HEREDITARY AND ENVIRONMENTAL FACTORS AFFECTING FEED LOT PERFORMANCE IN BEEF CATTLE

by

CECIL DURWOOD PIERCE

A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1953

ACKNOWLEDGEMENT

The writer wishes to express his sincere appreciation to H. G. Avery, Superintendent of the Eastern Oregon Branch Livestock Experiment Station, for materials and facilities used, and for technical advice and time so generously given in the research phase of this study; to Dr. Ralph Bogart, Professor of Animal Husbandry, Oregon State College, for his assistance and guidance in completing this study; to Martin Burris, Research Assistant, Animal Husbandry Department, Oregon State College, for his time so freely given in the completion of the statistical analysis; to Dr. Hugo M. Krueger, Professor of Physiology, Oregon State College, and Dr. Jerome C. R. Li, Associate Professor of Mathematics, Oregon State College, for their critical reading of the manuscript; to Otto Schuck, cattle feeder at the Eastern Oregon Station for his meticulous care and handling of the experimental animals; and to all others who helped in many ways in the preparation of this thesis.

To my wife, Marilyn, whose devotion and guidance made this study possible, I wish to express my most sincere appreciation.

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX TABLES

HEREDITARY AND ENVIRONMENTAL FACTORS AFFECTING FEED LOT PERFORMANCE IN BEEF CATTLE

INTRODUCTION

The animal breeder of the future is faced with the task of maintaining and improving the genotype of his herd.

Theoretically, an animals genotype places a limit on its development. New genes cannot be created by selection. The effectiveness of selection depends upon sorting and rearranging the genes into superior and inferior pairs, and into efficient and non-efficient working groups.

An animal is extremely complicated. Hundreds of units of inheritance control its functions and appearance. Each of its genes are inherited independently and combinations or aggregates of these genes determine the individual. Improvement through animal breeding may be effective without a complete knowledge of each detail in this extremely complicated inheritance of factors. The animal itself, from an unending array of phenotypic, genotypic, and environmental expression, is the unit of selection.

Environment plays a major roll in the development of an individual within the limits of its inherited ability to develop. An outstanding animal is produced when superior genetic material is exposed to optimal environmental conditions. While environment does not change the genotype, it may mask or alter genetic expression. These two forces, heredity and environment, account for the total variation between individuals. If environmental variations produce large trait differences between animals while the hereditary differences within the herd are small, we assume that trait to be low in heritability. If the opposite condition exists, the trait is considered highly heritable. Thus, selection on individual merit may not reflect the inherited ability of an animal to perform unless environment has been standardized or adequate corrections have been made for that which was not standard. This is especially true where estimates of heritabilities in a particular herd have not been established.

Whether selections are to be made on the basis of comparative feeding trials of prospective breeding animals, or on the basis of actual progeny tests, the productive traits studied must be used to predict future performance. If these factors or traits are to be of value, they must represent to as great an extent as possible, that portion of variation capable of reproduction in the genetic constitution of future generations.

For example, if gain per day during that period of development between birth and weaning is to be used to predict feed lot performance of an animal and thus the performance of the progeny of that animal, the variations due to environmental influences during that period should be held to a minimum. It is reasonable to assume that weight gained during the suckling period may have some effect on gains made during the feeding period. The weight of a calf at weaning is the result of at least two factors: age and gains made prior to that time. Age, as well as weight, may have an effect on gains during the post-weaning period. Thus, three factors - age at weaning, weight at weaning, and the interaction between these two -

exert various influences on future performance and thus affect the value of suckling gains in predicting the inherited constitution of an animal.

If we assume that greater weight at weaning, associated with more rapid suckling gains, causes lower gains after weaning, the correlation between the two would be negative. We might also assume that a positive relationship exists between age at weaning and weight at weaning. The older calves are the heavier calves. If we then found a positive correlation between age at weaning and gains after weaning, due to greater skeletal growth in the older calves, our results would appear contradictory; heavier calves gain less rapidly, older calves are heavier calves, and older calves gain more rapidly after weaning.

Actually such results may not be contradictory. The answer may well lie in the effects of environment during the suckling period.

REVIEW OF LITERATURE

Improvement of livestock through breeding and selection is at best a slow and laborious process. The very nature of beef cattle is a direct challenge to anyone who would attempt to accelerate their improvement through genotypic selection. In relation to laboratory animals, they reproduce at a very slow rate. They resist complete and fundamental studies because there are no litter mates of identical breeding to sacrifice by slaughter at various intervals throughout the test; and they are affected to varying degrees by innumerable external environmental conditions which are impossible to control completely.

Research workers throughout the years have attempted many methods of evaluating breeding animals for beef production. The value of any method must be measured in terms of its contribution to the actual improvement of beef cattle. Rate and economy of gain, from an economical viewpoint, are concrete examples of inherited performance which show promise for use as measures of genotypic selection (31, p.250).

The utilization of food energy, as viewed by Kleiber, (26, p.250) is the result of various physiological functions which are interrelated in many ways; thus, the genetics of efficiency is far from simple.

Morris, et al, (43, p.53) selected two lines of rats for different levels of efficiency in feed utilization. By applying an efficiency index, they were able to show, at the end of six generations, that the low efficiency line was about 40 per cent less efficient and was more variable than the high efficiency line. Palmer, et al, (45, pp.24, 50) also compared high and low efficiency strains of rats to determine the genetic differences in the biochemistry and physiology influencing food utilization. They found that the high efficiency strain of rats exhibited greater efficiency in the storage of food energy. They also found that within each strain, males were more efficient than females, possibly because they stored relatively more food energy as protein than females. They concluded that the over-all efficiency of food utilization in growing rats is controlled by inheritance factors. The difference between the two strains was not due to differences in ability to digest and metabolize the ration.

In studying the inheritance of feed utilization in growing chickens, Jull (24, pp.298-299) found that fast growing birds were more efficient than slow growing birds. He concluded that there were inherent differences in feed utilization efficiency among individuals, families, and strains. These differences could not be explained entirely on the basis of body weight, rate of gain, or time.

Blunn and Baker (5, pp.428, 431) tested the importance of environment in relation to rate of gain and body fatness in pigs and found its effect to be quite high. It is believed that continuous selection pressure reduces variation due to non-fixed or heterozygous factors and increases the magnitude of the environmental contribution to the total variation. According to Lush, (41, p.182) changes in the Danish swine population due to selection began in 1907 and has been continued to the present time. His estimates of the portion of individual variance due to additive genes after 29 years of selection range from averages of .08 for economy of gain to .54 for body length. He concluded that this variation was still high enough to permit changes in the population for a few more generations.

One of the classic demonstrations of selection and its effect on variation was reported by Goodale in 1938 (16, pp.109-110). In 12 to 16 generations, he increased the weight of mice by slightly more than 10 grams, and increased the average by several grams over the heaviest of his foundation mice. He found that the genetic variability in the later generations was actually much greater than in the early ones. This suggested that the limit of selection in this particular case had not even been approached.

Rate and Economy of Gain

Efficiency of meat production measures economy of meat production. An example of an early efficiency study was one proposed by Sheets in 1932, (49, pp.45-46). He suggested that a breeding animal be tested by the efficiency of meat production and carcass quality of his progeny. He proposed to base this economy of production on the number of pounds of cold dressed carcass per 100 pounds of digestible nutrients consumed during the life of the animal.

More recent studies indicate that on a comparative basis, sires may be evaluated by feeding their progeny over a shorter period of time. Knapp, et al, (27, p.292) found a feeding period of 186 days to be sufficient to indicate differences between progeny groups provided the data were adjusted for differences in initial weight. These workers also found that approximately eight steers were sufficient to give a good test of a bull's ability to transmit.

Black and Knapp, (2, p.105-107) in measuring efficiency of sires through progeny test, adopted the period from 500 to 900 pounds as a period in which as many variables as possible could be controlled. They found that differences in the progeny of various sires could best be demonstrated by efficiency of gain during this period.

The importance of size and a period of constant gain was also demonstrated by Bogart and Blackwell (6, p.2). They state that rate of gain is a dependable index of efficiency if comparisons are made when animals are the same size.

It should be pointed out that the relative efficiency of an animal changes as that animal approaches maturity and a higher degree of finish. In a study on the inheritance of efficiency of feed utilization in the growing domestic fowl, Hess and co-workers (22, pp.38-39) found that male chickens were consistently more efficient than females. They indicated that this could be due to a more rapid decrease in female efficiency because of a lower mature weight. Comstock, et al, (9, pp.126-127) in establishing growth rate of pigs, found a sex difference in rate of growth from weaning to 200 pounds. They state that this sex difference increased with age in both groups. Warnick and co-workers, (53, p.1) in measuring gains and feed efficiency of rabbits, found higher gains during the first part of the experiment than during the last part. Gramlich and Thalman (17, pp.52-53) compared growth rates of two-year-old steers, yearling steers, and steer calves and concluded that the two-year-olds required more feed for each 100 pounds gain in live weight than yearlings, and yearlings in turn, required more than calves.

Dahmen and Bogart, (10, p.14) as well as Bogart and Blackwell, (6, p.2) found significant differences between bull and heifer calves in feed efficiency. They found that, when fed to gain a constant amount, bulls not only gained faster but were more efficient in feed utilization than heifers. Guilbert and Gregory (20, pp.13-14) believe that such a conclusion is unwarranted, in that bulls and heifers of equal weight represent different segments of their respective growth curves. For this reason the composition of the gains made is different and can not be used in efficiency comparisons.

The ideal method of measurement, according to Lambert and co-workers, (40, p.239) may be one to determine initial efficiency and the rate of decrease in efficiency.

A relatively close positive association between rate of gain and economy of gain has been demonstrated by many workers: Winters and McMahon (56, p.27), Bogart and Blackwell (6, p.2), Blackwell (4, p.44), Roubicek (46, p.11), Kolhi, _et al_, (39, p.363), Black and Knapp (3, p.77). In studies with Shorthorn steers, Roubicek, (46, p.10) observed a positive correlation of 0.55 on rate of gain with initial height at withers. He also found that the correlation of efficiency with initial height, 0.52, was the same as that for initial height and rate of gain. Baker, et al, (1, p.6) studied the degree of correlation between feed efficiency and digestion coefficients, between the rate of gain and feed efficiency, and between rate of gain and digestion coefficients. They found that digestion of crude fiber was related to feed efficiency but that there was no significant relation between efficiency and other food nutrients. This would indicate that the digestion of crude fiber is possibly one of the most important factors involved in economy of gains. They also found a significant positive correlation between feed efficiency and rate of gain.

This relationship between rate and economy of gains indicates, as suggested by Bogart and Blackwell, (6, p.2) that selection for efficient gains can be made by measuring rate of gain. Such an association is indeed advantageous to beef cattle selection and improvement.

Birth Weight and Its Effect on Rate and Economy of Gain

Birth weight, as reported by Knapp and co-workers, (35, p.284) is primarily an expression of the size, weight, age, and physiological constitution of the dam. These same workers found that a large proportion of the variation in birth weight could be attributed to the weight of the cow, calving sequence, and length of the gestation period, with the latter having the greatest single influence. This would indicate that only a minor portion of variations in birth weight could actually be attributed to genetic growth factors in the calf. Sawyer, Li, and Bogart, (48, p.5) by holding the age and weight of the dam constant, found that each difference of one pound at birth made a difference of 2.14 pounds in the weaning weight of the calf.

Heritability estimates, as reported by Knapp and Nordskog, (36, p.66) list birth weight at 23 per cent and 42 per cent by intra-sire correlations and sire-progeny regressions respectively. Burris and Blunn (7, pp.39-40) give an estimate of heritability of birth weight from paternal half-sib regression of 0.22. Estimates from paternal half-sib correlations by Gregory, Blunn, and Baker (19, p.345) from two separate herds are given as 0.45 and 1.0. A heritability of 1.0 implies that all variation has been accounted for. From a genetic standpoint this seems improbable. These estimates indicate that considerable progress from selection could be realized in a program to increase birth weight of calves.

Many studies seem to agree on the importance of the dam in determining birth weight of the calf. Burris and Blunn (7, pp.39-40) state that the regression of birth weight on gestation length was a positive 0.376 and was highly significant. They also found a highly significant difference between the birth weight for the sexes. They indicate that gestation length accounted for about 10 per cent of the sex differences. They found a definite relationship between age of dam and birth weight of the calf, with the dam reaching her maximum production in birth weight of the calf at nine to ten years of age.

In a study by Gregory, Blunn, and Baker (19, p.345) weight of dam was shown to have a significant influence on the birth weight of the calf. They also recorded a significant difference in birth weight of bull over heifer calves. These workers, as well as Kolhi, *et al*, (39, p.364), state that calves heavier at birth were also heavier at weaning.

The effect of size of cow on birth weight of the calf is also emphasized by Knapp and co-workers (29, pp.11-12). Their analyses indicate that sex, sire, and dam influences have a significant effect on birth weight with size of cow being the most important single factor. Gestation length and cow size probably account for a large share of the variations in birth weight of calves. In their study, the age of the dam had no significant effect.

The birth weight of calves seems to give a fairly accurate indication of size at one year of age. Galgan, *et al*, (14, p.1) believe that larger, more vigorous calves at birth retain those advantages to maturity. The effects of birth weight on various production factors have been studied by numerous research workers. Dahmen and Bogart (10, p.16) showed that birth weight and age-on-test accounted for 40 per cent of the variations in gain during the test period. They listed a partial regression coefficient of rate of gain during test on birth weight as 0.01. This indicates that for every one pound increase in birth weight there is a corresponding 0.01 pound increase in gain per day during the test period. Of the factors studied by Dahmen and Bogart, only birth weight had a significant effect on feed efficiency during the test. A one pound increase above the mean in birth weight represented a two pound saving in total digestable nutrients for each 100 pound gain in live weight. These workers also found a correlation coefficient of economy of gain with birth weight of 0.4219. This indicates that 18 per cent ($R^2 = 18$) of the variance in economy of gain is accounted for by variations in birth weight.

Knapp, et al, (30, pp.12-17) believe that the factors governing growth in the pre-natal period are, in part, the same as those which govern growth in the post-natal period. They found that birth weight was not highly correlated with any of the performance factors, although the correlations were significant with daily gain during the suckling period. They also found that birth weight was correlated significantly in the total population with efficiency, but within years this correlation was not significant.

Birth weights are an important part of any record of performance. Evidence indicates that a large calf at birth is more valuable than a small calf. Sawyer, et al, (48, p.5) found that size at birth has a positive effect on size at weaning. This has been supported by the work of Gregory, et al, (19, p.345) and Kolhi, et al, (39, p.362). Galgan, et al, (14, p.6) indicate that birth size is an indication of the mature size of the animal.

Suckling Gain and Its Effect on Rate and Economy of Gain

Suckling gain is gain in live weight from birth to weaning. The genetic influence on suckling gain is difficult to measure. Milk from the dam makes up practically all of the ration during the early part of this period. It is reasonable to assume that variation in suckling gain between calves will be small unless each calf has access to all the milk it can consume. As the suckling period progresses and other foods begin to make up more and more of the calf's total ration, the variation in gain between calves will increase as each calf's individual inherent ability to gain is expressed.

Evidence indicates, however, that milk production is inherited. Sawyer, Li, and Bogart (48, p.6) found that large cows of the same age, that were handled under the same conditions, weaned heavier calves. This indicates that genes for growth may be associated with genes for heavy milk production, and selection for heavy calves at weaning will improve breeding herds.

Record of performance under limited versus full feeding was studied by Knapp and Baker in 1943 (28, p.324-326). They found that under limited feeding conditions, sire groups were significantly more alike in daily gains than would be expected by chance. On the other hand, these same groups, when put on unlimited feed, were significantly different from each other. Their frequency distributions of the total digestable nutrients consumed and daily gains made by the steers show that on limited feeding these steers were much less variable in daily gains than on unlimited feeding.

Weaning weight, according to Galgan and co-workers, (14, p.1) is to a great extent a measure of milk production in the dam plus pasture and other feeds available to the calf. Knapp and Black (31, p.250) report that the quantity of milk, hay, and grain consumed accounted for a large proportion of the variations in gains during the suckling period. Sire difference between progeny could not be demonstrated at this time. Black and Knapp (3, pp.73-77) found the correlation coefficient of average-daily-gain-from-birth-to-weaning to average-daily-gain-from-weaning-to-slaughter to be -0.36. This indicates that a high gain on milk probably results in a lower gain during the feeding period. This may be expected, in that the calf receiving more milk during the suckling period probably goes into the test carrying a higher degree of finish than the calf that received only enough milk during the suckling period to attain maximum skeletal growth. The latter calf would therefore have greater growth potentialities than the former.

Gregory, et al, (19, p.345) give heritability estimates of 0.0 and .45 for suckling gain, and .26 and .52 for weaning weight. These estimates were made simultaneously on two herds at two different stations. An estimate of 0.0 indicates that all variation in suckling gain is due to factors other than heredity. Such an occurrence is quite unlikely and probably results from an insufficient number of test animals. Knapp and Nordskog (36, p.69) found heritabilities for weaning weight of 12 per cent from intra-sire correlations and 0 per cent from sire-progeny regressions.

Gifford (15, p.606) believes that the ability of the calf to consume milk determines, to a large extent, the total milk production of the dam. He states that if milk is not removed from the udder, the production from high producing cows seems to level off before the normal decline occurs. This would seem to emphasize the importance of the individual calf and its inherited ability to perform and minimize the importance of milk production of the dam during the suckling period.

In the same manner, Clark, et al, (8, pp.5-6) found considerable difference between weaning weights of calves by different sires. These differences ran as high as 25 pounds in one year and 57 in another.

Knapp and co-workers (29, pp.11-12) studied data from weights and gains of 770 Hereford calves. Their analysis of weaning weights showed that age at weaning, sex, sire, dam, and age of dam had a significant influence on the weaning weights of these calves. They found that approximately 20 per cent of the total variance in weaning weights was due to cow influence. They also found a negative correlation between gain or loss of weight by the cow during suckling and weaning weight of the calf. Koch (37, pp.7-8) found that differences between cows accounted for 52 per cent of the variance in the corrected weaning weights of calves. He states that the extent to which the weaning weight of calves is a permanent characteristic of range Hereford cows is 0.52. He believes that this repeatability is high enough to permit reasonably accurate selection of cows for high life-time production on the basis of the first calf weaned. Gregory and co-workers (19, p.345) found that cow repeatability for suckling gain and weaning weight of their calves was higher than for birth weight. Sawyer, Li, and Bogart (48, p.6) found that approximately 23 per cent of the variation in the weaning weight of calves was accounted for by differences in birth weight, age of dam, and size of dam.

The effect of sex on suckling gain and weaning weight is obscured to some extent by sex differences in birth weight. Most authors have found a significant difference in birth weights between bull and heifer calves: Burris and Blunn (7, pp.39-40), Gregory, *et al*, (19, p.345), Knapp, *et al*, (29, pp.11-12), Dawson, *et al*, (12, p.249). Both Galgan, *et al*, (14, p.1) and Gregory, *et al*, (19, p.345) report that birth weight gives an indication of the mature size of an animal. Therefore, one would expect to find a significant sex difference in suckling gains and weaning weights. Gregory and co-workers (19, p.345) failed to find a significant sex difference in suckling gains and weaning weights, but stated that both were in favor of the males. Sawyer, Bogart, and Oloufa (47, pp.514-515) found that heifer calves were heavier at weaning than steer calves but the difference was not significant. Koger and Knox (38, pp.16-17) established the mean weaning weights for the two sexes, corrected for difference in weaning age, as 443 pounds for 419 steers and 411 pounds for 444 heifers. The steers were significantly heavier than the heifers each year throughout an eight-year period.

The effects of suckling gain on performance later in the calf's life has been the object of considerable study. As stated before, Black and Knapp (3, pp.73-77) found a negative correlation between average daily gain from birth to weaning and average daily gain from weaning to slaughter. They found a low correlation coefficient of 0.06 of economy of gain from birth to weaning and economy of gain from weaning to slaughter. However, they established the correlation of average daily gain with economy of gain from weaning to slaughter at 0.88 and from birth to slaughter at 0.89. This indicates that even though there is little relationship between economy of gain during the suckling period and during the test period, there is a high positive relationship between average daily gain and economy of gain during the entire life of the animal.

Knapp and Black (31, p.253) found evidence of a lack of correlation between the rate of gain during the suckling period and the rate of gain after weaning. Knapp and co-workers (30, pp.12-17) found no correlation between weaning weight or suckling gain and daily gain in the feed lot. They found a high negative correlation of both weaning weight and suckling gain with efficiency in the feed lot. This indicates that the heavier the calf at weaning the more feed is required for maintenance and thus the lower is the efficiency.

Dahmen and Bogart (10, p.17) found that suckling rate of gain, age put on test, and weaning score had no significant effect on economy of gain during the feeding period. It is interesting to note that Knapp, et al, (30, pp.12-17) as well as Blackwell (4, p.44) found a significant negative correlation between score at weaning and efficiency during the test period. Knapp believed that this was due to the fact that the high scoring animals at weaning were the heavy animals at weaning, and he had already shown a negative correlation between weaning weight and efficiency.

Dickerson (13, pp.492-493) found that in swine, differences in rate of gain to 225 pounds due to the pigs own genes were more largely in fat deposition than in bone and muscle growth. His evidence strongly indicates that rapid fat deposition, poor suckling ability, and low feed requirements, tended to be caused by the same genes.

In an attempt to correlate rapidity of growth with milk and fat production in dairy cows, Davis and Willett (11, p.624) found no apparent association.

Weight on Test and Its Effect on Rate and Economy of Gain

There undoubtedly is a relationship between weight at weaning and most conformation scores taken at that time (30, p.17). The heavier animal usually is the one carrying more finish. It has been demonstrated, however, that type or score evaluations of calves at weaning may show little or no association with feed-lot performance. Clark and co-workers (8, pp.6-7) found final feed-lot weight between progeny of two sires to vary as much as 100 pounds. They state that these differences could not be predicted by visual appraisal before the feeding period. Lush (42, pp.880-881) found that large amounts of variation in gain and final value could not be foreseen by trained men who spent considerable time in close study of the experimental animals before the beginning of the test. Roubicek (46, p.10) found negative correlations of conformation and quality scores with feed-lot efficiency, indicating the inability of judges to select high producing animals. Dahmen (10, p.12) found no significant correlation between weaning score and economy of gain during the feeding period. This suggests a possibility of revising scoring technique toward more successful visual selection.

Knapp and Clark (34, p.370) studied genetic and environmental relationships between weaning scores and gains in the feed-lot. They obtained a genetic correlation of 0.30 and an environmental correlation of -0.30. They state that the negative correlation may be due to compensating gains on feed for poorer conditions of environment before weaning, or a negative correlation that may exist between milk production and gains. They found little value in visual methods of selection for rapid gains in the feed-lot.

If the relation of weight to score is valid, then we might assume from these findings that the weight of an animal, at the time it goes on test, has very little effect on the performance of that animal. Research seems to indicate that the opposite is true. Joshi, et al, (23, p.301) made a study of feed consumption in relation to body weight in laying hens. He found that when the feed used for body maintenance and increase in body weight was deducted, the lower producing hens were just as efficient in egg production as the higher producing ones. Warnick, et al, (53, p.2) showed significant differences in rate of gain of rabbits between sexes and periods when adjustments were made for initial weight at the beginning of each period. Experimental evidence concerning the actual effect of weight on test as a production factor is limited. Knapp, et al, (30, pp.12-17) did show that weaning weight and efficiency of gain were negatively correlated. Black and Knapp (3, pp.73-77) showed a negative correlation between weaning weight and percent of fat in the carcass. They state that 40 per cent of the variations in the amount of subsequent fatness found in the steer at slaughter could be accounted for by variations in weaning weight.

Kolhi, et al, (39, p.363) found that steers which were shorter in height and length of body and smaller in circumference of fore-flank were slightly superior in rate and economy of gain. In a study of compress and conventional type Hereford steers, Stonaker (52, p.24) found that compress type steer calves, when fed to the grade of low choice, gained as efficiently per unit of feed eaten as the conventional type calves.

Williams and Wood (55, p.29) found that a calf's gain tended to be proportional to the weight of the calf at the time the particular gain was made. Black and Knapp (2, pp.105-107) found that measurement of sire differences by performance of their calves could be more clearly established when calves were tested between 500 and 900 pounds. They found that differences in weight of sire groups at 12 months of age were not significant. Bogart and Blackwell (6, p.2) state that if comparisons on rate of gain are made when the animals are the same size, the data will be dependable as an index of efficiency.

In view of the results obtained in testing animals at constant weights, it seems logical to assume that size or increased weight at a given age may be secured without detrimental effects on type or testing procedure. Performance of the Line 1 Hereford cattle at Montana State College (32, p.19) indicates that weight for age may be increased without apparent loss of quality of carcass.

Warwick (54, p.25) states: "The animal which is of the best type and therefore most nearly suited to the demands of the market, and which is at the same time the most productive, will be the one which is the most profitable."

Age on Test and Its Effect on Rate and Economy of Gain

Age is one of the most important factors to be considered in production-testing beef animals. As an animal increases in age and size, there is a corresponding change in the physiological functions governing the utilization and disposition of nutrients. After maintenance requirements are met, young cattle can use feed for both growth and fattening, whereas the mature animal's use of the ration above maintenance is confined largely to the production of fat. It is for this reason that calves fed on full rations usually gain more economically than yearlings, and yearlings in turn should make cheaper gains than two-year-olds (21, p.139).

Keith, et al, (25, p.15) compared steer calves with yearling steers on several different concentrate-to-hay ratios, and found that the calves were more efficient than the yearlings in every comparison.

Williams and Wood (55, p.29) state that if a relatively young animal is to lay on finish, it is obvious that a greater share of his feed will be used to produce this finish, leaving less for growth. A greater degree of finish in a young animal would mean either a greater appetite and increased food intake or a lower inherited growth potential. In either case, he would probably resemble a more nearly mature animal in that his efficiency would be decreased. The practical value in such an animal would be in a more rapid feed lot turnover or in the production of a finished carcass at a smaller size.

In comparative feed lot tests, it is important that environmental variation be reduced to a minimum. Variations due to differences in age and weight may be reduced by feeding on either an age-constant or weight-constant basis. Williams and Wood (55, p.30) determined, from graphs of individual growth rates of bulls, that each bull tended to grow at a constant percentage rate. That is, the rate of gain tends to depend on an animal's weight at the time the gain is made. They state that in view of this, animals should be compared at identical weights.

Blackwell (4, p.43) states that in efficiency tests, it is more accurate to feed to make a given amount of gain than to feed for a given period of time. Dahmen and Bogart (10, p.16) emphasize the importance of age by stating that 40 per cent of the variations in gains made during the test period could be accounted for by variations in birth weight and age put on test. They also state that suckling rate of gain, age put on test, and weaning score had no significant effect on economy of gains during the feeding period.

Knapp and Clark (33, pp.177-178) studied genetic and environmental correlations between growth rates of beef cattle at different ages. Their annual feeding was divided into three 84-day periods. They found little environmental correlation between the three periods while the genetic influence increased as the feeding period progressed.

Baker, Colby and Lyman (1, p.6) concluded from a study of digestion rates and efficiency that differences in rate of gain were probably not due to any large extent to individual differences in digestive powers of the animal. Snell (51, pp.5-7) found that age, individuality, length of feeding period, or previous treatment did not ordinarily affect the ability of a steer to digest his ration.

He stated that age was one of the most important factors controlling gains per unit of live weight. He pointed out that young steers tended to use feed for growth while older steers tended to fatten.

Gramlich (18, p.216) found that heifers produced the most desirable beef carcass at from eight to fifteen months of age. In a later study, Gramlich (17, pp.52-53) noted that heifers fattened faster than steers, due to the greater skeletal growth of the steers, or more precisely the lower mature weight of the heifers. In comparing ages, this author found results in favor of calves of both sexes in economy of production and popularity of carcass. His two-year-olds made greater gains during the first 100 days on feed, while his calves did best during the last 100 days. In contrast, his yearling gains were uniform throughout the 175 day feeding period.

METHODS AND MATERIALS

The data are compiled from a study of records of three years of individual and lot-fed calves at the Eastern Oregon Livestock Branch Experiment Station at Union, Oregon, on the Western Regional Beef Cattle Improvement project.

The total number of calves used in the study for the three-year period included 19 registered bulls, 18 registered heifers, and 9 grade steers fed individually, and 100 grade steers and 60 grade heifers fed in lots. All calves used in the study were produced on the station and were dropped in the Spring and early Summer. They were weaned each year between the first and the eighteenth of October.

Stall Calves

Bull, steer, and heifer calves were fed in individual stalls during the Winters of 1949-50 and 1950-51. Bull and heifer calves were fed individually in 1951-52. All individually fed calves except the steers were purebred.

All calves fed individually were confined in small individual stalls while they were eating, but were run together in a large pen between feedings. Calves that were stall-fed during the Winter of 1949-50 were held in an outside pen during the night. Those fed during the two Winters following were confined to their stalls each night. Feeding was done three times daily at uniform intervals. Feed was carefully weighed and placed in an individual manger for each calf. The calves spent about five hours outside each day where they had access to fresh running water.

Stall-fed calves each year were conditioned before the beginning of the official test. They were placed in stalls at weaning and fed for approximately one month before they were weighed onto the test.

The 1949-50 stall feeding period extended from January 3, 1950 to May 3, 1950. This was a total of 120 days. The 1950-51 period extended from November 27, 1950 to May 26, 1951, for a total of 180 days. During 1951-52 the feeding trials started on December 20, 1951 and ended 120 days later, on April 18, 1952. Throughout the test, calves were weighed at the end of each 30-day period with gains per head per day and feed consumption calculated after each weighing. Stall record sheets listed initial weight, final weight, total gains and daily gains, and total and daily feed consumption for each period.

All weights were taken between 1:00 and 3:00 P.M. This was done to limit, as much as possible, variations in weight due to fill.

Forage for the stall fed calves during the first Winter consisted of good quality chopped alfalfa-grass hay and equal amounts of chopped alfalfa-grass-pea hay during the second and third Winters. Grain for these calves during the first winter consisted of the Union feed mixture[1] and dried beet pulp. During the second Winter, the grain was changed to two-thirds wheat and one-third peas and a mineral mixture was added. This ration remained the same during the third Winter except for the addition of linseed meal.

Economy of gain, as used in this individual feeding study, is

[1] Union feed mixture: Oats, wheat and barley, each 29.07 per cent, linseed meal 11.63 per cent, and molasses 1.16 per cent.

a measure of total digestible nutrients required for each pound of gain. Feed analyses used were taken from Morrison's tables of average composition of feeding stuffs (44, pp.1086-1131).

Lot-Fed Calves

Grade steer and heifer calves were fed in groups of 10 in open lots each Winter throughout the three year period. They were confined to lots approximately 50 feet by 100 feet in size. The quality of forage and grain each year corresponded to that fed the stall-fed calves. Rations, however, differed between lots and between stall and lot-fed calves.[1] The hay was chopped and fed in self-feeders. Grain was weighed at each feeding. At the end of each thirty-day feeding period, all hay not consumed was removed from the feeders and weighed. The amount was deducted to give actual hay consumption. Grain was fed three times each day and fresh running water was provided in all lots.

All calves were conditioned before the beginning of the official test; that is, they were placed in lots at weaning and fed for approximately one month before they were weighed on to the test. Individual weights were taken at the onset and conclusion of each annual feeding period. The 1949-50 group feeding trials started on December 3, 1949 and extended to June 3, 1950, for a period of 182 days. During 1950-51 calves were fed for 194 days, from November 27, 1950 to June 9, 1951. The 1951-52 feeding began on December 20, 1951

[1] Complete rations by lots and years appear in Appendix Table II, page 66.

and ended April 18, 1952. This was a total of 120 days.

Throughout the test group weights were taken at the end of each 30-day period. Average gains and average feed consumption were calculated on each group of 10 calves at each weight period. Records were kept on sheets similar to those used for the stall-fed calves. Feed efficiency records were not available on the lot-fed calves.

In assigning calves to lots at the beginning of each test, an effort was made to equalize the weights of all lots as nearly as possible. The purpose was to place as much variation as possible within each lot in an effort to test each factor with a representative cross section of the calf population. Calves that were quite late or for any other reason small at weaning time were not included in the test.

Throughout each annual feeding period, the grain-hay ratio for both stall and lot calves averaged approximately two parts grain to one of hay.

The analyses measure the effects of the four independent variables — birth weight, suckling gain, weight-on-test, and age-on-test — on the three dependent variables — gain on test, economy of gain, and daily gain-from-birth-to-the-end-of-the-test-period. All birth weights were taken within 24 hours after birth. Suckling gain is weaning weight minus birth weight divided by age in days and expressed as pounds gain per day. Weight on test is the actual weight of each calf in pounds at the beginning of the test period. Age on test is the age of each calf in days at the beginning of the test period. Gain on test is expressed as pounds gained per day during the test period. Economy of gain is total digestible nutrients consumed for each 100 pounds gain in live weight. Gain from birth to the end of test is weight at the end of test minus birth weight divided by age in days at the end of test and expressed as pounds gain per day.

The statistical methods used in this study were analysis of variance, multiple regression, linear regressions, and correlations as outlined by Snedecor (50, pp.103-137; 138-168; 214-252; 340-373).

The method described by Snedecor (50, pp.369-370) for the deletion of a variate from a multiple regression equation is used in the analyses for the determination of significance of each independent variable in the regression equations. Differences were taken as statistically significant when the probabilities of their occurrence by chance alone were 0.05 or less.

RESULTS

Stall Fed Calves

A total of 46 Hereford bull, steer, and heifer calves were fed individually during the years 1949-50, 1950-51, and 1951-52. Sex and year variations were eliminated by analysis within sex groups within years. Records included birth weights, weaning weights, age at weaning, weight and age on test, gains per day on test, efficiency of feed utilization (total digestible nutrients per 100 pounds gain in live weight) and gain per day from birth to the end of the feeding period.

Average weights, gains, and economy of gains were computed on the stall fed calves for the three-year period.

Multiple regressions were computed to determine the regression coefficients of each of the three dependent variables — Y_1 (Gain per day on test), Y_2 (Economy of gain on test) and Y_3 (Gain per day from birth to end of test) — on the four independent variables — X_1 (Birth weight), X_2 (Suckling gain), X_3 (Weight on test) and X_4 (Age on test).

Average Weights and Gains of Stall Fed Calves

Table 1

Average Birth Weights, Weaning Weights, Suckling Gain, Gain-on-Test, and Economy-of-Gain — Total Digestible Nutrients (TDN) Required per 100 Pounds Gain — of Purebred Hereford Bull and Heifer Calves and Grade Steer Calves (Stall Fed) by Sex and Year

Year and Sex	No. of Animals	Ave. Birth Weights	Ave. Weaning Weights	Ave. Suckling Gain	Ave. Daily Gain on Test	TDN Per 100 Pounds Gain
1949-50						
Bull	6	65.0	555.0	1.92	2.28	465.9
Heifer	6	68.2	430.8	1.75	2.02	530.7
Steer	6	62.7	397.5	1.63	1.93	552.2
1950-51						
Bull	4	77.5	407.5	1.79	2.39	458.5
Heifer	8	72.7	408.7	1.71	1.75	577.5
Steer	3	74.8	463.3	1.87	1.89	587.0
1951-52						
Bull	9	73.1	431.1	1.93	2.57	405.6
Heifer	4	64.0	442.5	1.80	1.82	552.3
Steer						
3-Year Average						
Bull	19	71.5	433.7	1.89	2.44	435.8
Heifer	18	69.3	423.6	1.74	1.83	556.3
Steer*	9	66.8	419.4	1.71	1.92	554.9

* Two year average on steers.

In Table 1 it is evident in some instances that total gains made during the suckling period, as shown by weaning weights, are not consistent with average daily gains made during this period. This is apparently a result of weaning all calves at the same time regardless of age. For example, for the year 1950-51, bull calves were heavier than heifer calves at birth, gained more per day during the suckling period, but were lighter at weaning because a higher proportion were born during the last part of the calving season and thus were younger at weaning.

Effect of Birth Weight in Pounds, Suckling Gain in Pounds Per Day, Weight-on-Test in Pounds, and Age-on-Test in Days on Gain-Per-Day-On-Test.

The first multiple regression was designed to test the effects of birth weight, suckling gain, weight on test, and age on test on rate of gain during the test period.

The partial regression coefficients of the independent variables and their confidence intervals are presented in Table 2, with tests of significance shown in Table 3.

Table 2

Partial Regression Coefficients and Confidence Intervals of Gain-on-Test in Pounds per Day, on Birth-Weight in Pounds, Suckling-Gain in Pounds per Day, Weight-on-Test in Pounds, and Age-on-Test in Days.

Variate	Partial Regression Coefficient (b)	Units	95 percent Confidence Interval of b
Birth Weight	.012	lbs.per.day/lb.	.003 to .021
Suckling Gain	-.024	lbs.per day / lbs.per day	-.688 to .021
Weight on Test	.001	lbs.per day/lb.	-.001 to .002
Age on Test	.004	lbs.per day/day	.000 to .008

Table 3

Test of Significance of the Partial Regression Coefficients of Gain-on-Test, on Birth-Weight, Suckling-Gain, Weight-on-Test, and Age-on-Test.

(R = .530)

Source of Variation	d.f.	Mean Square		F
Regression	4	.1226		3.32*
Additional Variation due to:				
Birth Weight	1		.2797	7.57*
Suckling Gain	1		.0004	.01
Weight on Test	1		.0223	.60
Age on Test	1		.1707	4.62*
Residual	34	.0369		

* Significance.

The calculated partial regression coefficients, b, (Table 2) of gain on test on the four independent variables - birth weight, suckling gain, weight-on-test, and age-on-test - indicate that only X_1 (birth weight) and X_4 (age on test) have a significant effect on gain per day during the feeding period. The other two variables, X_2 (gain-per-day-during-the-suckling-period) and X_3 (weight-on-test) had no significant effect on feed-lot gain per day.

The test of significance of the completed multiple regression, given in Table 3, indicates that only birth weight and age-on-test have a significant effect on gain-on-test. Therefore, a second multiple regression was set up eliminating the two variables — suckling gain and weight-on-test. Partial regression coefficients and confidence intervals are given in Table 4, with the test of significance shown in Table 5.

Table 4

Partial Regression Coefficients and Confidence Intervals of Gain-on-Test in Pounds per Day, on Birth Weight in Pounds, and Age-on-Test in Days.

Variate	Partial Regression Coefficient (b)	Units	95 percent Confidence Interval of b
Birth Weight	.013	lbs.per day/lb.	.005 to .021
Age on Test	.004	lbs.per day/day	.003 to .005

The regression of .013 of gain-on-test on birth weight indicates that for each difference from the mean in birth weight of 10 pounds, there would be a difference in gain-per-day on test of 0.13 pound with the heavier calves at birth gaining faster during the test period. Also the regression of .004 for gain-on-test on age-on-test indicates that for every 10 days difference from the mean in age-on-test there is a difference in gain-per-day-on-test of .04 pounds with the older calves on test gaining faster.

Table 5

Test of Significance of the Partial Regression Coefficients of Gain-on-Test, on the Two Independent Variables, Birth Weight, and Age-on-Test.

(R = .511)

Source of Variation	d.f.	Mean Square	F
Regression	2	.2280	6.37*
Additional Variation due to:			
Birth Weight	1	.3496	9.76*
Age on Test	1	.2667	7.45*
Residual	36	.0358	

* Significance.

The value $R^2 = 0.26$ (R = .511, Table 5) means that 26 per cent of the variation in gain per day during the feeding period is accounted for by variations in birth weight and age of the animal when it goes on test.

Effect of Birth Weight in Pounds, Suckling Gain in Pounds Per Day, Weight-on-Test in Pounds, and Age-on-Test in Days on Economy-of-Gain-During-Test. (Total Digestable Nutrients Per 100 Pounds Gain)

The test of significance of the multiple correlation coefficients of Y_2 (economy of gain on test), on the four independent variables, X_1 (birth weight), X_2 (suckling gain), X_3 (weight on test), and X_4 (age on test) showed no statistical significance. This is presented in Table 6.

Table 6

Test of Significance of the Partial Regression Coefficients of Economy of Gain on Test, on Birth Weight, Suckling Gain, Weight on Test, and Age on Test.

(R = 0.412)

Source of Variation	d.f.	Mean Square	F
Regression	4	5,094.558	1.44
Residual	34	3,530.000	
Total	38		

Rate of Gain and Economy of Gain: Correlation Coefficient and Regression.

The correlation coefficient (r) of economy of gain (total digestible nutrients per 100 pounds gain) with rate of gain in pounds per day, was found to be -0.82. The regression of economy of gain on rate of gain resulted in b = -232.8. This indicates that for every one pound increase in gain per day above the mean, there is a corresponding saving of 232.8 pounds TDN (total digestible nutrients) for each 100 pounds gain in live weight.

Effect of Birth Weight in Pounds, Suckling Gain in Pounds Per Day, Weight-on-Test in Pounds, and Age-on-Test in Days, on Gain-From Birth-to-End-of-Test in Pounds Per Day.

Multiple correlations were designed to test the effects of X_1 (birth weight), X_2 (suckling gain), X_3 (weight on test) and X_4 (age on test) on Y_3 (gain per day from birth to the end of test). It was found that birth weight and weight-on-test had significant effects but that suckling gain and age-on-test did not.

The partial regression coefficients and confidence intervals of this test are shown in Table 7, followed by the test of significance in Table 8.

Table 7

Partial Regression Coefficients and Confidence Intervals of Gain From Birth to End of Test in Pounds per Day, on Birth Weight in Pounds, Suckling Gain in Pounds per Day, Weight-on-Test in Pounds, and Age-on-Test in Days.

Variate	Partial Regression Coefficient (b)	Units	95 percent Confidence Interval of b
Birth Weight	.0043	lbs.per day/lb.	.000 to .008
Suckling Gain	-.0611	lbs.per day / lbs.per day	-.271 to .147
Weight on Test	.0020	lbs.per day/lb.	.001 to .003
Age on Test	.0000	lbs.per day/day	-.002 to .002

Table 8

Test of Significance of the Partial Regression Coefficients of Gain per Day From Birth to End of Test, on the Four Independent Variables; Birth Weight, Suckling Gain, Weight on Test, and Age on Test.

(R = .825)

Source of Variation	d.f.	Mean Square	F
Regression	4	.146	18.17*
Additional Variation due to:			
Birth Weight	1	.036	4.49*
Suckling Gain	1	.003	.35
Weight on Test	1	.280	34.91*
Age on Test	1	.000	.00
Residual	34	.008	

* Significance.

Because suckling gain (X_2) and age-on-test (X_4) had no significant effect on gain-per-day-from-birth-to-end-of-test (Y_3) as shown in Table 8, these two variables were omitted and a second multiple regression was set up to test the significance of birth weight (X_1) and weight-on-test (X_3) on gain-per-day-from-birth-to-the-end-of-test (Y_3).

The partial regression coefficient, b, of birth weight was found to be 0.004 (Table 7). Thus, for every 10 pound increase above the mean in birth weight, there was a corresponding .04 of a pound increase in gain per day from birth-to-the-end-of-test. Weight on test shows a similar effect, where b = 0.002. For every 10 pound increase in weight-on-test above the mean of the group, there was an increase of 0.02 pound gain per day in that period from birth to the end of the test. These two variables, birth weight and weight-on-test, were studied with suckling gain and age-on-test held constant.

Partial regression coefficients and their confidence intervals are shown in Table 9. The test of significance is presented in Table 10.

Table 9

Partial Regression Coefficients and Confidence Intervals of Gain-from-Birth-to-End-of-Test in Pounds per Day, on the Two Variables, Birth Weight in Pounds and Weight-on-Test in Pounds.

Variate	Partial Regression Coefficient (b)	Units	95 percent Confidence Interval of b
Birth Weight	.004	lbs.per day/lb.	.000 to .008
Weight on Test	.002	lbs.per day/lb.	.001 to .002

Table 10

Test of Significance of the Partial Regression Coefficients of Gain-per-Day-from-Birth-to-End-of-Test, on the Two Independent Variables, Birth Weight and Weight-on-Test.

(R = .823)

Source of Variation	d.f.	Mean Square	F
Regression	2	.2897	37.74*
Additional Variation due to:			
Birth Weight	1	.0420	5.48*
Weight on Test	1	.4868	63.41*
Residual	36	.0077	

* Significance.

A comparison of Tables 8 and 10 shows very little difference between the two multiple correlation coefficients. In Table 8, $R = .825$, thus $R^2 = .68$. This means that 68 percent of the variations in gain from birth to the end of test are accounted for by the four variables, birth weight, suckling gain, weight-on-test, and age-on-test. In Table 10, $R = .823$ and $R^2 = .67$. Thus the two variables, birth weight and weight-on-test, remove practically as much of the total variation in gain-per-day-from-birth-to-the-end-of-test as the four combined.

Lot Fed Calves

A total of 160 Hereford steer and heifer calves were fed in lots of 10 each at the Union Station during the winters of 1949-50, 1950-51, and 1951-52. Sex, year, and ration variations were eliminated by analysis within lots within years. Records used in this study included birth weights, weight and age at weaning, weight and age on test, gain per day during the feeding period, weight and age at the end of the test, and gain per day from birth to the end of the test period.

Average weights and gains were computed on the group fed calves during the three-year period.

Multiple regressions were computed to determine the regression of each of the two dependent variables - Y_1 (gain per day on test) and Y_3 (gain per day from birth to the end of test) on each of the four independent variables - X_1 (birth weight) X_2 (suckling gain) X_3 (weight on test) and X_4 (age on test).

<u>Average Weights and Gains of Group Fed Calves</u>

Table 11

Average Birth Weights, Weaning Weights, Suckling Gain, and Daily Gain-on-Test, of Grade Hereford Calves (Group Fed) by Sex and Year.

Year and Sex	No. of Animals	Ave. Birth Weights	Ave. Weaning Weights	Ave. Suckling Gain	Ave. Daily Gain on Test
1949-50					
Steers	40	71.0	380.9	1.53	2.14
Heifers	20	70.6	388.0	1.50	1.96
1950-51					
Steers	30	77.5	449.9	1.76	2.00
Heifers	20	70.7	424.1	1.64	1.84
1951-52					
Steers	30	74.8	466.7	1.90	2.11
Heifers	20	72.1	438.7	1.80	1.82
3-year Average					
Steers	100	74.1	427.3	1.71	2.09
Heifers	60	71.1	420.4	1.66	1.86

In Table 11, the effects of age variations at weaning time are again reflected in average weaning weights and per day gain during the suckling period. The suckling gain per day--weaning weight association is dependent on the average age of the calves at weaning.

Effect of Birth Weight in Pounds, Suckling Gain in Pounds per Day, Weight-on-Test in Pounds and Age-on-Test in Days on Gain-per-Day-on-Test.

A multiple regression was set up to test the effects of birth weight, suckling gain, weight-on-test, and age-on-test on gain-per-day-during-the-feeding-period. Each of these independent variables was found to have a significant effect on gain per day. These results are presented in Tables 12 and 13.

Table 12

Partial Regression Coefficients and Confidence Intervals of Gain-on-Test in Pounds per Day on Birth Weight in Pounds, Suckling Gain in Pounds per Day, Weight-on-Test in Pounds, and Age-on-Test in Days.

Variate	Partial Regression Coefficients (b)	Units	95 percent Confidence Interval of b
Birth Weight	.041	lbs.per day/lb.	.025 to .057
Suckling Gain	3.79	lbs.per day / lbs.per day	2.03 to 5.55
Weight on Test	-.014	lbs.per day/lb.	-.007 to -.022
Age on Test	.036	lbs.per day/day	.019 to .053

Table 13

Test of Significance of the Partial Regression Coefficients of Gain-on-Test on Birth Weight, Suckling Gain, Weight-on-Test, and Age-on-Test.

(R = .5366)

Source of Variation	d.f.	Mean Square	F
Regression	4	.4585	10.00*
Additional Variation due to:			
Birth Weight	1	1.2459	27.18*
Suckling Gain	1	.8306	18.12*
Weight on Test	1	.7414	16.18*
Age on Test	1	.8193	17.88*
Residual	139	.0458	

* Significance.

The high partial regression coefficient of suckling gain on gain-on-test, b = 3.79, as shown in Table 12, is largely offset by the negative effect of weight-on-test on gain-on-test, b = -0.014. These indicate that each 0.1 pound increase above the mean in suckling gain per day results in a corresponding increase of almost 0.4 of a pound per day in gain on test. The negative effect of weight-on-test on gain-on-test (b = -0.014) means that an additional 10 pounds above the mean in starting weight would equal 0.14 pound less gain per day on test.

An R^2 of .29 (R = 0.536, Table 13) indicates that 29 per cent of the total variance in gain-on-test is accounted for by the four independent variables, birth weight, suckling gain, weight-on-test, and age-on-test.

Because of the significant effects of the three variables, suckling gain, weight-on-test, and age-on-test, on gain-on-test (Table 13), correlation coefficients were computed to determine the relationships between these three factors. These interactions are presented in Table 14.

Table 14

Correlation Coefficients of Suckling Gain in Pounds per Day with Weight-on-Test in Pounds, Suckling Gain in Pounds per Day with Age-on-Test in Days, and Weight-on-Test in Pounds with Age-on-Test in Days.

Interaction	r
Suckling Gain with Weight-on-Test	0.590
Suckling Gain with Age-on-Test	-0.405
Weight-on-Test with Age-on-Test	0.428

As shown in Table 14, there is a high positive relationship between suckling gain and weight-on-test and between weight-on-test and age-on-test, and a large negative relationship between suckling gain and age-on-test. These are all significant.

<u>The Effect of Birth Weight in Pounds, Suckling Gain in Pounds per Day, Weight-on-Test in Pounds and Age-on-Test in Days, on Gain-from-Birth-to-the-End-of-Test in Pounds per Day</u>

The effects of birth weight, suckling gain, weight-on-test, and age-on-test, on gain per day from birth to the end of test, as determined by multiple regression, are presented in Tables 15 and 16.

Table 15

Partial Regression Coefficients and Confidence Intervals of Gain from Birth to End of Test in Pounds per Day on Birth Weight in Pounds, Suckling Gain in Pounds per Day, Weight-on-Test in Pounds, and Age-on-Test in Days.

Variate	Partial Regression Coefficients (b)	Units	95 percent Confidence Interval of b
Birth Weight	.0083	lbs.per day/lb.	.002 to .014
Suckling Gain	.7413	lbs.per day / lbs.per day	.082 to 1.401
Weight on Test	.0005	lbs.per day/lb.	-.002 to .003
Age on Test	.0038	lbs.per day/day	-.002 to .010

Table 16

Tests of Significance of the Partial Regression Coefficients of Gain from Birth to End of Test on Birth Weight, Suckling Gain, Weight-on-Test, and Age-on-Test.

(R = .780)

Source of Variation	d.f.	Mean Square	F
Regression	4	.4375	53.91*
Additional Variation due to:			
Birth Weight	1	.0504	6.21*
Suckling Gain	1	.0317	3.91*
Weight on Test	1	.0008	.09
Age on Test	1	.0091	1.13
Residual	139	.0081	

* Significance.

In Table 16, both birth weight and suckling gain are shown as having significant effects on gain from birth to the end of the test period. The partial regression coefficient of gain from birth to the end of test on birth weight, b = .0083 (Table 15), indicates that for a 10 pound increase above the mean in birth weight there is a corresponding increase of .083 of a pound in gain per day from birth to the end of test. Also, an increase of .1 pound in suckling gain equals an increase in gain per day from birth to the end of test of .07 of a pound.

A second multiple regression was set up to determine the amount of total variation in gain from birth to the end of the feeding period attributable to the two independent variables, birth weight and suckling gain. These results are shown in Tables 17 and 18.

Table 17

Partial Regression Coefficients and Confidence Intervals of Gain from Birth to End of Test in Pounds per Day, on Birth Weight in Pounds and Suckling Gain in Pounds per Day.

Variate	Partial Regression Coefficient (b)	Units	95 percent Confidence Interval of b
Birth Weight	.006	lbs.per day/lb.	.004 to .008
Suckling Gain	.522	$\frac{\text{lbs.per day}}{\text{lbs.per day}}$	.431 to .613

Table 18

Tests of Significance of the Partial Regression Coefficients of Gain per Day from Birth to End of Test on Birth Weight and Suckling Gain.

(R = .7195)

Source of Variation	d.f.	Mean Square	F
Regression	2	.7450	75.68*
Additional Variation due to:			
Birth Weight	1	.2872	29.17*
Suckling Gain	1	1.1176	113.54*
Residual	141	.0098	

* Significance.

The R^2 of .52 (R = 0.7195, Table 18) indicates that 52 per cent of the variations in gain from birth to the end of the test is accounted for by birth weight and suckling gain.

DISCUSSION

In one respect, successful selection of beef animals would reflect the ability to accurately predict relationships in growth between different periods of development throughout the life of an animal. The magnitude of growth expressed during any period of development is an obscure blending of hereditary and environmental factors.

If environment could be held entirely constant, and we found positive relationships in growth tendencies between early and late periods of development, the accuracy of our predictions would be increased and selection would be much more simple. If, on the other hand, environmental factors are not constant throughout growth, we might expect gain during one period to compensate for high or low gains made during the previous period. Thus, negative as well as positive correlations would be found and would tend to result in a balance between factors. Prediction of results would become more and more difficult.

In this study both positive and negative relationships have been found and such a balance is quite evident. Analysis of data from the group feeding trials, indicates that for every 0.1 pound gain above the mean in suckling gain per day there is a corresponding increase in gain per day on test of approximately 0.4 pounds. On the other hand, it was found that weight had a significant negative effect on gain on test. Thus, for every 40 pounds increase above the mean in weight at the beginning of the test, there is a decrease of 0.4 pounds per day gain during the feeding period. Even though rapid gain during the suckling period indicates greater gains during the feeding period, the same calf that makes these rapid pre-feeding gains is the heavier calf at the beginning of the test; and we have shown that added weight at the beginning of the test has a negative effect on gains during the test period.

Discussion of Stall Feeding Results

In respect to the individually fed calves, the analysis indicates that only birth weight of the calf and age of the calf at the time it went on test had significant effects on gain per day during the test period. These two factors accounted for 26 percent of the variations in feed lot gain per day. Heavier calves at birth gained faster on feed than lighter calves at birth. Also, calves which were older at the beginning of the test gained significantly more than younger calves. This is in agreement with results obtained by Dahmen, *et al*,(10, p.16) and Kolhi, *et al* (39, p.364). It appears that calves heavier at birth have a tendency to retain this advantage throughout the feeding period.

Cow size has been quite well established as one of the more important factors affecting birth weight of calves: Gregory, *et al* (19, p.345); Knapp, *et al* (35, p.284). As the calf retains this advantage to maturity, it would appear that the importance of birth weight as a factor in beef cattle improvement through selection could hardly be over emphasized. Sawyer, Li, and Bogart (48, p.6) suggest that hereditary factors controlling "growthiness" and milk production may be the same or closely associated. Thus, dam size, heavier calves at birth, higher milk production in the dam, and a greater mature size of the calf suggest a positive association useful in predicting improvement through selection.

Gain per day during the suckling period and weight of the calf at the beginning of the test had no significant effect on gain per day during the test period on the stall fed calves. This lack of significance would indicate that these two variables, suckling gain and weight of the calf at the beginning of the test period are of minor importance in predicting gains in the feed lot. If these calves had all entered the feeding period at a constant age, it is conceivable that weight would have had a significant effect on feed lot gain per day. A six month old calf weighing 400 pounds would have less capacity for gains in the feed lot than a six month old calf weighing 300 pounds. This was emphasized by the significant effect of age on test on gain on test with weight, suckling gain, and birth weight held constant. The older calf at the beginning of the test is the calf that has gained less per day during a longer suckling period and has probably made satisfactory growth in terms of a circulatory and digestive system but is not carrying the finish of the younger calf, therefore, the older calf has a greater capacity to gain. The assumption that the longer suckling period, characteristic of the older calves, results in less gain per day during this period is based partially on the fact that calves at the Union Station are dropped while the cows are on dry feed. Thus, those dropped early in the calving season are subjected to from four to six weeks of cow milk production that is probably below that of cows that calve near the end of the calving season and near the time when grass raises milk production to its peak.

There was no significant association between economy of gain on test and the four independent variables studied - birth weight, suckling gain, weight on test, and gain on test.

In view of this lack of significant effect, the relationship between gain on test and economy of gain was studied. This correlation was found to be -0.82 and was highly significant. The unit of change in efficiency associated with each unit of change in gain on test was found to be -233. In other words, for every 0.1 pound increase in gain per day on feed, there was a corresponding saving of 23 pounds of TDN (total digestible nutrients) for each 100 pounds gain in live weight. This is in agreement with Black and Knapp (3, p.77), Kolhi, et al, (39, p.363), Blackwell (4, p.44) and others. This simply emphasizes again the indication that rapid gaining calves are efficient calves.

A study of factors affecting gain per day from birth to the end of the test period, indicated that, with the individually fed animals, only birth weight and weight on test had a significant effect. These two accounted for approximately 68 percent of the variations in gain per day from birth to the end of the test period.

Birth weight affected gain during this extended period to the extent that for a 10 pound increase in birth weight there was an associated 0.04 pound increase in daily gain. The magnitude of this effect of birth weight is less than that of birth weight on test gain only. It does indicate however, as pointed out before, that the effects of birth weight are extended throughout a good share of the developing life of the animal.

Each increase of 10 pounds above the mean in weight of the animal at the beginning of the test period had the effect of causing a 0.01 pound increase in gain per day during that period from birth to the end of the feeding period. Here the heavier calves are shown as having an advantage over lighter calves when age on test, suckling gain, and birth weight are held constant. This effect may be associated with the possible ability of an older calf to adjust or more readily take advantage of feed lot conditions. However, all calves in this study underwent a condition period, one of transition from mothers milk to concentrates and hay, of 30 days or more between weaning and the beginning of the official test. The other possible explanation is that these heavier calves are the larger framed, "growthier" calves, with more inherent ability to gain and more capacity to gain than the lighter individuals.

Suckling gain and age on test had no significant effect on gain of the animals from birth to the end of the test period.

Results of the two phases of this study, stall or individually fed calves and group fed calves, compare quite favorably. Birth weight was found to be significantly associated with all factors studied except economy of gain. Suckling gain was shown to have a significant effect on performance factors in the group fed animals but not in the stall fed animals. Age-on-test had a significant affect on gain-on-test in both phases. Weight-on-test significantly affected gain-from-birth-to-the-end-of-test in the stall fed animals but not in the group fed animals. Age-on-test had no affect on gain-from-birth-to-the-end-of-test in either phase. Differences that do exist may be partially due to the greater selection pressure which has been applied to the Purebred (stall fed) animals.

Discussion of Lot Feeding Results

Analysis of data from the group feeding trials indicates that gain-on-test was significantly affected by all four variables studied, birth weight, suckling gain, weight-on-test and age-on-test. Approximately 29 percent (R = .5366, Table 13) of the total variance in gain-on-test was accounted for by these four factors.

Birth weight affects gain-on-test to the extent that for every 1 pound increase in weight at birth above the mean there is an increase of 0.04 pounds per day in gain-on-test. This agrees quite closely with results from the stall feeding trials.

As mentioned before, suckling gains in the group feeding trials had a high positive effect on gain-on-test. High gains during the suckling period were associated with high gains during the feeding period. Black and Knapp (3, pp.73-77) found a negative correlation between suckling gain and gain-on-test. Others have found no association between these two factors (Knapp and Black, 31, p.253, and Knapp, et al, 30, pp.12-17). Treatment of the present data suggests two possible explanations. As stated before, the calves fed at the Union Station were conditioned to feed-lot environment for a considerable time before the beginning of the test. Thus, these calves may have been on a more equal basis, from the standpoint of gaining ability, at the time they were placed on test. It follows then, that the large positive effects of suckling gains on feed lot gains found in these trials may be largely due to the actual ability of the calves to make rapid gains. Or, more precisely, environmental factors, active during the suckling period, which tend to mask the inherited ability of the animal, were largely eliminated.

The other explanation lies in the possibility of correlations which may exist between gain made during different periods of growth. Gains per day during the test period are more dependent on suckling gains than are gains from birth to the end of test. This suggests a negative correlation between suckling gains and gains made during the conditioning period. Thus calves making the most rapid gains during the suckling period would make the least gain during the conditioning period and would again make rapid compensating gains during the later test period.

The negative partial regression of gain-on-test on weight-on-test has been discussed in a previous section.

The regression of gain-on-test on age-on-test coincides with that found in the stall calves. Calves which are older at the beginning of the test gain more rapidly than younger calves.

The fact that all four independent variables studied, birth weight, suckling gain, weight-on-test, and age-on-test, had significant effects on gain-on-test, would indicate significant interactions between these variables. It was found that significant correlations did exist between at least three of these factors. A positive correlation of 0.58 was found to exist between suckling gain and weight of the animal at the beginning of the test. The regression of weight-on-test on suckling gain indicates that for each 0.1 pound increase above the mean in suckling gain, there is an increase of almost 16 pounds in weight at the beginning of the test. This association should exist and does not necessarily detract from the value of the conditioning period in equalizing environmental variations. The conditioning period should not appreciably affect the weight of a calf which has the ability to consume feed and convert this consumption into high gains. Rather, its function should be that of allowing the calf to make a physiological conversion from a ration made up of milk and grass to one of dry concentrates and roughages.

The correlation between suckling gain and age on test was -0.40. Here the regression of age on test on suckling gain indicates that each 10 day increase in age reflected 0.04 pounds less gain per day during the suckling period. This again may reflect environmental conditions prevalent during the calving period. Early calves were subjected to lower milk production from cows on dry feed. Later calves received the advantage of higher milk production from cows on grass during a relatively greater portion of their suckling development.

The association between age-on-test and weight-on-test was a positive 0.43. The regression of weight-on-test on age-on-test meant that 10 days added age above the mean was accompanied by almost 12 pounds additional weight at the beginning of test. As was to be expected, older calves were heavier at the beginning of the feeding period.

The correlation between birth weight and suckling gain was not statistically significant.

When the effects of birth weight, suckling gain, weight on test, and age on test, on gain from birth to the end of the test were studied, it was found that only birth weight and suckling gain were statistically significant. Of the total variation in gain per day from birth to the end of the feeding period, 52 percent was accounted for by variations in birth weight and suckling gain.

When variations due to suckling gain, weight-on-test, and age-on-test were eliminated, a 10 pound increase in birth weight had the effect of increasing gain per day 0.05 of a pound throughout this period. This persistent effect of birth weight on gains made in later periods has been evident throughout each phase of this study.

Suckling gain had much the same effect when other factors were held constant. An increase of 0.1 pound above the mean during this period resulted in a corresponding increase gain of 0.05 pounds per day during that period of growth from birth to the end of the feeding test.

The results of this study emphasize the value of birth weight and suckling gain in predicting feed-lot performance of a beef animal. The age and weight of an animal at the beginning of the feeding period are influenced greatly by environment and by performance both during the suckling period and during the conditioning period prior to initiation of the test.

There is an indication that either weight-on-test or age-on-test could be used to advantage in predicting feed-lot performance if calves were fed through either a weight-constant period or an age-constant period. If both are allowed to fluctuate, the predictive value of these highly variable factors decreases considerably.

SUMMARY AND CONCLUSIONS

A total of 46 purebred and grade Hereford calves (fed in individual stalls) and 160 grade Hereford calves (fed in lots) were tested at the Union Experiment Station during the winters of 1949-50, 1950-51, 1951-52. Multiple correlations were set up to test the single and combined effects of the four independent variables—birth weight, suckling gain, weight-on-test, and age-on-test—on each of the three dependent variables—gain on test, economy of gain (total digestible nutrients per 100 pounds gain), and gain per day from birth to the end of the test period.

Two separate analyses were run, one on the individually fed calves and one on the group fed calves. The conclusions are presented in that order.

Stall Fed Calves

1. Bull calves have increased 0.29 pounds per day in average gain-on-test during the three year period. This increased gain has been accompanied by an average decrease of 60 pounds TDN (total digestible nutrients) per each 100 pounds gain in live weight.

2. Birth weight had a significant effect on gain-on-test and on gain-from-birth-to-the-end-of-the-test period. Calves 10 pounds heavier than average at birth gained 0.12 pound per day more on test, and 0.043 pounds per day more from birth to the end of test.

3. Gain per day during the suckling period had no effect on gain-on-test or gain-from-birth-to-the-end-of-test.

4. Age-on-test had a positive effect on gain-on-test. For each additional 10 days in age above the mean at the beginning of the test, there was an added 0.04 pound per day gain on test.

5. Weight-on-test had a positive effect on gain-from-birth-to-the-end-of-test. Calves 10 pounds heavier than average at the beginning of the test period gained 0.02 pounds per day more throughout the total period from birth to the end of test.

6. Economy of gain was not affected by either birth weight, suckling gain, weight-on-test, or age-on-test.

7. There was a significant regression of economy of gain on rate of gain. An increase of 0.1 pound per day above the mean in gain on test resulted in a saving of 23 pounds of total digestible nutrients for each 100 pounds gain in live weight.

Lot Fed Calves

1. Birth weight had a significant positive effect on gain-on-test and on gain-from-birth-to-the-end-of-test. An additional 10 pounds above the mean at birth resulted in 0.41 pounds added gain per day on test and 0.083 pounds added gain per day from birth to the end of the test. In both phases of this study, calves heavier at birth gained faster on test and from birth to market age.

2. Suckling gain had a significant positive effect on gain-on-test and on gain-from-birth-to-the-end-of-test. An increase of 0.1 pound above the mean in suckling gain per day resulted in an increase gain per day on test of 0.379 pounds and an increase in gain per day from birth to the end of test of 0.074 pounds. This effect was not

significant with the stall fed calves.

3. Weight-on-test had a significant negative effect on gain-on-test. Calves which were 10 pounds heavier than average at the beginning of the test gained 0.14 pounds per day less on test.

4. Age-on-test had a significant positive effect on gain on test. Calves 10 days older than average at the beginning of the test gained 0.36 pounds per day more during the test period.

5. Age-on-test and weight-on-test had no significant effect on gain-from-birth-to-the-end-of-test.

6. There was a significant positive correlation between suckling gain and weight-on-test and between weight-on-test and age-on-test.

7. There was a significant negative correlation between suckling gain and age-on-test. Calves younger at the beginning of the test period had made higher suckling gains over a relatively shorter period of time. Calves which were heavier at the beginning of the test had gained less per day during the suckling period but had made a greater total suckling gain because of their greater age at weaning.

8. It appears that the suckling period is subject to considerable environmental influence. Whether or not test calves are weaned at a constant age, they should undergo a conditioning period before being placed on official test.

9. This study indicates that production testing may be more valid if calves are fed through either a weight constant or an age constant period. Under range conditions where such controls are impractical, adequate correction factors would be used to standardize

test procedures.

BIBLIOGRAPHY

1. Baker, J. P., R. W. Colby, and C. M. Lyman. The relationship of feed efficiency to digestion rates of beef cattle. Journal of animal science 10:726,732. 1951.

2. Black, W. H. and Bradford Knapp, Jr. A comparison of several methods of measuring performance in beef cattle. Proceedings of the American society of animal production. 1938. 237p.

3. ———— and Bradford Knapp, Jr. A method of measuring performance in beef cattle. Proceedings of the American society of animal production. 1936. 73-77p.

4. Blackwell, Robert L. Relation of rate of gain to feed efficiency in beef cattle. M. S. Thesis. Oregon state college, 1951. 54p.

5. Blunn, Cecil T. and Marvel L. Baker. The relation between average daily gain and some carcass measurements. Journal of animal science 6:424-431. 1947.

6. Bogart, Ralph and Robert L. Blackwell. More beef with less feed. Corvallis, Oregon state college, 1950. 4p. (Oregon. Agricultural experiment station bulletin 488.)

7. Burris, Martin J. and Cecil T. Blunn. Some factors affecting gestation length and birth weight of beef cattle. Journal of animal science 11:39-40. 1952.

8. Clark, R. T., et al. Performance testing of beef cattle. Bozeman, Montana state college, 1943. 12p. (Montana. Agricultural experiment station bulletin 417.)

9. Comstock, R. E., L. M. Winters, and John N. Cummings. The effect of sex on the development of the pig. III. Differences in growth rate between gilts and barrows by lines of breeding. Journal of animal science 3:120-128. 1944.

10. Dahmen, Jerome J. and Ralph Bogart. Some factors affecting rate and economy of gains in beef cattle. Corvallis, Oregon state college, 1952. 23p. (Oregon. Agricultural experiment station technical bulletin 26.)

11. Davis, H. P. and E. L. Willett. Relation between rate of growth and fat production. Journal of dairy science 21:637-642. 1938.

12. Dawson, W. M., R. W. Phillips, and W. H. Black. Birth weight as a criterion of selection in beef cattle. Journal of animal science 6:247-257. 1947.

13. Dickerson, G. E. Composition of hog carcasses as influenced by heritable differences in rate and economy of gain. Ames, Iowa state college, 1947. 491-524p. (Iowa. Agricultural experiment station research bulletin 354.)

14. Galgan, M. W., M. E. Ensminger and C. R. Byd. Improvement of beef cattle through production testing. Pullman, Washington state college, 1952. 6p. (Washington. Agricultural experiment station circular 204.)

15. Gifford, Warren. Importance of high milk production in beef cows overestimated. Proceedings of the American society of animal production. Journal of animal science 8:605-606. 1949. (Abstract)

16. Goodale, H. D. A study of the inheritance of body weight in the albino mouse by selection. Journal of heredity 29:101-112. 1938.

17. Gramlich, H. J. and R. R. Thalman. Sex and age factors in cattle feeding. Lincoln, University of Nebraska, 1930. 55p. (Nebraska. Agricultural experiment station bulletin 252.)

18. ————————— The effect of spaying in beef production. Proceedings of the American society of animal production. 1926. 213-216p.

19. Gregory, Keith E., Cecil T. Blunn, and Marvel L. Baker. A study of some of the factors influencing the birth and weaning weights of beef calves. Journal of animal science 9:338-346. 1950.

20. Guilbert, H. R., and P. W. Gregory. Some features of growth and development of Hereford cattle. Journal of animal science 11:3-16. 1952.

21. ————————— and G. H. Hart. California beef production. Davis, University of California, 1946. 157p. (California. Agricultural extension service circular 131.)

22. Hess, Carl W. and Morley A. Jull. A study of the inheritance of feed utilization efficiency in the growing domestic fowl. Poultry science 27:38-39. 1948.

23. Joshi, Bhuwan C., C. S. Shaffner, and Morley A. Jull. Efficiency of feed utilization in relation to body weight and egg production. Poultry science 28:301. 1949.

24. Jull, Morley A. Inheritance of efficiency of feed utilization in growing chickens. Offprint of the official report of the eighth world's poultry congress. 1948. 298-299p.

25. Keith, T. B., R. F. Johnson, and W. P. Lehrer, Jr. The optimum ratio of concentrate to alfalfa hay for fattening steers. Moscow, University of Idaho, 1952. 15p. (Idaho. Experiment station bulletin 290.)

26. Kleiber, M. Problems involved in breeding for efficiency of feed utilization. Proceedings of American society of animal production. 1936. 248-258p.

27. Knapp, Bradford, Jr., et al. Length of feeding period and number of animals required to measure economy of gain in progeny tests of beef bulls. Journal of animal science 1:285-292. 1942.

28. Knapp, Bradford, Jr. and A. L. Baker. Limited versus full feeding in record of performance tests for beef cattle. Journal of animal science 2:321-327. 1943.

29. ——————————, et al. Growth and production factors in range cattle. Bozeman, Montana state college, 1942. 1-13p. (Montana. Agricultural experiment station bulletin 400.)

30. ——————————, et al. Record of performance in Hereford cattle. Bozeman, Montana state college, 1941. 30p. (Montana. Agricultural experiment station bulletin 397.)

31. ——————————, and S. H. Black. Factors influencing rate of gain during the suckling period in beef calves. Journal of agricultural research 62:249-254. 1941.

32. ——————————, Robert C. Church, and Alva E. Fowler. Genetic history of the Line I Hereford cattle. Bozeman, Montana state college, 1951. 19p. (Montana. Agricultural experiment station bulletin 479.)

33. —————————— and R. T. Clark. Genetic and environmental correlations between growth rates of beef cattle at different ages. Journal of animal science 6:174-181. 1947.

34. Knapp, Bradford, Jr. and R. T. Clark. Genetic and environmental correlations between weaning scores and subsequent gains in feed lot with record of performance steers. Journal of animal science 10:365-370. 1951.

35. ———————, W. B. Lambert, and W. H. Black. Factors influencing length of gestation and birth weight in beef cattle. Journal of agricultural research 61:277-285. 1940.

36. ——————— and Arne W. Nordskog. Heritability of growth and efficiency in beef cattle. Journal of animal science 5:62-70. 1946.

37. Koch, Robert M. Size of calves at weaning as a permanent characteristic of range Hereford cows. Journal of animal science 10:7-8. 1951.

38. Koger, Marvin and J. H. Knox. The effect of sex on weaning weight of range calves. Journal of animal science 4:15-19. 1945.

39. Kolhi, M. L., A. C. Cook, and W. M. Dawson. Relation between some body measurements and certain performance characters in milking Shorthorn steers. Journal of animal science 10:352-364. 1951.

40. Lambert, W. V., et al. The role of nutrition in genetic research. Proceedings of the American society of animal production 236-243p. 1936.

41. Lush, J. L. Genetic aspects of the Danish system of progeny-testing swine. Ames, Iowa state college, 1936. 107-196p. (Iowa. Agricultural experiment station research bulletin 204.)

42. ——————— Predicting gains in feeder cattle and pigs. Journal of agricultural research 42:853-881. 1931.

43. Morris, H. P., L. S. Palmer, and Cornelia Kennedy. Fundamental food requirements for the growth of the rat. Minneapolis, University of Minnesota, 1933. 56p. (Minnesota. Agricultural experiment station technical bulletin 92.)

44. Morrison, Frank B. Feeds and feeding, a handbook for the student and stockman. 21st. Ithaca, Morrison Publishing Co. 1948. 1207p.

45. Palmer, Leroy S., et al. Genetic differences in the biochemistry and physiology influencing food utilization for growth in rats. Minneapolis, University of Minnesota, 1946. 54p. (Minnesota. Agricultural experiment station technical bulletin 176.)

46. Roubicek, C. B., N. W. Hilston, and S. S. Wheeler. Progeny studies with Hereford and Shorthorn cattle. Laramie, University of Wyoming, 1951. 18p. (Wyoming. Agricultural experiment station bulletin 307.)

47. Sawyer, W. A., Ralph Bogart, and Mohamed M. Oloufa. Weaning weight of calves as related to age of dam, sex, and color. Journal of animal science 7:514-515. 1948. (Abstract)

48. ——————, Jerome C. R. Li, and Ralph Bogart. The relative influence of age of dam, birth weight, the size of dam on weaning weight of calves. Paper read at the annual meeting of the western section of the American society of animal production. Pullman, Washington, June 27-28. 1949. 7p.

49. Sheets, E. W. Evaluating beef cattle performance for a register of merit. Proceedings of the American society of animal production. 1932. 41-47p.

50. Snedecor, George W. Statistical methods. 4th. Ames, Iowa state college, 1946. 485p.

51. Snell, M. G. The utilization of feed by range steers of different ages. State College, New Mexico college of agriculture, 1923. 7p. (New Mexico. Agricultural experiment station bulletin 140.)

52. Stonaker, H. H., M. H. Hazaleus, and S. S. Wheeler. Feed lot and carcass characteristics of individually fed comprest and conventional type Hereford steers. Journal of animal science 2:17-25. 1952.

53. Warnick, Alvin C., Ralph Bogart, and Ruth Gysbers. Certain factors influencing rate of gain and feed efficiency in rabbits. Corvallis, Oregon state college, 1951. 5p. (Oregon. Agricultural experiment station technical paper 695.)

54. Warwick, E. J. Genetics and animal breeding. Pullman, Washington state college, 1948. 58p. (Washington. Agricultural experiment station bulletin 189.)

55. Williams, C. M. and A. J. Wood. Beef bull reaearch project. University of British Columbia. A mimeographed report. 1951-52. 31p.

56. Winters, Lawrence M. and Harry McMahon. Efficiency variations in steers. Minneapolis, University of Minnesota, 1933. 28p. (Minnesota. Agricultural experiment station technical bulletin 94.)

APPENDIX

Table I

Rations Fed to Stall Calves During the Winters
Of
1949-50, 1950-51, and 1951-52

	HAY	SUPPLEMENT
1949-50	Chopped Alfalfa-grass.	UNION FEED MIXTURE (Oats - - - - - - - - - - - - - - - -29.07%) (Wheat - - - - - - - - - - - - - - -29.07%) (Barley - - - - - - - - - - - - - - -29.07%) (Linseed meal - - - - - - - - - - -11.63%) (Molasses - - - - - - - - - - - - - 1.06%) Dried Beet Pulp.
1950-51	Chopped Alfalfa-grass-pea (Approximately 1/3 each)	Wheat 2/3 Peas 1/3 Dried beet pulp Mineral mixture
1951-52	Chopped Alfalfa-grass-pea (Approximately 1/3 each)	Wheat 2/3 Peas 1/3 Dried beet pulp Mineral mixture Linseed meal

Table II

Rations Fed to Lot Calves During the Winters
Of
1949-50, 1950-51, and 1951-52

	1949 - 1950		1950 - 1951		1951 - 1952	
	Hay	Supplement	Hay	Supplement	Hay	Supplement
Lot I Steers	Chopped alfalfa, grass and pea.	Ground wheat, Dried beet pulp.	Chopped alfalfa, grass and pea.	Ground wheat, Dried beet pulp.	Chopped alfalfa, grass and pea.	Ground wheat, Linseed meal, Dried beet pulp.
Lot 2 Steers	Chopped alfalfa, grass and pea.	Ground wheat, Linseed meal, Dried beet pulp.	Chopped alfalfa, grass and pea.	Ground wheat 2/3 Ground peas 1/3 Dried beet pulp.	Chopped alfalfa, grass and pea.	Ground wheat, 2/3 Ground peas, 1/3 Dried beet pulp.
Lot 3 Steers	Chopped Alfalfa, grass and pea.	Ground wheat 2/3 Ground peas 1/3 Dried beet pulp.	Chopped alfalfa, grass and pea.	Ground barley, Dried beet pulp.	Chopped alfalfa, grass and pea.	Ground wheat, Linseed meal, Dried beet pulp.
Lot 4 Steers	Chopped alfalfa, grass.	Union feed mixture, Dried beet pulp.				
Lot 4 Heifers			Chopped alfalfa, grass and pea.	Ground wheat 2/3 Ground peas 1/3 Dried beet pulp.	Chopped alfalfa, grass and pea.	Ground wheat, 2/3 Ground peas, 1/3 Dried beet pulp.
Lot 5 Heifers	Chopped alfalfa, grass and pea.	Ground wheat, Linseed meal, Dried beet pulp.	Chopped alfalfa, grass and pea.	Ground wheat 2/3 Ground peas 1/3 Dried beet pulp, Mineral mixture.	Chopped alfalfa, grass and pea.	Ground wheat, 2/3 Ground peas, 1/3 Dried beet pulp, Mineral mixture.
Lot 6 Heifers	Chopped alfalfa, grass and pea.	Ground wheat, Linseed meal, Dried beet pulp.			Chopped alfalfa, grass and pea.	Ground wheat, Linseed meal, Dried beet pulp. Mineral mixture.

Table III

Birth Weights, Suckling Gains, Weight-on-Test, Age-on-Test, Gain-on-Test, Total Digestible Nutrients (TDN) per 100 Pounds Gain, and Gain from Birth to End of Test, by Sex, Calf Number, and Year

Sex and No.	Birth Weight	Suck-ling Gain	Weight on Test	Age on Test (Days)	Gain on Test	TDN per 100 lbs. Gain	Total per day Gain
			-1949, 1950-				
B-10	55.0	1.78	590	313	2.33	433.2	1.85
B-51	63.0	1.73	510	297	1.96	531.4	1.63
B-54	67.0	1.92	580	296	2.33	442.5	1.91
B-63	63.0	1.99	605	293	2.46	423.1	2.03
B-64	63.0	1.82	515	293	2.46	408.7	1.81
B-68	79.0	2.30	705	290	2.13	556.7	2.15
S-20	62.0	1.36	480	310	1.75	599.3	1.46
S-23	49.5	1.49	465	309	1.67	576.4	1.43
S-35	60.0	1.53	510	303	2.00	541.3	1.63
S-41	62.5	2.06	615	301	1.92	583.7	1.86
S-65	68.0	1.77	535	293	2.25	471.0	1.78
S-77	74.5	1.60	505	279	2.00	541.7	1.68
H-16	62.0	1.74	560	311	2.00	558.7	1.71
H-26	80.0	1.77	555	309	2.13	497.2	1.70
H-39	74.0	1.73	495	302	2.08	510.3	1.59
H-46	59.0	1.66	535	299	2.00	557.4	1.71
H-52	70.0	1.92	570	297	1.92	579.5	1.75
H-74	64.0	1.71	455	284	1.97	481.2	1.50

Table IV

Birth Weight, Suckling Gain, Weight-on-Test, Age-on-Test, Gain-on-Test, Total Digestible Nutrients (TDN) per 100 Pounds Gain, and Gain from Birth to End of Test, by Sex, Calf Number, and Year

Sex and No.	Birth Weight	Suckling Gain	Weight on Test	Age on Test (Days)	Gain on Test	TDN per 100 lbs. Gain	Total per day Gain
			-1950, 1951-				
B-54	92	1.61	545	248	2.39	486.8	2.06
	83	1.69	415	227	2.75	382.8	2.03
B-85	74	1.87	380	175	2.33	446.7	2.04
B-666	61	1.98	500	251	2.08	517.8	1.89
S-3	67.5	1.97	535	275	2.14	518.6	1.87
S-55	75	1.75	470	248	1.61	676.7	1.60
S-74	82	1.90	475	218	1.92	565.8	1.85
H-25	82.5	1.41	400	262	2.10	454.0	1.53
H-35	79	1.53	430	259	1.97	498.2	1.58
H-42	67	1.72	470	257	1.73	577.4	1.63
H-63	76	1.79	450	229	1.67	598.2	1.65
H-65	73	1.69	400	227	1.37	696.8	1.41
H-68	62.5	1.83	420	224	1.67	574.4	1.62
H-69	69	1.91	450	224	1.77	567.3	1.73
H-73	73	1.81	430	218	1.74	654.1	1.57
			-1951, 1952-				
B-42	63	1.95	575	273	2.79	390.1	2.15
	70	1.60	500	270	2.58	411.4	1.90
B-53	66.5	1.87	480	264	2.50	402.1	1.86
B-55	69	1.82	515	262	2.46	435.0	1.94
B-39	78	2.40	690	275	2.96	371.8	2.45
B-69	68	1.72	500	254	2.37	431.0	1.92
B-78	84	1.94	535	242	2.67	375.6	2.13
B-83	84.5	2.05	465	219	2.62	386.1	2.05
B-88	75	2.00	390	193	2.17	447.5	1.84
H-29	64	1.81	510	288	1.79	552.1	1.62
H-34	58.5	1.77	510	277	1.50	654.5	1.59
H-64	66.5	1.50	425	256	2.08	453.9	1.62
H-40	67	2.11	595	274	1.92	548.9	1.92

Table V

Birth Weight, Suckling Gain, Weight-on-Test, Age-on-Test, Gain-on-Test, and Gain from Birth to End of Test, by Sex, Calf Number, Year, and Lot

Sex and No.	Birth Weight	Suckling Gain	Weight on Test	Age on Test (Days)	Gain on Test	Total per Day Gain
			-1949, 1950-			
			Lot No. 1			
S-12	71.0	1.30	415	281	1.91	1.49
S-19	80.0	1.67	555	278	2.10	1.86
S-27	74.0	1.52	505	276	1.88	1.69
S-32	80.0	1.68	590	273	2.24	2.02
S-29	67.0	1.70	525	276	1.99	1.79
S-70	71.0	1.73	550	258	1.77	1.82
S-42	71.0	1.66	575	269	1.94	1.90
S-48	68.0	1.58	495	266	1.97	1.75
S-61	81.0	1.47	465	262	2.38	1.84
S-66	64.0	1.34	425	260	1.69	1.51
			Lot No. 2			
S-3	73.5	1.49	515	287	1.72	1.61
S-6	81.5	1.66	580	284	2.24	1.94
S-17	64.0	1.67	525	278	1.97	1.78
S-22	75.0	1.39	470	277	2.54	1.87
S-57	63.0	1.52	445	264	2.05	1.69
S-25	68.0	1.64	550	277	1.99	1.84
S-28	69.0	1.36	525	276	1.86	1.73
S-34	70.0	1.75	540	271	2.05	1.86
S-36	67.0	1.38	435	270	2.08	1.65
S-58	66.0	1.65	470	264	2.10	1.76
			Lot No. 3			
S-45	67.0	1.62	490	268	2.18	1.82
S-33	69.0	1.75	530	271	1.94	1.80
S-72	66.0	1.39	420	255	1.94	1.62
S-30	68.0	1.67	505	276	2.10	1.79
S-59	71.0	1.63	500	264	2.18	1.85
S-8	80.0	1.25	465	281	2.40	1.78
S-21	73.0	1.69	545	278	2.59	2.05
S-50	74.0	1.90	585	265	2.65	2.22
S-43	71.0	1.44	500	269	2.20	1.99
S-24	62.0	1.59	525	277	2.18	1.88

Table V (Cont.)

Sex and No.	Birth Weight	Suckling Gain	Weight on Test	Age on Test (Days)	Gain on Test	Total per Day Gain
			Lot No. 4			
S-86	74.0	1.84	380	220	2.18	1.75
S-87	85.0	1.48	375	221	2.32	1.77
S-89	57.0	1.59	335	215	1.99	1.61
S-88	75.0	1.35	345	217	2.32	1.74
S-82	61.0	1.46	345	233	2.62	1.84
S-80	75.0	1.33	370	239	1.94	1.54
S-71	66.0	1.51	385	257	2.21	1.64
S-31	80.0	.90	355	273	2.10	1.45
S-38	78.0	1.28	470	270	2.68	1.95
S-56	65.0	1.58	435	264	2.38	1.80
			Lot No. 5			
H-1	71.0	1.45	495	289	1.72	1.56
H-7	72.0	1.77	545	284	1.88	1.75
H-9	61.0	1.32	445	281	2.02	1.62
H-15	70.0	1.52	520	279	1.86	1.71
H-40	68.0	1.11	425	270	2.43	1.77
H-44	78.5	1.77	525	269	1.91	1.76
H-49	63.0	1.45	450	266	1.75	1.57
H-60	68.0	1.40	470	263	1.97	1.71
H-69	71.0	1.37	420	258	2.08	1.65
H-85	69.0	1.23	505	348	1.80	1.44
			Lot No. 6			
H-2	79.5	1.67	565	287	2.08	1.84
H-4	65.5	1.41	485	285	1.72	1.57
H-5	70.0	1.48	495	285	2.18	1.76
H-13	65.5	1.41	455	281	1.58	1.46
H-14	71.0	1.45	490	279	1.83	1.63
H-18	81.0	1.75	575	278	2.10	1.91
H-53	71.0	1.47	465	265	1.94	1.67
H-79	71.0	1.67	455	241	2.16	1.84
H-81	80.0	1.56	460	238	1.97	1.76
H-75	66.5	1.68	410	249	2.21	1.73

Table VI

Birth Weight, Suckling Gain, Weight-on-Test, Age-on-Test, Gain-on-Test, and Gain from Birth to End of Test, by Sex, Calf Number, Year, and Lot

Sex and No.	Birth Weight	Suckling Gain	Weight on Test	Age on Test (Days)	Gain on Test	Total per Day Gain
			-1950, 1951-			
			Lot No. 1			
S-10	69.0	1.45	460	269	1.62	1.52
S-21	67.0	1.58	505	263	1.70	1.68
S-27	72.0	1.39	415	262	1.93	1.57
S-32	79.0	1.90	530	261	1.86	1.78
S-33	78.0	1.65	485	260	2.45	1.94
S-40	68.0	1.71	485	258	1.73	1.66
S-44	80.0	1.87	550	254	2.11	1.96
S-52	78.0	1.81	515	249	2.22	1.95
S-72	84.0	1.86	480	231	1.91	1.80
S-86	77.0	1.76	525	250	2.22	1.97
			Lot No. 2			
S-2	67.5	1.87	535	277	1.91	1.78
S-8	67.5	1.79	530	271	1.91	1.79
S-13	75.0	1.57	485	266	1.88	1.68
S-29	86.0	1.69	505	261	2.11	1.82
S-36	72.0	1.59	470	259	2.27	1.85
S-43	74.0	2.15	585	257	2.42	2.17
S-62	68.0	1.68	460	243	1.93	1.75
S-66	65.0	1.80	455	237	1.93	1.77
S-71	88.0	1.83	485	232	1.96	1.82
S-76	93.0	1.69	450	222	1.78	1.69
			Lot No. 3			
S-1	73.0	1.70	530	279	1.75	1.68
S-7	91.0	1.85	560	272	2.24	1.94
S-17	79.0	1.53	455	263	1.91	1.63
S-31	70.0	1.72	485	261	1.93	1.74
S-41	77.0	1.99	550	258	2.16	1.97
S-47	67.0	1.62	445	250	1.98	1.71
S-58	86.5	2.06	555	246	2.04	1.96
S-70	89.5	1.82	465	233	2.04	1.80
S-78	90.0	2.02	470	211	1.93	1.86
S-88	94.0	1.73	430	217	2.19	1.85

Table VI (Cont.)

Sex and No.	Birth Weight	Suck-ling Gain	Weight on Test	Age on Test (Days)	Gain on Test	Total per Day Gain
			Lot No. 4			
H-9	70.5	1.72	510	269	1.91	1.75
H-11	72.0	1.78	535	267	1.78	1.75
H-14	67.0	1.74	505	266	1.96	1.78
H-15	66.5	1.39	425	265	1.60	1.46
H-20	68.0	1.56	480	263	2.19	1.83
H-30	82.0	1.60	485	261	1.88	1.69
H-37	67.0	1.66	475	259	1.91	1.72
H-51	79.0	1.81	495	249	2.01	1.81
H-56	65.0	1.74	485	247	1.98	1.82
H-90	67.0	1.67	485	263	1.68	1.62
			Lot No. 5			
H-4	72.5	1.66	535	274	1.70	1.69
H-5	67.0	1.64	485	274	1.57	1.54
H-6	76.5	1.76	535	272	1.98	1.81
H-12	65.0	1.37	400	267	1.52	1.37
H-16	62.0	1.57	455	265	1.93	1.67
H-23	62.0	1.59	455	262	1.75	1.61
H-24	82.5	1.54	470	262	2.09	1.74
H-26	82.0	1.79	540	262	2.11	1.90
H-34	77.0	1.76	530	260	2.04	1.87
H-38	51.0	1.78	480	259	1.68	1.66

Table VII

Birth Weight, Suckling Gain, Weight-on-Test, Age-on-Test, Gain-on-Test, and Gain from Birth to End of Test, by Sex, Calf Number, Year, and Lot

Sex and No.	Birth Weight	Suckling Gain	Weight on Test	Age on Test (Days)	Gain on Test	Total per Day Gain
			-1951, 1952-			
			Lot No. 1			
S-2	64.0	1.78	605	318	2.04	1.79
S-8	72.0	1.91	580	288	2.00	1.83
S-9	81.0	1.89	630	293	2.33	2.01
S-10	78.5	2.19	665	288	1.83	1.98
S-18	79.5	1.74	580	283	2.25	1.91
S-20	66.0	1.81	555	281	2.00	1.82
S-25	71.5	1.97	600	279	1.88	1.89
S-38	63.0	2.09	600	273	1.88	1.94
S-44	75.5	2.15	595	268	2.33	2.06
S-68	70.0	2.26	600	252	2.21	2.14
			Lot No. 2			
S-3	62.0	1.81	620	312	2.08	1.87
S-11	87.0	2.16	635	288	2.50	2.08
S-12	90.5	1.75	610	287	2.50	2.01
S-16	84.0	2.08	660	286	2.38	2.12
S-26	88.0	2.05	605	279	2.08	1.92
S-32	80.0	1.89	550	275	1.92	1.77
S-36	78.0	1.92	585	273	1.67	1.80
S-47	73.0	2.05	605	267	1.79	1.93
S-48	79.5	2.13	605	266	2.13	2.02
S-52	83.0	1.92	560	263	2.08	1.89
			Lot No. 3			
S-23	73.0	1.79	540	280	2.92	2.04
S-27	76.0	1.72	550	279	2.50	1.94
S-56	61.0	1.58	435	260	1.75	1.54
S-65	76.0	1.49	450	254	2.08	1.67
S-66	63.0	1.87	515	252	1.96	1.85
S-67	77.5	1.79	510	252	2.58	1.99
S-75	68.0	1.57	420	247	1.79	1.54
S-79	75.0	2.06	500	234	1.67	1.75
S-81	81.0	1.64	455	225	1.88	1.74
S-89	68.0	1.99	420	193	2.17	1.95

Table VII (Cont.)

Sex and No.	Birth Weight	Suck-ling Gain	Weight on Test	Age on Test (Days)	Gain on Test	Total per Day Gain
			Lot No. 4			
H-1	65.5	2.04	675	317	1.42	1.78
H-14	63.0	1.72	485	286	1.75	1.56
H-13	77.0	1.63	535	287	1.88	1.68
H-15	77.0	1.77	575	286	1.79	1.78
H-17	64.0	1.76	550	283	1.83	1.75
H-21	83.0	1.97	600	281	1.79	1.82
H-28	87.0	1.94	600	279	1.83	1.84
H-33	75.0	1.94	570	275	1.50	1.71
H-35	71.0	1.91	560	275	1.71	1.76
H-58	63.0	2.00	545	257	1.71	1.82
			Lot No. 5			
H-4	74.0	1.89	585	295	1.46	1.65
H-5	72.0	1.80	570	293	1.92	1.76
H-6	81.0	2.07	680	290	1.83	2.00
H-7	73.0	1.89	580	290	1.58	1.70
H-19	78.0	1.67	535	283	1.54	1.59
H-22	73.0	1.81	575	280	1.33	1.65
H-24	74.5	1.92	580	280	1.75	1.79
H-37	59.5	1.80	510	273	1.79	1.69
H-57	74.5	2.20	610	257	2.46	2.20
H-50	79.5	1.68	500	264	1.83	1.74
			Lot No. 6			
H-46	52.0	1.09	360	268	1.75	1.33
H-54	51.0	1.68	465	260	1.75	1.64
H-59	59.0	1.69	465	257	1.67	1.61
H-71	74.0	1.27	390	250	2.17	1.56
H-72	69.0	1.61	435	248	2.13	1.69
H-74	58.0	1.73	450	247	2.13	1.76
H-80	85.0	1.89	440	225	2.25	1.81
H-84	86.0	1.95	425	215	2.08	1.76
H-85	75.0	1.91	415	213	2.04	1.76
H-86	89.0	1.85	385	194	1.92	1.67