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Rate and Efficiency of Gains in Beef Cattle

II. Some Factors Affecting Performance Testing

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This study was conducted in cooperation with Bureau of Animal Industry, United States Department of Agriculture, and State Experiment Stations under Western Regional Project 1 on Beef Cattle Improvement.

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Rate and Efficiency of Gains in Beef Cattle

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Introduction

Effective selection in beef cattle improvement depends upon the relative value of factors used in that selection. If selections are made on the basis of comparative feeding trials of prospective breeding animals, 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.

Individual beef animals differ in their ability to make gains and economically convert feed into gains. There is evidence the most rapid-gaining beef animals are also the most economical gainers. These are inherited characteristics. Controlled performance testing in sire selection is an effective method of measuring gain per day and economy of gain.

The performance of a beef animal, however, during a feeding period, is affected by factors which are often difficult, if not impossible, to control. Thus it is important to determine the effect of these factors on the test performance of the animal. Size and stage of development of a calf at birth, as measured by birth weight, may have a definite effect on the performance of that calf during a postweaning test period. Growth made by a calf from birth to weaning, as represented by suckling gain, may have considerable effect on that calf's ability to perform on test. Weight of a calf at weaning is the result of the age of the calf and the gains made prior to that time. Age, as well as weight, may have an effect on gains during the postweaning period. Thus, two factors—age at weaning and weight at weaning, as well as the interaction between these two—probably exert various influences on future performance.

The purpose of this study is to determine, where possible, the combined and single effects of (1) *birth weight;* (2) *suckling gains;* (3) *weight on test* and (4) *age on test* on (a) gain per day, (b) economy of gain during the test period, and (c) on gain per day *from birth to the end of the test.*

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Review of Literature

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 (Knapp and Black, 1941).

Recent studies indicate that, on a comparative basis, sires may be evaluated by feeding their progeny over a relatively short period of time. Knapp, *et al.* (1942) found a feeding period of 186 days to be sufficient to indicate differences between progeny groups, provided data were adjusted for differences in initial weight.

The importance of size and a period of constant gain were demonstrated by Bogart and Blackwell (1950). They state that rate of gain is a dependable index of efficiency if comparisons are made when animals are the same size.

Dahmen and Bogart, (1952) as well as Bogart and Blackwell, (1950) found significant differences between bull and heifer calves in feed efficiency. They found bulls not only gained faster when fed to gain a constant amount but were more efficient in feed utilization than were heifers.

A relatively close positive association between rate of gain and economy of gain has been demonstrated by many workers; Winters and McMahon (1933), Bogart and Blackwell (1950), Blackwell (1951), Roubicek, *et al* (1951), Kolhi, *et al,* (1951), Black and Knapp (1936).

This relationship between rate and economy of gains indicates, as suggested by Bogart and Blackwell, (1950) 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, as reported by Knapp and co-workers (1940), is primarily an expression of the size, weight, age, and physiological constitution of the dam. These same workers found 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. Sawyer, Li, and Bogart, (1949) by adjusting to a constant age and weight of dam, found that each difference of 1 pound at birth made a difference of 2.14 pounds in the weaning weight of the calf.

Many studies seem to agree on the importance of the dam in determining birth weight of the calf. Burris and Blunn (1952) state that the regression of birth weight on gestation length was 0.376 and highly significant.

In a study by Gregory, Blunn, and Baker (1950) 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,* (1951) state that calves heavier at birth were also heavier at weaning.

Effects of birth weight on various production factors have been studied by numerous research workers. Dahmen and Bogart (1952) 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 0.010. This indicates that for every 1-pound increase in birth weight there is a corresponding 0.010 of a 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 1-pound increase above the mean in birth weight represented a 2-pound saving in total digestible nutrients for each 100-pound gain in live weight. These workers also found a correlation coefficient of economy of gain with birth weight of 0.42. 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,* (1941) found birth weight was not highly correlated with any of the post weaning performance factors, although the correlation with daily gain was significant during the suckling period.

Evidence indicates that milk production is inherited. Sawyer, Li, Bogart (1949) found that large cows of the same age, 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. However, there is the possibility that increased milk production is related to cow size rather than being under genetic control.

Knapp and Black (1941) 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 (1936) found the correlation coefficient between *average daily gain from birth to weaning* and *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.

Gregory, *et al,* (1950) gave heritability estimates of 0.0 and .45 for suckling gain, and .26 and .52 for weaning weight. These estimates were made simultaneously on 2 herds at 2 different stations. Knapp and Nordskog (1946) found heritabilities for weaning weight of 12 per cent from intrasire correlations and 0.0 per cent from sire-progeny regressions.

Knapp and co-workers (1942) studied data from weights and gains of 770 Hereford calves. They found that age at weaning, sex, sire, dam, and age of dam had a significant influence on the weaning weights of these calves.

Gregory and co-workers (1950) state that cow repeatability for suckling gain and weaning weight of their calves was higher than for birth weight. Sawyer, Li, and Bogart (1949) 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.

Effect of sex on suckling gain and weaning weight is obscured to some extent by sex differences in birth weight. Gregory and co-workers (1950) failed to find a significant sex difference in suckling gains and weaning weights, stating both were in favor of the males. Sawyer, Bogart, and Oloufa (1948) found that heifer calves were heavier at weaning than steer calves, but the difference was not significant. Koger and Knox (1945) 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. Steers were significantly heavier than heifers each year throughout an 8-year period.

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 (1936) 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 (1941) found evidence of a lack of correlations between the rate of gain during the suckling period and the rate of gain after weaning. Knapp and co-workers (1941) found no correlation between weaning weight, or suckling gain, and daily gain in the feed lot. They found high negative correlations of both weaning weight and suckling gain with efficiency in the feed lot. This indicates the heavier the calf at weaning the more feed is required for maintenance, and thus efficiency is lower.

Dahmen and Bogart (1952) 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. Knapp, *et al,* (1941) and Blackwell (1951) found a significant negative correlation between score at weaning and efficiency during the test period.

Dahmen and Bogart (1952) found no significant correlation between weaning score and economy of gain during the feeding period. Knapp and Clark (1951) 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 this 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.

Black and Knapp (1936) showed a negative correlation between weaning weight and per cent 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,* (1951) 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 "comprest" and conventional-type Hereford steers, Stonaker, *et al* (1952) found that "comprest-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 (1951-52) found that a calf's gain tended to be proportional to the weight of the calf at the time the particular gain was made. Bogart and Blackwell (1950) state that if comparisons on rate of gain are made when the animals are the same size, data will be dependable as an index of efficiency.

Keith, *et al,* (1952) compared steer calves with yearling steers on several different concentrate-to-hay ratios, finding calves were more efficient than yearlings in every comparison.

Williams and Wood (1951-52) state that if a relatively young animal is to lay on finish, it is obvious that a greater share of 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 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 (1951-52) 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 (1951) says 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 (1952) 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.

Knapp and Clark (1947) 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 3 periods while the genetic influence increased as the feeding period progressed.

Gramlich (1926) found heifers produced the most desirable beef carcass at from 8 to 15 months of age. In a later study, Gramlich and Thalman (1930) noted 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, Gramlich and Thalman found results in favor of calves of both sexes in economy of production and popularity of carcass. Two-year-olds made greater gains during the first 100 days on feed; calves did best during the last 100 days. In contrast, yearling gains were uniform throughout the 175-day feeding period.

Methods and Materials

Data were compiled from a study of records for 3 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.

Total number of calves used in this study for the 3-year period included 19 registered bulls, 18 registered heifers, 9 grade steers fed individually, with 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 1st and the 18th of October.

Stall-Fed 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 eating but ran together in a large pen between feedings. Calves stall-fed during the winter of 1949-50 were held in an outside pen during the night. Those fed during the 2 winters following were confined to their stalls each night. Feeding was done 3 times daily at uniform intervals. Feed was carefully weighed and placed in an individual manger for each calf. Stalls were not provided with water. Calves spent about 5 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 1 month before they were weighed onto the test.

In 1949-50 the 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, 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.

Roughage 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. In each instance the alfalfa-grass hay was first cutting. Hay fed during the year 1949-50 was approximately 50 per cent grass. In leafiness, it was considered average or above for baled hay. For the year 1949-50 the straight alfalfa-grass hay tested 11.88 per cent natural protein. This was an average of 3 tests. During the 2 following years, roughage was a mixture of approximately one-half alfalfa, one-quarter grass, and one-quarter pea hay. This mixture averaged 9.17 per cent natural protein for the year 1950-51.

Grain for these calves during the first winter consisted of the Union feed mixture 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 (Table 1).

Economy of gain, as used in this individual feeding study, is 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 (1948).

Lot-Fed Calves

Grade steer and heifer calves were fed in groups of 10 in open lots each winter throughout the 3-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 (Table 2). The hay was chopped and fed in self-feeders. Grain was weighed at each feeding and fed in bunks. At the end of each 30-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 3 times each day and fresh running water was provided in all lots.

All calves were conditioned before beginning official test; that is, they were placed in lots at weaning and fed for approximately 1 month before being 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—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 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.

Table 1. Rations Fed Stall Calves During Winters: 1949-50, 1950-51, 1951-52

Feed source	1949-50	1950-51	1951-52
Supplement	*Union feed mixture* (*Per cent*) Oats 29.07 Wheat 29.07 Barley 29.07 Linseed meal 11.63 Molasses 1.06 Dried beet pulp	Wheat 2/3 Peas 1/3 Dried beet pulp Mineral mixture	Wheat 2/3 Peas 1/3 Dried beet pulp Mineral mixture Linseed meal
Hay	Chopped: Alfalfa-grass	Chopped: Alfalfa-grass-pea (Approx. 1/3 ea.)	Chopped: Alfalfa-grass-pea (Approx. 1/3 ea.)

Table 2. Rations Fed Lot Calves During Winters: 1949-50, 1950-51, 1951-52

	1949-1950		1950-1951		1951-1952	
	Hay	Supplement	Hay	Supplement	Hay	Supplement
Lot 1 steers	Chopped alfalfa, grass and pea.	Ground wheat, Dried beet pulp.	Chopped alfalfa, grass and peas.	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 peas.	Ground wheat $\frac{2}{3}$ Ground peas $\frac{1}{3}$ Dried beet pulp.	Chopped alfalfa, grass and pea.	Ground wheat $\frac{2}{3}$ Ground pea, $\frac{1}{3}$ Dried beet, pulp.
Lot 3 steers	Chopped alfalfa, grass and pea.	Ground wheat $\frac{2}{3}$ Ground peas $\frac{1}{3}$ Dried beet pulp.	Chopped alfalfa, grass and peas.	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 peas.	Ground wheat $\frac{2}{3}$ Ground peas $\frac{1}{3}$ Dried beet pulp.	Chopped alfalfa, grass and pea.	Ground wheat, $\frac{2}{3}$ Ground peas, $\frac{1}{3}$ Dried beet pulp
Lot 5 heifers	Chopped alfalfa, grass and pea.	Ground wheat, Linseed meal, Dried beet pulp.	Chopped alfalfa, grass and peas.	Ground wheat $\frac{2}{3}$ Ground peas $\frac{1}{3}$ Dried beet pulp, Mineral mixture,	Chopped alfalfa, grass and pea.	Ground wheat, $\frac{2}{3}$ Ground peas, $\frac{1}{3}$ 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.

Throughout each annual feeding period, the grain-hay ratio for both stall and lot calves averaged approximately 2 parts grain to 1 of hay.

Analyses measured the effects of 4 independent variables: *birth weight, suckling gain, weight on test,* and *age on test*—on 3 dependent variables—*gain on test, economy of gain,* and *daily gain from birth to end of test.* The following terms (with meanings) were used throughout the test period:

- ▶ *Birth weight*—weight taken within 24 hours after birth;
- ▶ *Suckling gain*—weaning weight minus birth weight divided by age in days; expressed as "pounds gain per day";
- ▶ *Weight on test*—actual weight in pounds of each calf beginning of test;
- ▶ *Age on test*—age in days of each calf beginning of test;
- ▶ *Gain on test*—pounds gained per day on test;
- ▶ *Economy of gain*—total digestible nutrients (TDN) consumed per 100 pounds gain in live weight;
- ▶ *Gain from birth to end of test*—weight end of test minus birth weight divided by age in days end of test; expressed as "pounds gain per day."

The statistical methods used in this study, as outlined by Snedecor (1946) were: analysis of variance, multiple regression, linear regressions, and correlations. The method described by Snedecor (1946) 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 3-year period.

Table 3. 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	Number of animals	Average birth weights	Average weaning weights	Average suckling gain	Average age on test	Average daily gain on test	TDN per 100 pounds gain
		Pounds	*Pounds*	*Pounds per day*	*Days*	*Pounds per day*	*Pounds*
1949-50							
Bull	6	65.0	555.0	1.92	297	2.28	465.9
Heifer	6	68.2	430.8	1.75	300	2.02	530.7
Steer	6	62.7	397.5	1.63	299	1.93	552.2
1950-51							
Bull	4	77.5	407.5	1.79	225	2.39	458.5
Heifer	8	72.7	408.7	1.71	238	1.75	577.5
Steer	3	74.8	463.3	1.87	247	1.89	587.0
1951-52							
Bull	9	73.1	431.1	1.93	250	2.57	405.6
Heifer	4	64.0	442.5	1.80	274	1.82	552.3
3-Year average							
Bull	19	71.5	433.7	1.89	260	2.44	435.8
Heifer	18	69.3	423.6	1.74	267	1.83	556.3
Steer*	9	66.8	419.4	1.71	282	1.92	554.9

* Two-year average on steers.

Multiple regressions were computed to determine regression coefficients on each of 3 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*) and on 4 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

In Table 3 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, Suckling Gain, Weight on Test, and *Age on Test 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 4, with tests of significance shown in Table 5.

Table 4. PARTIAL REGRESSION COEFFICIENTS AND CONFIDENCE INTERVALS OF *Gain on Test (Pounds/Day)*, ON *Birth Weight, Suckling Gain, Weight on Test,* AND *Age on Test*

Variate	Partial regression coefficients (b)	95 per cent confidence interval of b
Birth weight (pounds)	.012	.003 to .021
Suckling gain (pounds/day)	–.024	–.688 to .021
Weight on test (pounds)	.000559	–.000906 to .00202
Age on test (days)	.0039	.00021 to .00764

The calculated partial regression coefficients, b, (Table 4) of *gain on test* on the 4 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 2 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.

Table 5. ANALYSIS OF VARIANCE OF *Gain 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	

* Significant at 5% level.

The tests of significance of the completed multiple regression, given in Table 5, indicate 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 2 variables *suckling gain* and *weight on test.* Partial regression coefficients and confidence intervals are given in Table 6, with the tests of significance shown in Table 7.

Table 6. PARTIAL REGRESSION COEFFICIENTS AND CONFIDENCE INTERVALS OF *Gain on Test* (*Pounds/Day*), ON *Birth Weight,* AND *Age on Test*

Variate	Partial regression coefficients (b)	95 per cent confidence interval of b
Birth weight (pounds)	.013	.005 to .021
Age on test (days)	.00438	.00336 to .00541

The regression of .013 of *gain on test* on birth weight indicates that for each difference in birth weight of 1 pound, there would be a difference in *gain per day* on test of 0.013 of a pound with the heavier calves at birth gaining faster during the test period. Also the regression of .00438 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 .043 of a pound with the older calves on test gaining faster.

Table 7. ANALYSIS OF VARIANCE OF *Gain 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	

* Significant at 5% level.

The value $R^2 = 0.26$ (R = .511, Table 7) 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, Suckling Gain, Weight on Test, and Age on Test on Economy of Gain During Test (Total Digestible Nutrients Per 100 Pounds Gain)

The test of significance of the multiple correlation coefficients of Y_2 (*economy of gain on test*), on the 4 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 8.

Table 8. ANALYSIS OF VARIANCE OF *Economy of Gain 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 1-pound increase in gain per day, there is a corresponding saving of 232.8 pounds of TDN (total digestible nutrients) for each 100-pounds gain in live weight.

Effect of Various Factors

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 9, followed by the test of significance in Table 10.

Table 9. PARTIAL REGRESSION COEFFICIENTS AND CONFIDENCE INTERVALS OF *Gain From Birth to End of Test* (POUNDS/DAY), ON *Birth Weight, Suckling Gain, Weight on Test,* AND *Age on Test*

Variate	Partial regression coefficients (b)	95 per cent confidence interval of b
Birth weight (pounds)	.0043	.00017 to .0083
Suckling gain (pounds/day)	–.061	–.271 to .147
Weight on test (pounds)	.0020	.0013 to .0026
Age on test (days)	.00004	–.0016 to .0017

Table 10. ANALYSIS OF VARIANCE OF AVERAGE *Gain from Birth to End of Test*

($R = .825$)

Source of variation	d.f.	Mean square	F
Regression	4	.1457	18.17*
Additional variation due to:			
Birth weight	1	.03604	4.49*
Suckling gain	1	.0028	.35
Weight on test	1	.28005	34.91*
Age on test	1	.000021	.00
Residual	34	.00802	

* Significant at 5% level.

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 10, these 2 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 9). 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 of a pound gain per day in that period from *birth to end of the test.* These 2 variables, *birth weight* and *weight on test,* were studied with *suckling gain* and *age on test* constant.

Partial regression coefficients and their confidence intervals are shown in Table 11. The test of significance is presented in Table 12.

Table 11. PARTIAL REGRESSION COEFFICIENTS AND CONFIDENCE INTERVALS OF *Gain from Birth to End of Test* (POUNDS/DAY) ON *Birth Weight* AND *Weight on Test*

Variate	Partial regression coefficient (b)	95 per cent confidence interval of b
Birth weight (pounds)	.0042	.00055 to .00785
Weight on test (pounds)	.0018	.00139 to .00234

Table 12. ANALYSIS OF VARIANCE OF *Gain per Day* FROM *Birth to End of 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	

* Significant at 5% level.

A comparison of Tables 10 and 12 shows very little difference between the two multiple correlation coefficients. In Table 10, $R = .825$, thus $R^2 = .68$. This means that 68 per cent of the Variance in *gain from birth to the end of test* is accounted for by the 4 variables: *birth weight, suckling gain, weight on test,* and *age on test.* In Table 12, $R = .823$ and $R^2 = .67$. Thus the 2 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 3-year period.

Multiple regressions were computed to determine the regression of each of the 2 dependent variables: Y_1 (*gain per day on test*) and Y_3 (*gain per day from birth to end of test*), on each of the 4 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 Group-Fed Calves

In Table 13, 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.

Table 13. AVERAGE *Birth Weights, Weaning Weights, Suckling Gains,* AND *Daily Gain on Test* OF GRADE HEREFORD CALVES (GROUP-FED) BY SEX AND YEAR

Year and sex	Number of animals	Average birth weights	Average weaning weights	Average suckling gain	Average age on test	Average daily gain on test
		Pounds	*Pounds*	*Pounds per day*	*Days*	*Pounds per day*
1949-50						
Steers	40	71.0	380.9	1.53	264	2.14
Heifers	20	70.6	388.0	1.50	275	1.96
1950-51						
Steers	30	77.5	449.9	1.76	252	2.00
Heifers	20	70.7	424.1	1.64	263	1.84
1951-52						
Steers	30	74.8	466.7	1.90	270	2.11
Heifers	20	72.1	438.7	1.80	282	1.82
3-year average						
Steers	100	74.1	427.3	1.71	262	2.09
Heifers	60	71.1	420.4	1.66	273	1.86

Effect of Birth Weight, Suckling Gain, Weight on Test and Age on Test 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 feeding period.* Each of these independent variables was found to have a significant effect on gain per day. These results are presented in Tables 14 and 15.

Table 14. PARTIAL REGRESSION COEFFICIENTS AND CONFIDENCE INTERVALS OF *Gain on Test* (POUNDS/DAY) ON *Birth Weight, Suckling Gain, Weight on Test,* AND *Age on Test*

Variate	Partial regression coefficients (b)	95 per cent confidence interval of b
Birth weight (pounds)	.041	.025 to .057
Suckling gain (pounds/day)	3.79	2.03 to 5.55
Weight on test (pounds)	-.014	-.007 to -.022
Age on test (days)	.036	.019 to .053

Table 15. ANALYSIS OF VARIANCE OF *Gain on Test* (R = .537)

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	

* Significant at 5% level.

The high partial regression coefficient of *gain on test* on *suckling gain,* b = 3.79, as shown in Table 14, is largely offset by the negative effect of *weight on test* on *gain on test,* b = 0.014. These indicate that each 0.1 of a 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 of a pound less gain per day on test.

An R^2 of .29 (R = 0.537, Table 15) indicates that 29 per cent of the total variance in *gain on test* is accounted for by the 4 independent variables, *birth weight, suckling gain, weight on test,* and *age on test.*

Because of the significant effects of the 3 variables, *suckling gain, weight on test,* and *age on test,* on *gain on test* (Table 15), correlation coefficients were computed to determine the relationships between these 3 factors. These interactions are presented in Table 16.

As shown in Table 16, 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 with 159 degrees of freedom.

Table 16. CORRELATION COEFFICIENTS

Factors	r
Suckling gain and weight on test	0.590
Suckling gain and age on test	-0.405
Weight on test and age on test	0.428

The Effect of Birth Weight, Suckling Gain, Weight on Test and Age on Test, on Gain from Birth to End of Test

The effects of *birth weight, suckling gain, weight on test,* and *age on test,* on *gain per day from birth to end of test,* as determined by multiple regression, are presented in Tables 17 and 18.

Table 17. PARTIAL REGRESSION COEFFICIENTS AND CONFIDENCE INTERVALS OF *Gain from Birth to End of Test (Pounds/Day)* ON *Birth Weight, Suckling Gain, Weight on Test,* AND *Age on Test*

Variate	Partial regression coefficients (b)	95 per cent confidence interval of b
Birth weight (pounds)	.008	.002 to .014
Suckling gain (pounds/day)	.522	.431 to .613
Weight on test (pounds)	.0005	-.00221 to .00313
Age on test (days)	.0038	-.0025 to .0102

In Table 18, 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 17), indicates that for

Table 18. ANALYSIS OF VARIANCE OF *Gain from Birth to End of 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	

* Significant at 5% level

a 10-pound increase 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 of a 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 2 independent variables, *birth weight* and *suckling gain.* These results are shown in Tables 19 and 20.

Table 19. PARTIAL REGRESSION COEFFICIENTS AND CONFIDENCE INTERVALS OF *Gain from Birth to End of Test* (POUNDS/DAY), ON *Birth Weight* AND *Suckling Gain*

Variate	Partial regression coefficient (b)	95 per cent confidence interval of b
Birth weight (pounds)	.0059	.0039 to .0079
Suckling gain (pounds/day)	.74	.08 to 1.4

Table 20. ANALYSIS OF VARIANCE OF *Gain per Day from Birth to End of Test*

(R = .720)

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	

* Significant at 5% level

The R^2 of .52 ($R = 0.720$, Table 20) 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, any prediction of growth during 1 period of life would be complicated by conflicting environmental influences during previous periods.

Analysis of data from the group feeding trials indicates that for every 0.1 of a pound increase in suckling gain per day there is a corresponding increase in *gain per day on test* of approximately 0.4 of a pound. On the other hand, it was found that weight had a significant negative effect on *gain on test.* Thus, for every 40 pounds of increase in weight at the beginning of the test, there is a decrease of 0.4 of a pound 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 prefeeding 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, keeping in mind the age differences of these calves.

Stall-Feeding

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 2 factors accounted for 26 per cent 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 and Bogart (1952) and Kolhi, *et al* (1951). 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; cf. Gregory, *et al* (1950); Knapp, *et al* (1940). 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 overemphasized. Sawyer, Li, and Bogart (1948) 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 2 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 6-month-old calf weighing 400 pounds would have less capacity for gains in the feed lot than a 6-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 holding 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 4 to 6 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 4 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 0.10 of a 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 (1936), Kolhi, *et al,* (1951), Blackwell (1951), 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 per cent 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 0.043 of a 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 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 0.010 of a 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 effect 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 effect 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.

Lot-Feeding

Analysis of data from the group-feeding trials indicates *gain on test* was significantly affected by all 4 variables studied: *birth weight, suckling gain, weight on test, and age on test.* Approximately 29 per cent (R = .537, Table 15) of the total variance in *gain on test* was accounted for by these 4 factors.

Birth weight affects *gain on test* to the extent that for every 1-pound increase in weight at birth there is an increase of 0.041 of a pound 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 (1936) found a negative correlation between *suckling gain* and *gain on test.* Others have found no association between these 2 factors (Knapp and Black, 1941; and Knapp *et al,* 1941). 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 4 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 of a pound increase 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 0.040 of a pound 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 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 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 per cent 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 of a pound for this period resulted in a corresponding increase gain of 0.05 of a pound 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. 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 4 independent variables: *birth weight, suckling gain, weight on test,* and *age on test,* on each of the 3 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 in average daily gain on test from 2.28 in 1949-50 to 2.57 in 1951-52. This is a difference of 0.29 of a pound per day during the 3-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 (Table 3).

2. Birth weight had a significant effect on *gain on test* and on *gain from birth to the end of test.* Calves 10 pounds heavier at birth gained 0.13 of a pound per day more on test, and 0.041 of a pound 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 at the beginning of the test, there was an added 0.039 of a 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 at the beginning of the test period gained 0.020 of a pound 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 of a 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 at birth resulted in 0.41 of a pound added gain per day on test and 0.083 of a pound 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 of a pound in suckling gain per day resulted in an increase *gain per day on test* of 0.38 of a pound and an increase in *gain per day from birth to the end of test* of 0.074 of a pound. 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 at the beginning of the test gained 0.14 of a pound per day less on test.

4. *Age on test* had a significant positive effect on *gain on test.* Calves 10 days older at the beginning of the test gained 0.36 of a pound 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 could be used to standardize test procedures.

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