calculated selection differentials for age and sex corrected weaning weights. Within each year and age group, the selection differential was the difference between the cows retained in the herd for further use and the average of all cows in the group before calving. The average selection differential was one pound and was ruled out as a factor affecting production of the older cows. All cows five years and older were considered mature and weaning weights of calves by three and four-year-old cows were corrected to the mature equivalent by the addition of 35 pounds and 15 pounds, respectively. Birth weights were adjusted by adding four pounds to the weights of calves from three-year-old cows and two pounds to the weights of calves from four-year-old cows. This correction removed 82 per cent and 62 per cent of the variation in weaning weights and birth weights, respectively, due to differences in ages of dams.

Burgess et al. (1954) reported that, from the analysis of weaning weights of 546 conventional type purebred Hereford calves, cows reached their peak of production between six and eight years of age. Evans et al. (1955) obtained age of dam differences at weaning from data on over 1,700 purebred and grade Hereford calves. Cows reached their maximum production, based on the weaning weights of their calves, between five and eight years of age. Correction factors obtained for two, three, four, nine, and ten-year-old cows were 106, 54, 20, 14, and 43 pounds, respectively.

Hitchcock et al. (1955) found that the ages of the dams when the offspring were dropped had no significant effect on the yearling weights of the calves. Koch and Clark (1955d) studied two methods of calculating correction factors for age of dam influences on weights which were as follows: (1) the comparison of the averages of all records made at each age and (2) the comparison of records made by the same cow at different ages. Both methods indicated that the cow's production increased steadily from three to six years of age and then declined for both birth and weaning weights.

Additive adjustment factors were compiled for weaning weights. The adjustment for three-year-old cows and ten-year-old cows was the addition of 41 pounds and 24 pounds, respectively. Adjustments for fall yearling weights were about one-half the magnitude of those for weaning weights.

Rollins and Wagnon (1956) found that cows were at their maximum production at seven and eight years of age in both of the herds studied. The age correction for three-year-old cows was approximately 50 pounds, while 10 to 15 pounds were needed to correct weights of calves from ten-year-old cows to the mature equivalent.

The Effects of Other Sources of Variation

Rollins and Guilbert (1954) found it necessary to make adjustments for season of birth and year effects when comparing weights of calves dropped in different years and in different seasons within a year. Calves dropped from 1948 through 1951 were lighter than those dropped from 1944 through 1947.

Koch (1951) found that for each 1 per cent inbreeding of the dam, the weaning weight of the calf was decreased 2.54 pounds. Weaning weight was decreased .48 of a pound for each 1 per cent inbreeding of the calf. Tyler et al. (1947) found that the birth weight of the Holstein-Friesian calves studied declined an average of .28 of a pound for each 1 per cent inbreeding of the calf.

Burgess et al. (1954) analyzed data collected over the six year period from 1946 through 1951. Year differences were found to have a significant effect on weaning weight. In 1947, the average weaning weight of the calves was 24 pounds less than the average of all years, while, in 1951, the average weaning weight was 20 pounds greater than the average of all years. Inbreeding of the cow and the calf had significant effects on weaning weight. For each 1 per cent inbreeding of the calf, weaning weight at 210 days of age decreased 1.76 pounds, while an increase of 1 per cent inbreeding of the cow decreased weaning weight 1.15 pounds.

Botkin and Whatley (1953) found that the effect of years on weaning weights was due to grazing conditions, as influenced largely by rainfall during July and August, but the year effect on birth weights was not consistent. All weights were corrected for year effects by adjusting the weights of calves in each year to the average of all years. The dams of the calves in the study were subjected to different nutritional regimes. Botkin (1952) found these treatment differences to be significant. However, corrections for these effects reduced total variance and the variance between cows nearly the same. He concluded that the increase in repeatability after adjusting for treatment differences was not enough to warrant the extra time and labor required for making corrections. Rollins and Wagnon (1956) concluded that the levels of nutrition to which the two herds in their study were subjected did not appreciably affect repeatability and heritability estimates of weaning weight when calculated on an intra-herd basis, although the average performance of the two herds differed greatly.

DESCRIPTION OF THE DATA

The data used in this study were a series of weights of calves produced in four experimental beef cattle herds maintained at three locations in the State of Oklahoma. The cattle in these four herds differed in location, breeding, nutritional treatments, and, to some extent, in management practices under which the herds were maintained. Because of these differences, the data were treated separately. The distribution of the data in each herd is given in Table I. To each herd has been assigned a research project number. In the following discussion, reference will be made to the project numbers in describing the data from each herd.

TABLE I

DISTRIBUTION OF DATA FROM FOUR SOURCES

Project No.	670		650		526-S		526-W	
Locations	Fort Reno		Fort Reno		Stillwater		Wilburton	
Standard Ages of Calves	112	210	112	210	112	210	112	210
No. of Cows	77	76	109	111	62	62	55	52
No. of Calves	229	230	494	543	232	232	155	146

Only those cows having two or more records were considered, since the study was designed to estimate the repeatability of calf weights at 112 days and 210 days of age. Birth weights were obtained for all calves within 24 hours of birth. Weights were available near 112 days of age for 1,110 calves produced by 303 cows. Weaning weights were available for a total of 1,151 calves produced by 301 cows during the period 1950 through 1955. The average weight of all calves at weaning was 454 pounds, and the average age was 208 days. The pooled data are shown in Table II.

TABLE II

DISTRIBUTION OF POOLED DATA FROM FOUR HERDS

Standard Age of Calves	112 Days	210 Days
No. of Cows	303	301
No. of Calves	1110	1151
No. of Males	576	595
No. of Females	534	556
Ave. Age (days)	110	208
Standard Dev.	15	19
Ave. Weight (pounds)	279	454
Standard Dev.	42	65

Most of the calves were dropped during the three-month period of February, March, and April, although a few were dropped in January and May. The male calves in the grade herds were castrated when most of the calves were between two and four months of age. The male and female calves in these herds were dehorned at the same time. None of the purebred calves were dehorned, and few of the male calves were castrated in the registered herd. All calves were weaned at the same time, usually in early October. With the exception of 62 calves in Project 670 which were creep fed during the summer of 1953, all calves were with their dams on native pasture from birth to weaning with access to no feed other than their dams' milk and what grass and salt-mineral mixture they would eat.

The cattle in Project 670 were registered animals of Hereford and Aberdeen-Angus breeding maintained at the Fort Reno Experiment Station near El Reno. This project was initiated in 1949 for the purpose of studying the genetic aspects of some of the more economically important traits in beef cattle. There are three separate lines of cattle which are unrelated in this project, and they have been handled under similar environmental and management conditions from their beginning. The bulls which were used in each line were similar in type and breeding to the cows of that line. Some inbreeding has been practiced in two of the lines. The data from this project were collected during the years 1951 through 1955. Weights near 112 days of age were available for 229 calves produced by 77 cows, while weaning weights were available for 230 calves from 76 cows.

Project 650 was initiated in 1948 at the Fort Reno Experiment Station with 120 choice grade, unregistered, weanling Hereford heifers. The heifers were allotted at random to eight lots of 15 head each. Three levels of supplemental winter feeding, designated as high, medium, and low, were assigned to the lots. Two of the lots (7 and 8) also were assigned to supplemental summer feeding regimes. Superimposed on these nutritional treatments were differences in the ages of the heifers at first calving. The heifers in lots 1, 3, 5, and 7 were calved first as two-year-olds, while the heifers in lots 2, 4, 6, and 8 calved first at three years of age. All groups grazed native grass pastures of similar quality throughout the year. The supplemental winter feeding regimes were as follows: low level (lots 1 and 2), 1 pound of cottonseed cake per head daily; medium level (lots 3, 4, 7, and 8), 2.5 pounds of cottonseed cake per head per day; and high level (lots 5 and 6), 2.5 pounds of cottonseed cake and 3.0 pounds of oats per head per day.

On the summer supplement phase, the cows in lot 7 received 1.5 pounds of cottonseed cake and 3.5 pounds of oats per head daily from July 1 to October 1. The cows in lot 8 received the same supplemental ration containing 1.0 to 1.5 grams of thyroprotein daily per hundred pounds of body weight.

The cows bred to calve as two-year-olds calved first in the spring of 1950. Weights during the suckling period were not obtained for these calves; however, their weaning weights were included in the 210-day analyses. The cows bred to calve first at three years of age calved in the spring of 1951. Weights were available near 112 days of age and at weaning for these calves. Weights near 112 days of age were available for 494 calves produced by 109 cows. Weaning weights were available for 543 calves from 111 cows including those produced by cows two years of age.

Project 526-S was conducted at the Lake Carl Blackwell Experimental Range near Stillwater. Sixty-four grade Hereford cows of varying ages were assigned to four lots of sixteen head each. These lots were assigned to a study designed to determine the effect of high manganese intake on the performance of beef cows. Several weights of these calves were available between birth and weaning during the five year period, 1951 through 1955. Weights near 112 days of age and at weaning were obtained for 232 calves produced by 62 cows during that period.

Project 526-W was begun in 1951 at the Range Cattle Minerals Station near Wilburton. Sixty head of two-year-old grade Hereford heifers were divided into six lots of ten head each. The treatments assigned to these cattle were designed to investigate the influence of the following factors on production of beef cattle: (1) parasite control, (2) summer shade, (3) phosphorus intake, and (4) feeding trace minerals. The weights used in the present study were from the 1953, 1954, and 1955 calf crops. Weights near 112 days of age were available for 155 calves produced by 55 cows. Weaning weights for 146 calves from 52 cows were available in this project.

METHODS OF ANALYSIS AND RESULTS OF THE STUDY

Some of the major sources of variation, in addition to differences in the mothering ability of beef cows, which are known to influence weights of beef calves include variations in the following factors: (1) ages of the calves at the time they are weighed, (2) sex of the calves, (3) ages of the dams at the time of calving, (4) years, (5) treatments to which the cows are subjected, and (6) lines of breeding. Some correction must be made for the effects of the major sources of variation in an effort to adjust weights to a more comparable basis before a reliable estimate of the differences in mothering ability among cows may be determined.

Evaluating the average influence of these identifiable sources of variation and adjusting the observations for them amount to controlling, statistically, a portion of the variation. Statistical control may not remove all variation due to a given source because of the errors in evaluation. If the effect varies from one observation to the next, only the average effect will be removed by statistical control. Even so, any variation removed increases the accuracy with which the real differences between cows can be assessed.

In the present study, the data were classified according to the sex of the calf, age of the dam, year of birth, and treatment lot or line of breeding. Therefore, the weights in each class were from calves of the same sex, dropped in the same year, and produced by cows of the same age that had been subjected to the same treatment or were of the same line of breeding. The methods employed to determine the correction factors used to adjust weights to a comparable basis are explained in the succeeding subsections.

The Influence of Age of Calf

The age intercept method was used in this study to obtain correction factors for adjusting calf weights to the standard ages of 112 days and 210 days. This method was introduced by Bywaters and Willham (1935) and used by Whatley and Quaife (1937) to standardize the weights of pigs to a common age. Phillips and Brier (1940) used the method to standardize the weights of lambs to a constant age of twenty weeks. Several workers have extended the method for standardizing weights of beef calves to a standard age. This method is based upon the regression of weight on age and assumes essentially linear growth during that age period to which the correction factors are to be applied.

The uncorrected average weights were plotted for the calves in each project at five-day intervals during the age range from which 112-day weights were obtained. The range in ages for the earlier weights and for weaning weights are given for each project in Appendix Table I. A line representing the average regression of weight on age for each project was then superimposed on the weight-for-age plot. In each project, the regression line closely followed the plotted weights, the major deviations from the regression line being the points at the extreme ages, each of which was composed of only a few weights. Although this method is not an exact test for linearity of growth, it does indicate that growth does not differ greatly from linearity during that age range to which correction factors were applied. Although weights were not plotted for that age range from which corrected 210-day weights were obtained, linearity of growth during that period was assumed. The same method of standardizing weights was used for both ages to make comparisons between weights at the two ages more accurate than if different methods had been used.

The age intercept method involves the use of the intraclass regression of weight on age, as determined from an analysis of covariance. It is the regression of weight on age with the effects of sex, age of dam, year, and treatment or line of breeding removed. The intraclass regression coefficients for each group of data are presented in Table III for both 112-day and 210-day weights. A sample of the method of covariance analysis used is presented in Appendix Table II for the data from project 650 near 112 days of age. The analyses from which the project intraclass regression coefficients were determined are presented in Appendix Tables III and IV for the earlier and the later data, respectively.

TABLE III

INTRACLASS REGRESSION COEFFICIENTS FOR EACH PROJECT

Project	670		650		526-S		526-W	
Standard Age	112	210	112	210	112	210	112	210
Regression (Weight on Age)	1.83	2.23	1.26	1.31	1.49	0.99	1.19	1.52

It was desired to pool the data from these herds in order to obtain composite age correction factors. It was believed that the data should be pooled only when the growth rate of the calves in the different projects was similar. The difference between the regression coefficients for the four groups of data was tested by the method described by Snedecor (1946). This test is presented in Appendix Tables VII and VIII for the regression coefficients for early weights and weaning weights, respectively.

The tests indicated that there were significant differences between the project regression coefficients at both ages. The coefficients for project 670 were larger than those for the other herds. After the removal of the data from project 670, the test made, as shown in Appendix Tables

IX and X, indicated no significant differences among the regression coefficients from the other three herds. Since the coefficients from project 670 were significantly different from those calculated for the other three projects, correction factors were computed for adjusting the weights of calves in that project to 112 days and 210 days of age using the coefficients derived from that project only. From the composite regression coefficients obtained from the pooled data of the other three projects, age adjustment factors were calculated for use on all calves in the three remaining projects.

The age intercept method of standardizing the weights of calves to a constant age involves the following series of formulae:

Age intercept

$$= \text{Average Age} - \frac{(\text{Average Weight})}{(\text{Intraclass Reg. Coeff.})}$$

Corrected Weight

$$= \text{Actual Weight} \times \frac{(\text{Standard Age}) - (\text{Age intercept})}{(\text{Actual Age}) - (\text{Age intercept})}$$

Age correction factors for the two ages were determined as follows:

(1) For calves in project 670

$$112 \text{ day age intercept} = 119 - \frac{302}{1.8292} = -46$$

$$\text{Corrected 112-day weight} = \text{Actual Wt.} \times \frac{158}{\text{Actual Age} + 46}$$

$$\text{210-day age intercept} = 207 - \frac{448}{2.2336} = +6$$

$$\text{Corrected 210-day Wt.} = \text{Actual Wt.} \times \frac{204}{\text{Actual Age} - 6}$$

(2) For calves in projects 650, 526-S, and 526-W

$$\text{112-day age intercept} = 110 - \frac{279}{1.2751} = -109$$

$$\text{Corrected 112-day wt.} = \text{Actual wt.} \times \frac{221}{\text{Actual Age} + 109}$$

$$\text{210-day age intercept} = 208 - \frac{454}{1.3139} = -138$$

$$\text{Corrected 210-day wt.} = \text{Actual wt.} \times \frac{348}{\text{Actual Age} + 138}$$

A table of the correction factors for the various ages can be made for convenience in standardizing weights. The correction factor for a given age is multiplied by the actual weight of a calf at that age. Some sample correction factors for a few selected ages are given in the following tables.

TABLE IV

CORRECTION FACTORS FOR VARYING AGES OF CALVES AT 112 DAYS IN PROJECT 670

Age	C.F.	Age	C.F.
111	1.0064	113	.9937
110	1.0128	114	.9875
109	1.0194	115	.9814
108	1.0260	116	.9753
107	1.0327	117	.9693

TABLE V

CORRECTION FACTORS FOR VARYING AGES OF CALVES AT 210 DAYS IN PROJECT 670

Age	C.F.	Age	C.F.
209	1.0049	211	.9951
208	1.0099	212	.9903
207	1.0149	213	.9855
206	1.0200	214	.9808
205	1.0251	215	.9761

TABLE VI

CORRECTION FACTORS FOR VARYING AGES OF CALVES AT 112 DAYS IN POOLED PROJECTS

Age	C.F.	Age	C.F.
111	1.0046	113	.9955
110	1.0091	114	.9910
109	1.0138	115	.9866
108	1.0184	116	.9822
107	1.0231	117	.9779

TABLE VII

CORRECTION FACTORS FOR VARYING AGES OF CALVES AT 210 DAYS IN POOLED PROJECTS

Age	C.F.	Age	C.F.
209	1.0029	211	.9971
208	1.0058	212	.9943
207	1.0088	213	.9915
206	1.0116	214	.9886
205	1.0146	215	.9858

The 112-day weights of 100 calves adjusted by these correction factors were correlated with the 112-day weights of the same calves adjusted by average daily gain interpolation. These calves were all dropped during the same year in project 670. The average age of these calves was 122 days with a range from 42 days to 155 days. After the effects of line of breeding, age of dam, and sex were removed, the correlation between weights adjusted by the two methods was only .50. After the removal of the weights of all calves beyond 30 days either side of the standard age, the correlation was increased to .95. Although based on a small number of calves, these correlations indicate that the correction of calf weights by use of the age intercept method beyond 30 days either side of the standard age contains considerable error.

The Influence of Sex of Calf

It was known from previous studies that differences in growth rate exist among bulls, steers, and heifers. In the use of repeated records by the same cow, some adjustment may be necessary for sex differences, since the weights of both males and females usually will be present. The accuracy of the comparison of the production of different cows may be increased by making adjustments for sex differences among their offspring.

After calf weights had been adjusted to the standard ages of 112 and 210 days of age, the average differences between male and female calves were determined for each project. These differences are presented in Table VIII for calves at both ages. Males were heavier than females in all cases.

TABLE VIII

WEIGHT DIFFERENCES BETWEEN MALES AND FEMALES AT 112 AND 210 DAYS OF AGE FOR EACH PROJECT

Project	670		650		526-S		526-W	
Standard Age	112	210	112	210	112	210	112	210
Sex Differences (Males-Females) Pounds	18	38	15	26	11	28	20	27

The difference between male and female calves at 210 days of age was greater in project 670 than in the other projects. With few exceptions all male calves in project 670 were left as bulls. In the other three projects weight differences between steer and heifer calves were quite similar. The data from the three grade herds were pooled to obtain sex correction factors. These are presented in Tables IX and X.

TABLE IX

SEX DIFFERENCES AT 112 DAYS OF AGE IN PROJECTS 650, 526-S, AND 526-W

Sex	Number of Calves	Average Weight (pounds)
Male	457	289
Female	429	275
Difference (Males-Females)		14

TABLE X

SEX DIFFERENCES AT 210 DAYS OF AGE IN PROJECTS 650, 526-S, AND 526-W

Sex	Number of Calves	Average Weight (pounds)
Male	475	470
Female	445	443
Difference (Males-Females)		27

In this study, the age adjusted weights of female calves were corrected to a male equivalent. In project 670, 18 pounds were added to female weights at 112 days of age, and 38 pounds were added to the 210-day weights of these heifers. The weights of the heifer calves in the other projects were increased by 14 pounds at 112 days of age and by 27 pounds at 210 days of age.

The Influence of Age of Dam

Previous studies indicated that calf weights varied among cows of different ages. Therefore, in comparing the productivity of cows of varying ages, some adjustment should be made for this bias.

In the present study, the ages of the cows in projects 650 and 526-W were completely confounded with years because the cows in these two projects were the same age at the time the projects were initiated. Therefore, direct evaluation of the effects of age of dam on calf weights could not be made. However, the removal of the average differences associated with year effects automatically removed the effects of age of dam in these two herds.

After adjustments had been made for differences in age and sex of the calf, the average weights of calves by dams of each age were calculated in projects 670 and 526-S. The average calf weights for each age of dam are given in Table XI at the earlier age and in Table XII at weaning in project 670.

TABLE XI

ADJUSTED 112-DAY WEIGHTS OF CALVES FROM DAMS OF DIFFERENT AGES IN PROJECT 670

Age of Dam	Number of Calves	Average 112-Day Weights	Corrections (pounds)
2	13	262	+43
3	33	289	+16
4	43	305	
5	48	307	
6	49	303	
7	25	306	
8	12	303	
9	6	275	+30

TABLE XII

ADJUSTED 210-DAY WEIGHTS OF CALVES FROM DAMS OF DIFFERENT AGES IN PROJECT 670

Age of Dam	Number of Calves	Average 210-Day Weights	Corrections (pounds)
2	13	402	+74
3	35	449	+27
4	44	479	+ 1
5	49	489	-13
6	46	493	-17
7	25	493	-17
8	12	502	-26
9	6	442	+34

The cows in project 670 ranged from two through nine years of age. A study of the average 112-day weights for each age of dam revealed that cows from four through eight years of age were almost identical in their production. The average calf weight produced by these cows was 305 pounds. The average weights of calves produced by cows two, three, and nine years of age were found to be lighter by 43, 16, and 30 pounds, respectively, than the average for the mature group. These differences were added to the weights of calves produced by cows of the respective ages.

The average weights of calves produced by cows of the same intermediate age group were not as consistent at 210 days as they were at 112 days of age. A weighted average for dams of all ages was calculated. The deviation of each age of dam group from the average of all dams was added to, or subtracted from, the 210-day weights of all calves from cows of that age.

In project 526-S, calves were produced by cows which varied from four to ten years of age. The average weights of calves produced by each age of dam and the number of weights contained in each average are shown in Table XIII for 112-day weights and in Table XIV for weights at 210-days of age. All calves produced by four-year-old cows and most of those produced by five-year-old cows were dropped in 1951. All of the calves produced by cows ten years of age were dropped in 1954. Calves produced by cows of all other ages were available during three or four years. Therefore, weights of calves produced by cows four and five years of age were compared with the weights of calves produced by six, seven, and eight-year-old cows in the same years. In a like manner, the average weights of calves produced by ten-year-old cows were compared with the average weights of calves produced by six, seven, and eight-year-old cows in the same year. From these comparisons, adjustment factors were obtained for the adjusting of calf weights produced by the four, five, and ten-year-old cows. These adjustment factors are presented in Table XIII for the weights of calves at 112 days of age and in Table XIV for 210-day weights.

TABLE XIII

ADJUSTED 112-DAY WEIGHTS OF CALVES FROM DAMS OF DIFFERENT AGES IN PROJECT 526-S

Age of Dam	Number of Calves	Average 112-Day Weights	Corrections (pounds)
4	7	259	+30
5	32	260	+30
6	35	282	
7	56	278	
8	48	293	
9	32	282	
10	22	301	-17

TABLE XIV

ADJUSTED 210-DAY WEIGHTS OF CALVES FROM DAMS OF DIFFERENT AGES IN PROJECT 526-S

Age of Dam	Number of Calves	Average 210-Day Weights	Corrections (pounds)
4	7	446	+40
5	32	444	+40
6	35	476	
7	56	468	
8	48	474	
9	32	479	
10	22	477	-35

The Influence of Years

The preliminary analysis of the data used in this study indicated that years had significant effects on the weights of the calves in two of the projects. Large differences between years were to be expected in projects 650 and 526-W since year differences were confounded with age of dam differences.

The greatest deviation of a single year average from the weighted average at 112 days in project 670 was only two pounds. Therefore, no year adjustments were made on 112-day weights in that project. Correction factors which were applied to calf weights are shown in Table XV for the two standard ages in each project.

TABLE XV

CORRECTION FACTORS FOR YEAR EFFECTS[1]

Project	670		650		526-S		526-W	
Std. Age	112	210	112	210	112	210	112	210
1950				+55				
1951	0	-32	-27	+33	0	- 5		
1952	0	+11	-13	+20	- 9	-18		
1953	0	+ 3	+12	-38	+ 8	- 5	-16	- 6
1954	0	+26	+18	-32	0	+31	-17	+48
1955	0	+32	+10	-15	- 4	+21	0	-44

[1] Given as the pounds added to, or subtracted from, each calf's weight, based on the deviation of each year's average from the weighted average of all years.

Although year differences had no significant effect on 112-day weights in project 526-S, the greatest deviation was nine pounds, and correction factors were applied to 112-day weights of calves in that herd. The correction factors for year effects at 210 days indicate that years have a much more pronounced influence on weights at the later age than at 112 days of age.

The variable effects of years on calf weights probably are due largely to differences in annual and seasonal rainfall and other climatic variations. There was considerable variation in the rainfall during the period from which these data were obtained. The use of different sires during the six years of this study might be expected to contribute to the differences between years. Sires were not known for most calves, and their effects were not removed except when sires were confounded with season or treatment groups.

Correction factors for year influences were calculated for each project at the two standard ages and were applied to the calf weights in that project. The weights of calves produced in each year were adjusted to the average of all years by adding to, or subtracting from, each weight the deviation of that year's average from the weighted average of all years.

Because of the confounding of years with age of dam in two of the herds, the data could not be pooled to obtain composite year effects. Therefore, year corrections were made on an intra-herd basis, and the correction terms were determined after weights had been adjusted to a standard age and corrected for sex of calf and age of dam effects in the two herds in which age of dam differences could be determined.

The Influence of Treatment and Line of Breeding

The calves included in the study from the three grade herds were produced by cows which were subjected to different nutritional treatments and, to some extent, to different management procedures. The calves from project 670 were from three different lines of breeding, including two breeds. In this project, some selection had been directed toward the producing ability of the cows.

Preliminary analysis of the data indicated that treatment and line differences influenced calf weights at 112 days of age to the extent that corrections should be made for these effects. The greatest variation in calf weights between treatments at this age was in project 650, in which the treatment influences were highly significant. Treatment differences were not as great in projects 526-S and 526-W, but they were significant, indicating the advisability of making adjustments.

The differences between the three lines of breeding in project 670 had highly significant effects on 112-day weights of the calves from that herd. Line III (large type Herefords) had the heaviest calves on the average at both 112 and 210 days of age. The cows in Line II (medium type Herefords) produced the lightest calves at both ages, while the cows in Line I (Aberdeen-Angus) produced calves which were intermediate to the weights of calves produced in the other two lines.

Corrections were made for the treatment and line differences within each project at the two ages. After adjustments were made for the age of the calf, sex, age of dam, and year, the average weights of the calves in each lot or line were obtained. A weighted average was then calculated for all lots within each project by dividing the sum of the weights of each lot by the total number of calves. Adjustments for lot or line differences were made by adding to, or subtracting from, each weight the deviation of its respective lot average from the weighted average. This corrected the average of each lot to the average of all lots.

The Influence of Mothering Ability of the Cow

In order to determine to what extent the adjusted weights of calves at 112 and 210 days of age were permanent characteristics of their dams, repeatability estimates were derived by two different methods for each of the four groups of data. It was of particular interest in this study to determine and compare the estimates of repeatability obtained from the same calves at 112 and 210 days of age.

Repeatability estimates for adjusted calf weights at the two ages were obtained first by an analysis of variance from which an intraclass correlation was obtained. The basis for this method is the comparison of the variation among the average calf weights of different dams with the variation of calf weights from the same cows. A second estimate of repeatability was obtained for each group of data by the regression of subsequent records on the first record of the same cow. The estimates obtained by the two methods for each project are given in Table XVI. All estimates were determined after calf weights had been adjusted to a standard age and after corrections had been made for the effects of the sex of the calf, the age of the dam, year, and treatment or line of breeding.

TABLE XVI

REPEATABILITY ESTIMATES AS DETERMINED BY TWO METHODS FOR EACH PROJECT

Project	670		650		526-S		526-W	
Std. Age	112	210	112	210	112	210	112	210
r[1]	.32	.31	.29	.34	.20	.29	.36	.36
b[2]	.37	.32	.44	.35	.15	.42	.27	.23

[1] r = intraclass correlation

[2] b = regression of subsequent records on the first

These estimates did not vary greatly among projects for weights at the same age. Therefore, the data from all four projects were pooled to obtain a single estimate of repeatability of weights at the two ages. The analyses of variance of calf weights from which project intraclass correlation coefficients were determined are presented in Appendix Table V, for 112-day weights, and in Appendix Table VI, for weights at 210 days of age.

Repeatability of Weights at 112 Days of Age

To determine the portion of variance in calf weights due to permanent differences between cows, weights of calves at 112 days of age were analyzed from the pooled data of all projects by an analysis of variance, as shown in Table XVII.

TABLE XVII

ANALYSIS OF VARIANCE OF ALL CORRECTED 112-DAY WEIGHTS

Source of Variation	D.F.	Sum of Squares	Mean Square	Mean Square is an Estimate of:
Total	1106	1,047,476		
Cows	299	501,439	1677.1	$\sigma^2_e + 3.68^1 \sigma^2_c$
Calves by the same cow	807	546,037	676.6	σ^2_e

[1] The average number of records per cow was 3.68.

The value obtained for σ^2_e was 676.6, which represents the variance remaining between calves produced by the same cow after adjustments have been made for some of the sources of variation due to temporary environmental effects. The value of σ^2_c was calculated to be 271.9 using the following formula:

$$\sigma^2_c = \frac{1677.1 - 676.6}{3.68} = 271.9,$$

in which 1677.1 is the mean square representing the variation between cows; 676.6 is the mean square representing the variation between calves by the same cow; and 3.68 is the average number of calf weights for each cow included in the analysis.

The value, $\sigma^2_c = 271.9$, represents the increase in variance between calves having different dams. The sum of these two variance estimates, $\sigma^2_e + \sigma^2_c = 676.6 + 271.9 = 948.5$, provides an estimate of the variance of all corrected calf weights at 112 days of age.

After σ^2_c has been determined, the repeatability of 112-day calf weights may be calculated as follows:

$$\text{Repeatability} = \frac{\sigma^2_c}{\sigma^2_c + \sigma^2_e} = \frac{271.9}{948.5} = .29$$

This fraction of the variance in calf weights, .29, is the intraclass correlation coefficient between the 112-day weights of calves produced by the same cow. The upper and lower limits of the 95 per cent confidence interval are .34 and .24, respectively.

To further determine the effectiveness of culling cows on the basis of 112-day weights of their first calves, a regression was obtained for the average of all weights taken later than the first on the weight of the first calf produced by the same cow. The adjusted weight was obtained for the first calf produced by each cow included in the study. The cows were then divided equally into a high group and a low group on the basis of the 112-day weights of their first calves. The average weights of all calves after the first one were then determined for each cow. A comparison of the difference between the average weights of the first calves by these two groups of cows and the difference between the averages of all later calves produced by the same cows give a measure of the repeatability of the dam's performance for this trait.

The average weights of the first calves and of all later calves for the high and low groups are given in Table XVIII and are shown graphically in Figure 1. The herd average for all 112-day weights was 295 pounds.

TABLE XVIII

AVERAGE 112-DAY WEIGHTS OF CALVES FROM HIGH AND LOW GROUPS OF COWS SELECTED ON THE WEIGHT OF THEIR FIRST CALF

	Total No. of Calves	High Group	Low Group	Difference (High-Low)
Ave. 112-day Wt. of First Calves	303	318	272	46
Ave. 112-day Wt. of all Later Calves	805	303	287	16

From these data the repeatability of 112-day calf weights may be calculated by dividing the difference between the average weights of all calves subsequent to the first by the difference between the average weights of the first calves produced by cows in the high and low groups.

$$\text{Repeatability} = \frac{16}{46} = .35$$

Repeatability of Weights at 210 Days of Age

Repeatability estimates for calf weights at 210 days of age were determined by the same methods used to determine those for weights at 112 days of age. The analysis of variance of 210-day weights from the pooled data of all projects is shown in Table XIX.

TABLE XIX

ANALYSIS OF VARIANCE OF ALL CORRECTED 210-DAY WEIGHTS

Source of Variation	D.F.	Sum of Squares	Mean Square	Mean Square is an Estimate of:
Total	1147	2,200,260		
Cows	297	1,097,869	3696.5	$\sigma^2_e + 3.90^1 \sigma^2_c$
Calves by the same cow	850	1,102,392	1296.9	σ^2_e

[1] The average number of records for each cow was 3.90.

The increased variance among calves due to their having different dams was calculated as follows:

$$\sigma^2_c = \frac{3696.5 - 1296.9}{3.90} = 615.3$$

The intraclass correlation of weights by the same cow, which provided the estimate of repeatability, was calculated as the ratio of the variance between cows to the total variance as follows:

$$\text{Repeatability} = \frac{615.3}{615.3 + 1296.9} = .32$$

The upper and lower limits of the 95 per cent confidence interval are .37 and .27, respectively.

The repeatability estimate for weights at 210 days of age was obtained by the regression of all weights subsequent to the first on the first weight in the same manner used for 112-day weights. The averages for the high and low groups are given in Table XX and are shown graphically in Figure 2. The herd averages for all adjusted 210-day weights was 471 pounds.

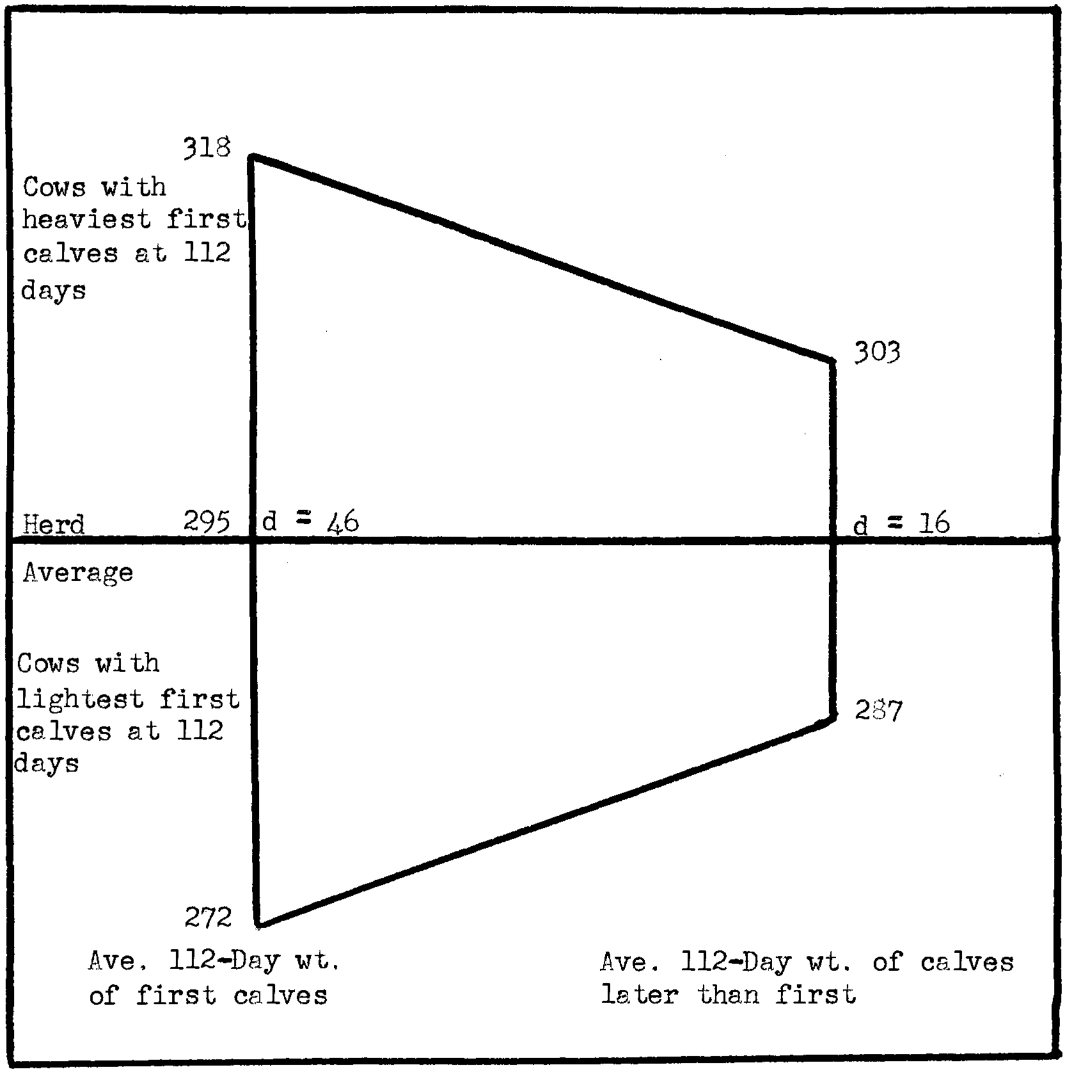
From these data, the repeatability of 210-day weights was calculated by the same manner used for 112-day weights and is as follows:

$$\text{Repeatability} = \frac{23}{68} = .34$$

TABLE XX

AVERAGE 210-DAY WEIGHTS OF CALVES FROM HIGH AND LOW GROUPS OF COWS SELECTED ON THE WEIGHT OF THEIR FIRST CALF

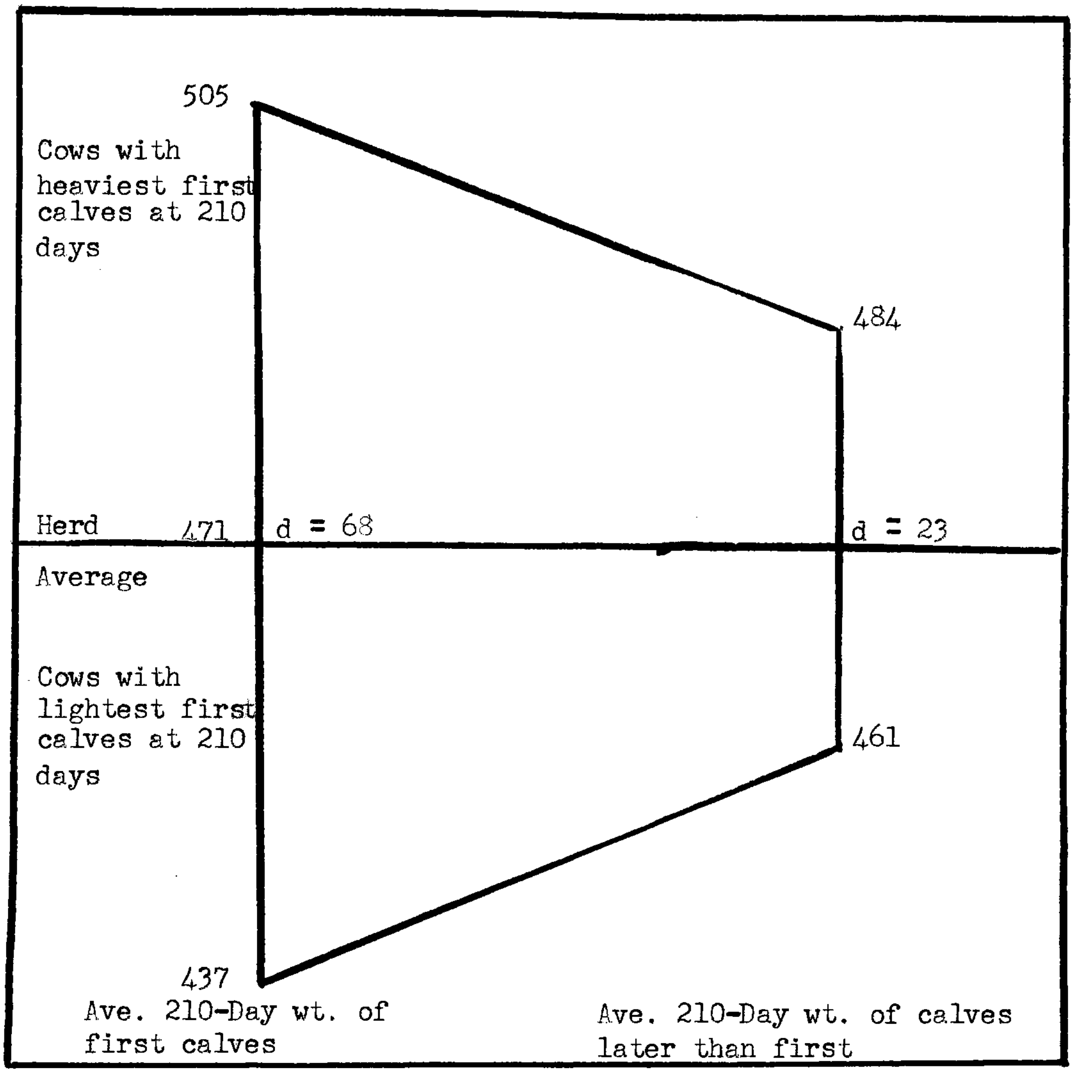
	Total No. of Calves	High Group	Low Group	Difference (High-Low)
Ave. 210-day Wt. of First Calves	301	505	437	68
Ave. 210-day Wt. of All Later Calves	851	484	461	23



d = difference between average 112-day weights of calves produced by the two groups of cows.

Figure 1. - - Regression of 112-day weight of later calves on the 112-day weight of the first calves. Dams divided equally into high and low groups on the 112-day weight of their first calf.

$$\text{Repeatability} = \frac{16}{46} = .35$$



d = difference between average 210-day weights of calves produced by the two groups of cows.

Figure 2. - - Regression of 210-day weight of all later calves on the 210-day weight of the first calves. Dams divided equally into high and low groups on the 210-day weight of their first calf.

$$\text{Repeatability} = \frac{23}{68} = .34$$

Correlation of Calf Weights at 112 and 210 Days of Age

Since the repeatability estimates obtained for adjusted calf weights at 112 and 210 days of age did not differ appreciably in this study, it appeared that selection would be equally effective at either age of calf. The other purpose of this study was to determine the relationship between 112-day and 210-day weights of the same calves. Correlation coefficients were then calculated between the adjusted 112-day and 210-day weights of the first calves produced by the cows in each project. These coefficients are presented in Table XXI.

TABLE XXI

CORRELATIONS BETWEEN ADJUSTED 112-DAY AND 210-DAY WEIGHTS OF FIRST CALVES

Project	670	650	526-S	526-W
Correlations	.66	.83	.72	.74

The correlation coefficients for weights at the two ages were not greatly different considering the relatively small number of cows in each project. The pooling of the data from the four projects resulted in a correlation of .74 between the weights of the first calves at 112 and 210 days of age. The data were then pooled for all calves produced in the four herds. The correlation coefficient between the average 112-day calf weights and the average 210-day weights for all calves produced by the same cow was found to be .86, with upper and lower limits at the 95 per cent confidence level of .90 and .83, respectively. This high correlation indicates that cows which have the heaviest calves at 112 days of age usually produce the heavier calves at 210 days of age. This was demonstrated by sorting all cows into high producing and low producing groups based upon the 112-day weights of their first calves. The same cows were sorted again into high and low groups based on the 210-day weights of their first calves. It was found that 80 per cent of the cows were in the same high or low production group at both 112 and 210 days. If these cows were sorted into high and low production groups based on the average 112-day and 210-day weights of two or more calves, an even higher percentage might be expected to remain in the same groups.

DISCUSSION AND APPLICATION

The primary purpose of this study was to determine the importance of some of the factors which influence the 112-day and 210-day weights of beef calves which were produced in herds handled under range conditions. Of particular interest was the determination of the degree to which calf weights at the two different ages reflected permanent effects of the dams. Correction factors were calculated from the data which were then used to reduce the variation among calf weights known to be associated with certain sources of temporary environmental variation. The removal of the average effects of these variables from individual calf weights should accentuate real differences between the producing ability of different dams and make selection based upon these adjusted weights more effective. The removal of the average effects of these sources of variation left considerable variance between calves by the same cow, much of which may be attributed to varying temporary environmental conditions which were not adequately adjusted for by the correction factors which were applied.

The age intercept method was used in this study to adjust calf weights to a standard age, since it had been found to be reasonably accurate and usable under practical conditions. The age intercept is based on the regression of calf weight on the age of the calf. Essentially linear growth is assumed to occur during that age period to which adjustments are to be applied. The plotting of the average calf weights at various ages indicated that growth rate of calves near 112 days did not deviate greatly from linearity in this study. The regression of calf weight on age near 112 days in project 670 was found to be 1.83, which is quite similar to the regression of 1.91 reported by Rollins and Guilbert (1954). The corresponding regression coefficient of 1.28, obtained by pooling the data from the three grade herds in this study, was lower than the regression in project 670 or that reported by Rollins and Guilbert (1954). Some of the slower rate of growth observed in the grade herds might have been expected. The grade cows differed in breeding from the purebred cows and were subjected to nutritional treatments and management procedures which might have prevented as rapid growth as that of the purebred calves. Probably of greater importance is the fact that more selection for cow productivity has been practiced in the purebred herd than in the grade herds.

The same trend was noted for the regression of weaning weight on weaning age. Regression coefficients of 2.23 and 1.31 were obtained in this study for projects 670 and the pooled data, respectively. Rollins and Guilbert (1954) reported a regression of 1.81 for weaning weight near 240 days of age. Koger and Knox (1945a, 1945b) reported the regression of weaning weight on weaning age near 205 days to be 1.21 and 1.33, respectively. Sawyer et al. (1948) found that growth was uniform between 25 weeks and 35 weeks of age and that the regression of weight on age at weaning was 1.28. Johnson and Dinkel (1951) reported regression coefficients of 1.85 from 0 to 154 days of age and of .85 from 155 to 225 days of age for purebred calves on South Dakota range. Koch (1951) reported the regression of weaning weight on age to be 2.27 for calves averaging 176 days of age. Botkin and Whatley (1953) reported the regression of weight on age to be 1.46 for grade calves averaging 217 days of age. In 1954, Burgess et al. reported a regression of 1.67 for calves averaging 210 days of age, while Evans et al. (1955) reported regression coefficients of .91 and 1.08 for purebred and grade calves, respectively, which averaged 210 days of age.

Obviously, regression coefficients reported by the various workers should not be compared directly because of the differing conditions under which they were obtained. The differences in the regressions emphasize the differences in growth rate of calves in different herds and indicate that no "standard" set of correction factors is likely to adjust with equal accuracy weights of calves raised under variable conditions. However, the use of such correction factors may make comparisons more accurate than if no adjustments are made at all.

Another method which may be used to adjust calf weights for differences in age is made possible by obtaining two or more weights at ages which bracket the standard age. Individual weights then may be adjusted by making a linear interpolation based on the average daily gain of each calf during that period. A limited study of these data indicated that the age intercept and average daily gain methods made about the same adjustment for calf weights taken within 30 days of the standard age. The age intercept method was less accurate for adjusting weights of calves which deviated widely from the average age. Similar conclusions were drawn by Sawyer et al. (1948) and by Johnson and Dinkel (1951). Botkin (1952) reported that differences between weights corrected by the two methods were particularly noticeable for calves which differed more than 50 days from the standard age. Therefore, the method of obtaining weights which bracket the standard age would be of most value to those ranchers whose calves are dropped during a period of several months. The increased accuracy of these adjusted weights possibly might offset the added labor and expense required to take the second record. It usually is not possible to weigh the calves twice in order to bracket the weaning age since the majority of calves are sold at weaning. However, when productivity of the dam is estimated from calf weights at some other age during the suckling period, such as weight at 112 days of age, records may be taken which bracket the standard age.

If the rate of growth during different parts of the suckling period is not linear, then correction of weights on the basis of average daily gain between bracketed weights should be more accurate than correction by means of the regression coefficient covering the entire period.

In this study, sex differences were determined after the calf weights had been adjusted to a standard age. A significant difference of 18 pounds was found between bull and heifer calves in project 670 at 112 days of age. Rollins and Guilbert (1954) reported that the difference between bulls and heifers was not significant at four months of age, although bull calves gained an average of .13 of a pound more per day than heifers, which is an advantage of about 15 pounds for bulls over heifers at four months.

At 210 days of age, the bull calves in project 670 averaged 38 pounds heavier than heifers. Rollins and Guilbert (1954) reported that bulls outweighed heifers by 68 pounds at 240 days of age. Evans et al. (1955) found that bull calves were only 22 pounds heavier than heifers at weaning. Koch (1951) found that bulls were 44 pounds heavier than heifers at 176 days of age but attributed some of this difference to selection. The older and heavier males were left as bulls. In any herd where some males are castrated and some are left for breeding bulls, selection is likely to be an important factor contributing to differences observed between bull and steer calves at weaning.

Although only a relatively small number of weights for bull calves were available in project 670, a study of the sex differences indicated that differences between bulls and steers, on the average, were small at 112 days of age. Adjustment for differences between bulls and steers at 112 days of age would probably not be necessary. The difference between bulls and steers was more pronounced at 210 days of age.

The differences between steers and heifers in the three grade herds revealed the same trend at the two standard ages. From the pooled data, steers were heavier than heifers by 14 pounds and 27 pounds at 112 and 210 days of age, respectively. These figures were used to correct female weights to the male equivalent. No direct comparisons were available from previous studies for the sex difference at the earlier age. Although the magnitude of the difference at 112 days of age was only about one-half that at 210 days of age, adjustments for sex differences undoubtedly would be worthwhile also at the earlier age.

The difference of 27 pounds between steer and heifer weights at weaning was in general agreement with results reported by other workers. Koch (1951) found that steers averaged 13 pounds heavier than heifers at 176 days of age. These steers were the cull males of a purebred herd. The author concluded that this, along with the fact that the steers probably had not sufficiently overcome the setback caused by castration, resulted in a smaller sex difference than normally would be observed. Koger and Knox (1945a) reported that steers averaged 32 pounds heavier at 205 days of age than heifers. Rollins and Wagnon (1956) reported that steers averaged 31 pounds heavier than heifers in a herd maintained at a high nutritional level, while the sex difference was only 18 pounds in a herd on a low level of nutrition. This indicates that the more extreme sex differences might be partially due to varying levels of nutrition, but sufficient data are not available to make a definite statement. Most reports indicate that the difference between steers and heifers in range herds is near 25 pounds, which compares favorably with the 27 pounds found in this study.

Corrections for weight differences associated with variable ages of dams were made by correcting the calf weights of each age of dam to the average of all ages. The deviation of the average of each group from the weighted average of all groups was added to, or subtracted from, the weight of each calf in its respective age of dam group.

Appropriate correction factors for age of dam effects were difficult to obtain in this study because cow age groups were not represented equally within years, and not all age of dam groups were present each year. Cow ages and years were completely confounded in two projects. Although age of dam influences could not be evaluated in these two herds, correction for the effects of years automatically removed the effects of different ages of dam at the same time. In project 526-S, cows four and ten years of age had calves in only one year. It was thought that the method of comparing calf weights of these cows with the records made by cows of other ages in the same year would provide the most logical correction for age of dam effects in that herd. In this group of cows, the period of maximum production was from six through ten years of age for both 112-day and 210-day calf weights. The actual peak of production was at ten years and nine years for weights at 112 and 210 days, respectively.

Calf weight records were available from cows which varied from two through nine years of age in project 670. The period of maximum production was between four and eight years of age based on calf weights at both standard ages. The actual peak of production was at seven years of age for 112-day weights and eight years for 210-day weights. In this project, age of dam effects on 112-day weights were between one-half and two-thirds the size of those at weaning. At both ages, the correction factor for a three-year-old cow was about one-third the size of that for two-year-old cows, while the nine-year-old correction factor was about two-thirds the magnitude of that for cows two years of age. Less confidence can be placed in the averages of the young and old cows than in those of cows in the intermediate age range since the former contain only a small number of records.

These age-of-dam differences may not be the same for cows under environmental conditions differing from those in the present study. However, the production curves obtained here were in general agreement with those found in previous studies. Botkin and Whatley (1953) reported that ten, eleven, and twelve-year-old cows produced heavier calves at weaning than cows of some younger age groups but attributed this high level of production in older cows to chance in sampling. The age of peak production for beef cows, based on weaning weights, was reported to be six years by Knapp et al. (1942), seven years by Knox and Koger (1945a) and Burgess et al. (1954), and eight years by Sawyer et al. (1948). The ages at which the calves were weaned varied in these reports, and the averages of the different age groups were not directly comparable. However, they did indicate a definite influence of age of dam on productivity based on weaning weights of calves.

Correction factors used to adjust weights of calves for the effects of yearly variation were computed from the data to which they were to be applied. The confounding of age of dam with years in the two projects, and the climatic variation within and among years at the three locations were expected to make year effects markedly different for the four herds.

In each herd, year variations had a much more pronounced effect on calf weights at 210 days of age than at 112 days of age. This indicates that seasonal variations within years were present and had their greatest influence on 210-day weights. This seasonal variation was probably the result of the unusually dry and hot late summers which have occurred during the last three years included in this study. Weight records for calves at 112 days of age, which were not confused by the interaction of year and age of dam, required little, if any, adjustment for year differences.

If cows are compared on the basis of records made in the same year, no adjustment is necessary. Weights need be adjusted for yearly variation only when cows are compared on the basis of one or several records made in different years. If about the same number of females go into the herd each year as replacements, there should be no confounding of age of dam and year as was encountered in this study. This does make it necessary, however, to make some adjustments for both age of dam and year effects when comparing cows of different ages which have produced calves in different years.

For the purpose of this study, adjustments for the effects of treatment and line of breeding differences were made on an intra-herd basis by correcting the weights of all calves in each lot or line to the average of all groups in each herd. Group averages were obtained after the weights had been adjusted for the effects of age of calf, sex of calf, age of dam, and years. Although the various treatments to which the cows were subjected might be considered good in range herds, significant differences were found between lots for both the 112-day and 210-day weights. However, lot and line differences were not expressed to as great an extent in 112-day weights as they were in weaning weights. In each herd, group differences for the earlier weight were about one-half the size of the differences at 210 days of age. For the most part, cattlemen compare the production of cows that have been handled under similar methods of management and have had access to the same kind of feed. In that case, treatment differences are not encountered. If comparisons are made between cows which differ markedly in breeding, the producer might wish to determine the extent of these line differences as a basis for family selection.

Botkin (1952) found significant differences between treatment groups at weaning. However, adjustment for these effects reduced the variance between calves by the same cow and the variance between cows to nearly the same extent, making little change in the repeatability estimate. His final analysis was on weights which were not corrected for treatment differences. If the weights of calves produced by cows in each group were permanently influenced by treatment effects, the repeatability estimate would be biased upward. It was thought that the method used in this study removed the major portion of any treatment effects that might have permanently affected adjacent records of the same cow.

Although the adjustments made in this study do not necessarily represent the most accurate corrections possible, the procedures may be used by cattlemen whose herds are handled in a manner similar to those in this study. The intelligent application of the proper correction factors should make selection for mothering ability more effective than if no adjustments were made.

The repeatability of calf weights is that portion of the total variation between corrected calf weights which may be attributed to permanent differences between cows. The remaining fraction of the variance between weights is due to temporary circumstances which have variable effects on different records made by the same cow. An estimate of repeatability describes the population from which it is computed and may not be applicable to herds of different breeding or those handled under different climatic conditions or systems of management.

The higher the repeatability of the trait, the more accurately producing ability can be predicted from a single record. When the repeatability of a trait is low, it may require an average of several records to estimate the real producing ability of an individual cow.

Lush (1945) states that the "most probable producing ability of the cow

$$= \frac{nr}{(1-r) + (nr)} \text{ x (her average record)} + \frac{1-r}{(1-r) + (nr)}$$

$$\text{x (the herd average)."}$$

In the equation, n is the number of records, and r is the repeatability of the trait in question. The fraction

$\frac{nr}{1 + (n-1)r}$ shows how much confidence can be placed in the cow's average as an indication of her real producing ability. Table XXII (from Lush, 1945) shows the progress that can be made by selection for traits with different values of repeatability and with varying numbers of records.

TABLE XXII

PROGRESS WHEN SELECTING BETWEEN ANIMALS WITH n RECORDS EACH, AS A MULTIPLE OF THE PROGRESS WHICH COULD BE MADE BY SELECTING BETWEEN THEM WHEN THEY HAD ONLY ONE RECORD EACH[1]

n	.1	.2	.3	.4	.5	.6	.7	.8	.9
2	1.35	1.29	1.24	1.20	1.15	1.12	1.08	1.05	1.03
3	1.58	1.46	1.37	1.29	1.22	1.17	1.12	1.07	1.04
4	1.75	1.58	1.45	1.35	1.26	1.20	1.14	1.08	1.04
6	2.00	1.73	1.55	1.41	1.31	1.22	1.15	1.10	1.04
10	2.29	1.89	1.64	1.47	1.35	1.25	1.17	1.10	1.05

r = repeatability of the trait

n = number of records for each animal

[1] Lush, Jay L. 1945. Animal Breeding Plans. p. 175.

Estimates of repeatability of calf weights obtained in the present study indicate that about 30 per cent of the variation in calf weights at both 112 and 210 days of age may be attributed to permanent differences between cows. Estimates obtained by the regression of all subsequent records on the first record were slightly higher than those obtained by the intraclass correlation method. This might indicate that the first record predicts future production a bit more reliably than latter single records. Actually, confidence intervals of the intraclass correlation coefficients cover all estimates, indicating no real differences among the repeatability estimates obtained at the two ages. Botkin (1952) observed that the repeatability estimate for weaning weight was higher when obtained from the regression method than that determined from an intraclass correlation coefficient. Gregory et al. (1950) found a higher correlation between first and second weaning weights than between first and third or second and third weights. Similar results were reported by Koger and Knox (1947).

The repeatability estimates of .29 and .35 for 112-day weights obtained from the pooled data are in close agreement with the estimate of .34 reported by Rollins and Guilbert (1954) for growth from birth to four months of age. The cows in their study were maintained on irrigated pastures the greater part of the year, while those in the present study were handled under range conditions. Rollins and Wagnon (1956) concluded that different levels of nutrition did not appreciably affect repeatability estimates, although it did affect the average performance of the two herds studied. For weaning weight, repeatability estimates of .32 and .34 are lower than most estimates reported by other workers. Rollins and Guilbert (1954) reported the repeatability of 240-day weight to be .48. Repeatability estimates of weaning weight have been reported to be .49 by Koger and

Knox (1947), .52 by Koch (1951), .35 to .50 by Gregory et al. (1950), and .43 and .49 by Botkin and Whatley (1953). Koch and Clark (1955a) reported the repeatability of 182-day weaning weights and gains from birth to weaning to be .34, which is quite comparable to the estimates obtained for weaning weight in the present study.

Selection for cow productivity is directed toward increasing the average weaning weights of the calves, since that is the time when a majority of the calves are sold. Therefore, the value of culling cows on the basis of 112-day calf weights depends largely on the relationship of weights at 112 and 210 days of age.

The correlation coefficient between 112 and 210-day weights of the first calves, as calculated from the pooled data, was .74. The correlation between the average 112-day weights and the average 210-day weights of all calves produced by the same cow was .86. This high relationship between weights at the two ages was demonstrated by dividing all cows into high and low producing groups based on the 112-day weights of their first calves. It was found that 80 per cent of the cows remained in the same high or low groups when they were sorted on the basis of the 210-day weights of their first calves. It was concluded that the cows which have the heavier calves at 112 days of age usually will have the heavier calves at 210 days of age. Rollins and Guilbert (1954) reported that the correlation between growth from birth to four months of age and 240-day weaning weights of calves by the same cow was .91.

From Table XXII, it may be seen that progress by selection for a trait with the repeatability of .30 would be increased by approximately 25 per cent by the inclusion of the second record. The addition of more records would increase the accuracy in predicting future production, but to a decreasing extent for each additional record.

The value of including the second or later records will depend, to some extent, on the amount of culling which can be practiced. In most breeding herds, much of the selection emphasis must be placed on factors other than productivity. A large percentage of the heifers dropped each year must be saved for replacements. Therefore, since only a small number of cows can be culled on the basis of productivity alone, the poorest producers could be culled after the first record with little danger of culling the cows above average in productivity.

If the repeatability estimates obtained from these data for weights at the two ages may be assumed equally reliable for appraising cow productivity, the breeder can cull the very low producing cows on the basis of 112-day calf weights without reducing the effectiveness of selection. This would permit flexibility of management procedures which could result in more effective selection and more economical production in some herds. The results of this study indicate that 112-day weights are not influenced as much by seasonal variations or by differences between bull and steer calves as 210-day weights, allowing more accurate comparisons between weights at 112 days than at 210 days when no corrections are made for these effects.

The breeder might desire to reduce the size of the herd during unfavorable grazing seasons, or he might wish to market cull cows before the calves are weaned. The lowest producing heifers could be culled on the basis of their first calf's weight at 112 days with little fear of culling the best producing cows. If older cows are culled at the same time, the breeder could use the 112-day weights of their calves if no earlier weight records were available upon which to make a decision. However, if two or more earlier records were available for the older cows, an average of these probably would be of more value in appraising productivity than a single 112-day weight in view of the degree of the repeatabilities involved.

Some breeders might wish to segregate the cull cows and their calves from the breeding herd early in the summer based on the 112-day weights of their calves. The calves in the cull group might be handled differently to prevent economic loss often encountered in the marketing of stunted calves. Purebred breeders who creep feed all calves might find the 112-day weights of more value in appraising cow productivity. The earlier weight is useful for appraising differences in cow productivity in those herds which produce calves that are sold early in the suckling period for veal.

Of importance, also, is the fact that the standard age of 112 days may be bracketed with weights from which age corrections may be obtained. The adjustment of calf weights by their individual average daily gains during that period appears to be more accurate than the age intercept method for weights beyond 30 days either side of the standard age. Therefore, this method of standardizing weights to a common age would have its greatest advantage in those herds in which calves are dropped over a period of several months.

The results of this study do not give evidence that 112-day weights more accurately measure differences in milking ability than 210-day weights, although it is possible that the earlier records do contain more of the maternal effects than those at weaning.

Repeatability and heritability can be directly compared only if estimates have been obtained from the same data. No heritability estimates were made in this study. Gregory et al. (1950) obtained heritability estimates for weaning weight which were higher than repeatability estimates from the same data. Koch and Clark (1955a) found that the heritability of weaning weight was .24, as compared to the repeatability of .34 determined from the same data. Knapp and Nordskog (1946) obtained heritability estimates for weaning weights of .12 and .30, as determined by the intra-sire correlation and the sire--offspring regression, respectively. The heritability estimate reported by Knapp and Clark (1950) was .28. Other heritability estimates ranged from .23 to .11 for weaning weight, as reported by Shelby et al. (1955) and Koch and Clark (1955b).

SUMMARY

The purpose of this study was to determine the value of using weights of calves at 112 days of age, as compared to 210-day weights, to estimate the productive ability of range beef cows. The accuracy of predicting 210-day weights from weights at 112 days of age for the same calves also was determined.

Data were obtained from four herds maintained at three locations. Analyses were made on an intra-herd basis and the data were pooled when possible. The investigation included weights near 112 days of age for 1,110 calves produced by 303 cows and weaning weights for 1,151 calves produced by 301 cows. Only cows which had calved at least twice during the period from 1950 through 1955 were included in the analyses.

The average age at which 112-day weights were obtained was 110 days with a standard deviation of 15 days. The average unadjusted weight at this age was 279 pounds with a standard deviation of 42 pounds. The average age at weaning was 208 days with a standard deviation of 19 days, while the average weaning weight was 454 pounds with a standard deviation of 65 pounds.

The effects of several sources of variation on calf weights at the two ages were studied, and correction terms

were used to adjust calf weights for these differences. Weights were adjusted to the standard ages of 112 and 210 days by use of the age intercept method. Corrections were made for the effects of sex of calf, age of dam at calving, years, and treatment or line of breeding differences.

Weights of heifer calves were adjusted to the bull equivalent weight in the purebred herd by the addition of 18 pounds to age-adjusted 112-day weights and the addition of 38 pounds to age-adjusted weights at 210 days of age. Steer calves averaged 14 pounds heavier than heifers at 112 days of age and 27 pounds heavier at 210 days of age in the grade herds. Weights were adjusted for the effects of age of dam, year, and treatment or line of breeding by correcting the weights of calves in each group to the average of all groups on an intra-herd basis.

Repeatability estimates for weights at the two ages were determined from the pooled data of the four herds by the intraclass correlation and the regression method of analysis.

Repeatability estimates obtained for weight at 112 days of age were .29 and .35, as determined by the intraclass correlation and the regression methods, respectively. Estimates obtained for weights at 210 days of age were .32 by the intraclass correlation and .34 by the regression methods. The correlation between weights at 112 days and 210 days of age for calves produced by the same cow was .86.

The results of this study indicate that repeatabilities of weights at the two standard ages were not appreciably different and that a portion of the cows producing the lightest calves at 112 days of age may be culled from the herd with little fear of culling cows which have average or above average ability to produce heavy calves. The high correlation between 112-day weights and weights at 210 days of age indicates that, with few exceptions, cows having heavier calves at the earlier age produce heavier calves at 210 days of age.

Under certain management conditions, selection for cow productivity on the basis of 112-day calf weights may have an economic advantage over selection based on the weights of the same calves at 210 days of age.

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APPENDIX

APPENDIX TABLE I

AGE AND WEIGHT RANGES OF UNCORRECTED DATA BY PROJECTS

Project	670		650		526-S		526-W	
Standard Age (days)	112	210	112	210	112	210	112	210
Age Range (days)	114	142	96	105	68	95	64	103
Weight Range (lbs.)	300	365	300	385	180	270	140	290

APPENDIX TABLE II

COVARIANCE ANALYSIS OF UNADJUSTED DATA FROM PROJECT 650 NEAR 112 DAYS

Sources	D.F.	Sum x^2 (age)	Sum xy	Sum y^2 (Weight)	b
Total	495	102,502	170,605	852,898	1.56
Subclass	79	21,800	10,511	254,680	
Lots	7	2,282	15,472	23,127	
Years	4	5,060	-12,430	111,646	
Sex	1	2	252	26,214	
LxY	28	8,211	1,824	67,473	
LxS	7	559	-11,199	13,775	
YxS	4	1,627	1,931	492	
LxYxS	28	4,059	14,661	11,953	
Intraclass	416	80,702	160,094	598,218	1.26

APPENDIX TABLE III

ANALYSIS OF COVARIANCE OF CALF WEIGHTS NEAR 112 DAYS OF AGE BY PROJECTS

Source	D.F.	Σx^2	Σxy	Σy^2	B
Project 670					
Total	253	94,176	157,288	745,031	1.67
Subclass	83	55,546	50,727	408,084	
Intraclass	170	38,630	106,561	336,947	2.76
Project 650					
Total	495	102,502	170,605	852,898	1.56
Subclass	79	21,800	10,511	254,680	
Intraclass	416	80,702	160,094	598,218	1.26
Project 526-S					
Total	230	26,902	30,582	244,107	1.14
Subclass	91	12,617	9,256	116,828	
Intraclass	139	14,285	21,326	127,279	1.49
Project 526-W					
Total	157	22,625	30,364	162,809	1.37
Subclass	35	5,044	9,519	63,876	
Intraclass	122	17,581	20,845	98,933	1.19

APPENDIX TABLE IV

ANALYSIS OF COVARIANCE OF CALF WEIGHTS NEAR 210 DAYS OF AGE BY PROJECTS

Source	D.F.	Σx^2	Σxy	Σy^2	B
		Project 670			
Total	254	129,069	268,806	1,686,406	2.08
Subclass	88	71,476	140,169	1,059,934	
Intraclass	166	57,593	128,637	626,472	2.23
		Project 650			
Total	544	181,015	246,959	2,083,356	1.36
Subclass	87	37,629	59,848	900,985	
Intraclass	457	143,386	187,111	1,182,371	1.31
		Project 526-S			
Total	230	52,680	68,464	577,639	1.30
Subclass	91	23,536	39,582	337,602	
Intraclass	139	29,144	28,882	240,037	.99
		Project 526-W			
Total	152	65,319	90,656	568,806	1.39
Subclass	35	13,943	12,466	283,581	
Intraclass	117	51,376	78,190	285,225	1.52

APPENDIX TABLE V

ANALYSIS OF VARIANCE OF ADJUSTED 112-DAY WEIGHTS BY PROJECTS

Source	D.F.	Sum of Squares	Mean Square	Estimate of:
		Project 670		
Total	228	280,199		
Between cows	76	152,015	2,000	$\sigma^2_e + 2.97\ \sigma^2_c$
Within cows	152	128,184	843	σ^2_e
		Project 650		
Total	493	519,018		
Between cows	108	230,569	2,135	$\sigma^2_e + 4.55\ \sigma^2_c$
Within cows	385	288,449	749	σ^2_e
		Project 526-S		
Total	231	149,230		
Between cows	61	60,843	997	$\sigma^2_e + 3.74\ \sigma^2_c$
Within cows	170	88,387	520	σ^2_e
		Project 526-W		
Total	154	99,029		
Between cows	54	58,012	1,074	$\sigma^2_e + 2.88\ \sigma^2_c$
Within cows	100	41,017	410	σ^2_e

APPENDIX TABLE VI

ANALYSIS OF VARIANCE OF ADJUSTED 210-DAY WEIGHTS BY PROJECTS

Source	D.F.	Sum of Squares	Mean Square	Estimate of:
		Project 670		
Total	229	607,252		
Between cows	75	324,140	4,322	$\sigma^2_e + 3.02\ \sigma^2_c$
Within cows	154	283,112	1,838	σ^2_e
		Project 650		
Total	542	1,055,534		
Between cows	110	498,959	4,536	$\sigma^2_e + 4.90\ \sigma^2_c$
Within cows	432	556,575	1,288	σ^2_e
		Project 526-S		
Total	231	348,752		
Between cows	61	165,048	2,706	$\sigma^2_e + 3.74\ \sigma^2_c$
Within cows	170	183,704	1,181	σ^2_e
		Project 526-W		
Total	145	188,723		
Between Cows	51	109,722	2,151	$\sigma^2_e + 2.81\ \sigma^2_c$
Within cows	94	79,001	840	σ^2_e

APPENDIX TABLE VII

ANALYSIS OF ERRORS OF ESTIMATE FROM AVERAGE REGRESSION WITHIN HERDS AND POOLED REGRESSION COEFFICIENT OF WEIGHT ON AGE NEAR 112 DAYS

Intraclass Sums of Squares and Products						Errors of Estimate		
Project	D.F.	Sum x^2	Sum xy	Sum y^2	b	Sums of Squares	D.F.	M.S.
670	170	38,630	70,660	340,186	1.83	210,938	169	
650	416	79,702	100,094	594,218	1.26	468,515	415	
526-S	139	14,285	21,326	127,279	1.49	95,442	138	
526-W	122	17,581	20,845	98,933	1.19	74,218	121	
Pooled	847	150,198	212,925	1,160,616	1.42			
	Deviations from Average Intraclass Regression within Herds					858,767	846	
	Deviations from Individual Herd Regression					849,113	843	1,007.3
	Differences Between Individual Herd Regressions					9,654	3	3,218.0*

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* Probability of chance occurrence less than .05.

APPENDIX TABLE VIII

ANALYSIS OF ERRORS OF ESTIMATE FROM AVERAGE REGRESSION WITHIN HERDS AND POOLED REGRESSION COEFFICIENT OF WEIGHT ON AGE NEAR 210 DAYS

Intraclass Sums of Squares and Products						Errors of Estimate		
Project	D.F.	Sum x^2	Sum xy	Sum y^2	b	Sums of Squares	D.F.	M.S.
670	166	57,593	128,637	626,472	2.23	339,154	165	
650	457	143,386	187,111	1,182,371	1.31	938,201	456	
526-S	139	51,376	78,190	285,225	1.52	166,226	138	
526-W	117	29,144	28,882	240,037	.99	211,415	116	
Pooled	879	281,499	422,820	2,334,105	1.50			
Deviations from Average Intraclass Regression Within Herds						1,699,017	878	
Deviations from Individual Herd Regressions						1,654,996	875	1,891.4
Differences Between Individual Herd Regressions						44,021	3	14,653.7**

** Probability of chance occurrence less than .01.

APPENDIX TABLE IX

ANALYSIS OF ERRORS OF ESTIMATE FROM AVERAGE REGRESSION WITHIN HERDS AND POOLED REGRESSION COEFFICIENT OF WEIGHT ON AGE NEAR 112 DAYS

Intraclass Sums of Squares and Products						Errors of Estimate		
Project	D.F.	Sum x^2	Sum xy	Sum y^2	b	Sums of Squares	D.F.	M.S.
650	416	79,702	100,094	594,218	1.26	468,515	415	
526-S	139	14,285	21,326	127,279	1.49	95,442	138	
526-W	122	17,581	20,845	98,933	1.19	74,218	121	
Pooled	677	111,568	142,265	820,430	1.28			
Deviations from Average Intraclass Regression Within Herds						639,022	676	
Deviations from Individual Herd Regressions						638,175	674	946.8
Differences Between Individual Herd Regressions						847	2	423.5

APPENDIX TABLE X

ANALYSIS OF ERRORS OF ESTIMATE FROM AVERAGE REGRESSION WITHIN HERDS AND POOLED REGRESSION COEFFICIENT OF WEIGHT ON AGE NEAR 210 DAYS

Intraclass Sums of Squares and Products						Errors of Estimate		
Project	D.F.	Sum x^2	Sum xy	Sum y^2	b	Sums of Squares	D.F.	M.S.
650	457	143,386	187,111	1,182,371	1.31	938,201	456	
526-S	139	29,144	28,882	240,037	.99	211,415	138	
526-W	117	51,376	78,190	285,225	1.52	166,226	116	
Pooled	713	223,906	294,183	1,707,633	1.31			
Deviations from Average Intraclass Regression Within Herds						1,321,115	712	
Deviations from Individual Herd Regressions						1,315,842	710	1,853.3
Differences Between Individual Herd Regressions						5,273	2	2,636.5

VITA

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Candidate for the Degree of

Master of Science

Thesis Title: PRODUCTIVITY OF BEEF COWS AS APPRAISED BY CALF WEIGHTS AT 112 AND 210 DAYS OF AGE

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