Some Factors Affecting Rate and Economy of Gains in Beef Cattle

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The authors are grateful to Martin Burris for assistance in gathering these data, to Dr. A. C. Warnick for his supervision in the herd management and record keeping, and to Professor A. W. Oliver, as well as the men mentioned above, for help in establishing an average score for the calves. Many helpful suggestions in the preparation of this bulletin were made by Dr. Hugo Krueger of the Department of Zoology.
A BEEF ANIMAL might well be compared to a factory. Assuredly, this animal is a living factory very complex and intricately designed and developed into patterns of living cells. One great advantage beef animals have over a factory is that they themselves under favorable conditions are able to reproduce their kind. A factory is not only evaluated by adequate standards of equipment and facilities, but to a greater extent by the rate, economy, and quality of the items produced. Perhaps we may well think in synonymous terms when evaluating beef animals by rate and economy of gains.

With relatively little knowledge of the basic principles involved from the genetic standpoint breeders have made much progress in raising the inherent level of production in beef cattle. Individuality was brought up to a standard and that standard was raised and has continued to improve until we now have some cattle that, perhaps, approach our ideal from the standpoint of type.

There is a need to maintain this ideal type and at the same time look forward to additional means of improvement. Thus, the performance of beef cattle in rate and efficiency of production must be developed along with the improvements made in type and conformation.

Meat yields are the physiological results of energy conversion. A great number of studies have shown that these processes of energy conversion proceed at greatly differing levels of efficiency. It is fortunate, however, that a portion of these variations are under genetic influences, thus justifying selection for economy and rate of gain in a constructive program. As the mode of inheritance is known to be very complex, it would seem that the exploitation of these genetic differences might be quite difficult. To further complicate matters, these modes of inheritance are obscured by a great number of fluctuating environmental conditions. Many of these conditions may cause changes during the entire life-span of the animal.

It is difficult to predict the relative breeding values of animals for efficiency in meat production. Animal calorimetry or slaughter tests, very carefully carried out, are the only means of an accurate measurement of that characteristic. For the selection of breeding stock neither method is widely practiced.
When looking for a means of predicting genetic constitution of beef cattle for efficiency, the desired information must be determined without sacrificing the animal. This may be accomplished through obtaining rate of gain easily and accurately computable over a designated period. It would appear logical that this information should be acquired during the early part of the animal's life, possibly from the date of birth.

With these facts in mind and remembering that a beef animal is a factory, let us consider, therefore, a means of measuring the amount of edible meat obtained from a beef animal at a given age. This may be accomplished by measuring efficiency of production in terms of feed consumed, ideally in terms of protein and calories produced compared with protein and calories consumed.

The present study is concerned with some of the factors affecting rate and economy of gains and the conditions under which cattle selected for high rate of gain in the early growth period also will be those superior in ability to convert feed into beef.

Review of Literature

Growth rate and the economy of this function were considered as being very complex by Brody (1945), and to involve innumerable genetic, physiological, and environmental factors.

Birth weight

The birth weight of an animal is easy to measure and has the advantage that it does not change appreciably during the first few days of life. If accurate rates of growth in pounds per day from birth are to be obtained it is essential that birth weight be taken.

Dawson, Phillips, and Black (1947) reported a heritability estimate of 0.11 whereas, Knapp and Nordskog (1946) reported an estimate of 0.23 for birth weight.

A number of workers have shown correlations (within breeds) between birth weight and weaning weight of calves. The heritability estimates by Gregory, Blunn, and Baker (1950) obtained from paternal half-sib correlations were .45 and 1.00 for birth weight; .26 and .52 for weaning weight at the two stations used in their study. They also reported that calves which were heavier at birth tended to maintain this advantage and thus be heavier at weaning.

The Arizona Agricultural Experiment Station (1937) has observed a correlation of $0.57 \pm 0.031$ between birth weight and average daily gain of calves from birth to weaning.
However, Knapp, Lambert, and Black (1940) have shown that birth weight is of limited value as an index of a calf’s growth potentialities. They showed that a calf’s prenatal growth was primarily an expression of the dam, and therefore that little of the variation in prenatal growth can be attributed to genetic differences between calves.

Dawson, Phillips, and Black (1947) stated that the largest calves at birth and those with the highest prenatal growth rates tended to reach 500 pounds (weaning weight) and 900 pounds (slaughter weight) at the youngest age. There was little relationship between birth weight or prenatal growth and the length of the feeding period from weaning to slaughter. Correlation coefficients between birth weight or prenatal growth rate and economy of gain during the feeding period showed there was practically no association. They indicated that birth weight should be given some consideration in selection, in view of the fact that it had an influence on the time required for the animal to attain a slaughter weight of 900 pounds. Also, these authors showed that birth weight is a better indicator of postweaning growth than is preweaning growth.

In sheep, Phillips and Dawson (1940) found that the differences due to birth weight were still present at three months of age but tended to disappear by the time the sheep were a year old. Dawson, Phillips, and Black (1947) state that a similar situation might be found in cattle if they were carried to an older age.

**Suckling period**

After prenatal growth, the next period of development (the suckling period) is, at first, one of adjustment to a new environment following parturition. Milk makes up the larger portion of the diet, though in the latter part of the suckling period other feeds gradually replace it. Knapp and Black (1941) stated that approximately 80 per cent of the mature skeletal size of cattle had been attained by the end of the suckling period, whereas only about 40 per cent of the mature weight had been reached.

Knapp and Black (1941) showed that in beef calves 41 per cent of the variation in rate of gain during the suckling period was accounted for by differences in the amount of milk, hay, and grain consumed, and particularly in the amount of milk. Season of birth had no effect and there was no significant difference between sires. Incidentally they noticed that the calves kept for bulls had consumed more milk than those castrated (at 140 days) and they suggested that males were being selected for breeding on the basis of the milkiness of their dams.
Gifford (1949) presented figures which show a high correlation between milk yield of Hereford dams and rate of growth of their calves during the first four months. He suggested, however, that the rate of growth is controlled by the capacity of the calf to consume milk rather than being restricted by the milk yield of the dam.

Both birth weight and weaning weight are influenced by the size of the dam and the sex of the calf as reported by Knapp et al, (1942). Whether either birth or weaning weight give any indication of slaughter value depends entirely on the feeding of the calf up to the time of slaughter.

Knox and Koger (1945) and Knapp et al, (1942) reported that the heaviest calves at weaning are those from cows at the age when maximum mature size is reached. Sawyer, Li, and Bogart (1949) found that the largest cows of the same age wean the heaviest calves. Sawyer, Bogart, and Oloufa (1948) stated that 2-year-old cows weaned calves that were considerably lighter than those from mature cows. In these instances, milk-producing capacity is considered the fundamental influence affecting the weaning weight of the calves. This coincides with Knapp and Black (1941) in their earlier statement indicating that the amount of milk consumed was the greatest factor influencing the rate of gain in calves during the suckling period.

Gregory, Blunn, and Baker (1950) found that sires did not significantly influence weaning weight or gain from birth to weaning. Their findings may be due to the small number of sires used and the small size of the sire progeny groups used to evaluate the sires.

Other experiments by Clark et al, (1943) and by Knapp et al, (1941) have revealed significant differences between sires in the weaning weights of their steer progeny. These authors also reported that heritability estimates for birth weight are lower than for weaning weight.

Gregory, Blunn, and Baker (1950) found considerable differences in their heritability estimates for gain from birth to weaning when working with data from two different stations.

Dickerson's analysis (1947) strongly indicated that there is a tendency for poor suckling ability in swine to be caused by the same genes responsible for rapid fat deposition and low feed requirements. Davis and Willett (1938) found no apparent correlation of rapidity of growth from birth to 2 years of age with milk and fat production during the first lactation or for lifetime averages in dairy cattle.

Donald (1939) working with swine stated that the lightest pigs at, or before, weaning are by no means always the "poorest doers" in later life. It was found that milk production of the sow and other
influences attributable to the sow had a greater effect on the gains of the animals during the suckling period than did any other sources of variation. He found that there was no correlation between weaning weight and postweaning growth in swine when growth rate was calculated at a comparable stage. His suggestion was that the absence of correlation may be due partly to growth limitations of some of the pigs during the suckling period and partly to different genes controlling growth during the suckling and postsuckling periods.

Black and Knapp (1936) showed that there was no correlation between efficiency of gain before and after weaning in their study of record of performance steers. They also noted a low negative correlation in rate of gain before and after weaning. They suggested that the lack of correlation with gains during the suckling period with both efficiency and rate of gain during the feeding period may have been due to inhibition in growth of steers with inherently high efficiency during the suckling period because of limited nutrients; the calf's true inherited efficiency was displayed after weaning when feed was not limited.

Size and age

There is no question but what size and age, because of their physiological effects upon the production of body substance, are of great importance in cattle feeding.

As stated by Brody (1945), the increase in size of a given animal associated with increasing age would be expected to increase the energy cost of its maintenance and reduce correspondingly the total efficiency of growth unless this increase in maintenance is compensated by an increase in growth rate. In the case of different species, such as when cattle and chickens are compared, there is such compensation and, thus, nearly the same efficiency of growth at equivalent physiologic ages. The increase in size associated with increasing age in the same animal, however, is not compensated for by an increase in growth rate. There is decrease in efficiency of growth with increasing age or weight.

Brody (1945) states that with increasing age gross energy efficiency of meat production declines rapidly. Hankins and Titus (1939), by use of graphs illustrate the relation between feed efficiency and weight. Efficiency of feed utilization was a straight-line function of live weight; efficiency decreases in direct proportion to the increase in live weight. Feed efficiency plotted against age gave a curve showing a downward trend in efficiency with increasing age. This is verified by Lambert et al (1936) in a statement that the ability of an animal to convert feed into gain in live weight is de-
dependent upon at least two factors, initial efficiency and rate of decline in efficiency. Thus, efficiency is a function of live weight.

Warnick, Bogart, and Gysbers (1951) working with weaner rabbits observed that larger gains were made during the first half of the experiment than during the last half.

Snell (1923) found age to be one of the most important factors controlling gain per unit of body weight, but this had little effect on a range steer’s ability to digest feed. The younger steers tended to use their feed for body growth, while the older steers had a tendency to fatten; thus, the rate of gain per 100 pounds live weight declined with age. Younger steers required less feed per 100 pounds gain and consumed more feed per unit of weight.

Gramlich (1925) found that weaner calves, both heifers and steers, fed for a period of 250 days, then an additional 50-day period, made different gains during the two periods. Both heifers and steers showed a marked decrease in average daily gain during the latter period. Gramlich and Thalman (1930) observed that 2-year-old cattle made larger daily gains during the first 100 days than during the latter part of the feeding period. When comparing 2-year-old cattle, yearlings, and calves they found the following: 2-year-old cattle gained more rapidly and required more feed per 100 pounds gain than did the yearling cattle, and the yearlings in turn made greater gains with a higher feed requirement per 100 pounds of gain than did the calves. It was found by Jones, Lush and Jones (1923) that younger steers made cheaper gains. Older steers gained more per animal but less per unit of live weight. The older steers were fatter at the end of a specified feeding period.

Blackwell (1951) obtained weights at 325 days of age from original data on beef calves. The mean weight of bulls at this age was approximately 732 pounds while the heifers averaged approximately 565 pounds. A significant difference in daily gains was found between bulls and heifers, but there was no significant difference in their feed efficiency at this age. He stated that the size difference between bull and heifer calves at this age accounts for a part of the similarity in efficiency as well as for a part of the difference in rate of gain. As live weight increased during the growth period, feed efficiency declined and rate of gain increased. Therefore, he implies that it cannot be said that either a constant rate of gain or a constant feed efficiency is an attribute of growing beef calves.

**Weaning score**

Type and conformation in beef cattle are a combination of body height, width and length interrelated; whereas, score is a subjective
value obtained when comparing the above-named factors to the ideal animal.

Knapp et al, (1941) working with feeder calves found that the appearance of these calves was not reliable as an indication of efficiency or capacity for growth.

Knapp, Black, and Phillips (1939) made a study of the accuracy of scoring certain beef cattle characteristics. They found that scoring technique is subject to considerable error and is of doubtful value when animals are quite similar. Lush (1931) brings out the fact that trained men who spent much time in studying such animals were unable to foresee large variations in rate of gain and final value of experimental animals. He stated that perhaps the major factors determining feed-lot performance and end value are not closely associated with the visible differences in the animals. Lush (1932) working with correlations between measurements of feeder steers and subsequent gains found these correlations to be low. It was not possible to predict future performance of individual steers accurately because form and function were not sufficiently related.

Roubicek, Hilston, and Wheeler (1951) reported in their progeny studies with Shorthorn and Hereford cattle that the animal measurements and scores prior to the time they started on feed were not indicative of their ability to gain rapidly or efficiently. The judge’s impression of an animal at the time it went on feed was not indicative of the yield of the preferred cuts when the animal was slaughtered following the fattening period.

Blackwell (1951) stated that conformation score at 500 pounds live weight was negatively correlated with both gains and efficiency during the feeding period.

Sex

Animals possessing similar breeding and being exposed to the same environment have shown marked sex differences in their growth and efficiency.

Bogart et al, (1939) found that ovariectomized female rats grow more rapidly early in life than virgins or breeding animals, but the growth period is no longer than for the virgins. Further research by Bogart, Lasley, and Mayer (1944) showed that estrone injected into prepubertal or postpubertal female rats retards the growth of the normal and the ovariectomized animals of both groups. In contrast to the estrone effects, progesterone accelerated the rate of growth. Slonaker (1930) found normal rats of each sex were more active, consumed more food and had less energy available for growth and metabolism than gonadectomized animals. Growth of the different
groups was correlated with the amount of available energy. Mendel and Cannon (1927) report that in the growth of the albino rat, except for a short early period, males grow at a faster rate than do females and reach a larger adult size than the latter; both sexes being held under similar environment. Kellermann (1939) found that male rats made more efficient use of their food than females.

Palmer et al, (1946) working with two inbred strains of rats—one selected for high and the other for low efficiency of food utilization—were able to demonstrate marked strain differences after a few generations of selection. Within strains, the males were more efficient than the females; however, the carcasses of female rats contained a higher percentage of ether extract and a lower percentage of protein than did the carcasses from the males.

In an experiment with weaner rabbits Warnick, Bogart, and Gysbers (1951) found that females gained faster than males, and the former were significantly more efficient in feed utilization than were the latter. The increased gain in females appeared to be independent of a corresponding increase in feed intake, which may suggest smaller maintenance requirements or increased feed utilization compared to males.

In growing chickens, Hess and Jull (1948) found that males were a bit more efficient than females in feed utilization; and differences between sexes increased progressively in favor of the males. This was interpreted as indicating either a more rapid decrease in the efficiency of the female or a lower maintenance requirement for the male. The faster growing individuals were more efficient feed utilisers than were the individuals that grew slower.

Comstock, Winters, and Cummings (1944) making progeny comparisons in swine, found in certain lines that barrows grew faster than gilts; thus, the consideration of sex as a factor in these comparisons is necessary.

Dawson, Phillips, and Black (1947) reported that birth weights of male calves averaged 4.2 pounds more than females. Gregory, Blunn, and Baker (1950) found that male calves were 5 pounds heavier than female calves in one set of data and 4 pounds heavier in another.

Early workers (Hammond, 1920 and Gramlich, 1925) reported that steers were heavier than heifers at approximately 2 years of age. Knapp et al, (1942), Lush et al, (1930), Koger and Knox (1945), and Schutte (1935) all reported that steer calves were heavier than heifer calves at weaning. However, it was found by Sawyer, Bogart, and Oلونfa (1948) that the sex of the calf had no effect on weight. Furthermore, the difference was slightly in favor of heifer calves,
but analyses of variance showed that this difference lacked significance. Since these range calves were much smaller at weaning than the ones reported by Koger and Knox (1945) it appeared that the calves did not show a sex difference because other factors had such a large effect on weaning weights that the sex effect never became operative.

Gramlich (1925) stated that heifer calves will not gain as rapidly nor will they gain as efficiently as steer calves, although they show flesh at an earlier date and will yield very favorably when slaughtered.

Trowbridge and Moffett (1932) reported that with calves of similar age, size, and fleshing and fed the same way for 6 months, the steer calves gained more rapidly than the heifers. The heifers required more feed than the steers to produce an equal total weight.

Blackwell (1951) working with weaner calves fed to a given weight, found that bulls gained faster and were more efficient than steers or heifers; the latter made the slowest gain and had the lowest efficiency. Also, at a constant weight of 650 pounds, bulls gained faster and were more efficient than heifers. The heifers, however, were much older than bulls at this weight.

Materials and Methods

The data used in this study are from 74 beef calves individually fed at the Oregon Agricultural Experiment Station on the Western Regional Beef Cattle Improvement Project. The calves were purebred Hereford and Angus bulls and heifers, and grade Hereford heifers and steers. One group of 25 purebred Hereford and Angus bull and heifer calves were born in the spring and summer of 1949 and were fed the following winter and spring. The rest of the calves, one group of purebred Hereford and Angus bulls and heifers and another group of grade Hereford steers and heifers, were all born during the spring and summer of 1950 and were fed the following winter and spring.

Some of the calves from the 1949 group that went on feed early in the winter were confined in small individual stalls while they were eating and during the night, but were allowed to run together in a large pen during the day. Later, new barn facilities became available so that the calves could be kept in groups of six and tied at mangers at feeding time. Feeding was done twice daily at uniform times and the calves remained tied for approximately seven hours each day. The mangers were so constructed that each calf had access only to the feed weighed out to it. Water was supplied at all times in
automatic drinking cups installed along the manger. Wood shavings were used for bedding rather than straw to insure that nothing would be eaten other than the ration. The purebred bulls and heifers were fed separately, as were the grade Hereford steer and heifer calves.

Table 1. The Concentrate Mixture Used in the Experimental Feeding During Years 1949 and 1950.

<table>
<thead>
<tr>
<th>Feed stuff</th>
<th>Percentage of mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolled barley</td>
<td>60.0</td>
</tr>
<tr>
<td>Ground oats</td>
<td>20.0</td>
</tr>
<tr>
<td>Dried beet pulp</td>
<td>10.0</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>5.0</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>2.5</td>
</tr>
<tr>
<td>Linseed meal</td>
<td>1.0</td>
</tr>
<tr>
<td>Dried skim milk</td>
<td>0.5</td>
</tr>
<tr>
<td>Bone meal</td>
<td>0.5</td>
</tr>
<tr>
<td>Salt</td>
<td>0.45</td>
</tr>
<tr>
<td>Irradiated yeast (9,000 units Vitamin D per gram)</td>
<td>0.05</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

The feeding during both years, 1949 and 1950, was carried out in the same manner. The roughage fed was high quality alfalfa hay, chopped to facilitate weighing and to avoid waste. The concentrate mixture (see Table 1) consisted largely of rolled barley, ground oats, and dried beet pulp with several sources of protein included. The plan was to feed the concentrate mixture and hay in ratio of 1 concentrate to 3 hay during the period from 500 to 600; from 600 to 700 pounds it was 1 concentrate to 2 hay; and at weights above 700 pounds equal quantities of concentrate and hay were fed. The amount of concentrate fed was governed by the quantity of hay consumed. Hay was fed slightly in excess of consumption in order for calves to show the ability to utilize large quantities of roughage. Small quantities of hay were refused making the over-all concentrate-to-hay ratio somewhat less than 1 to 2.

Live weights were taken between 10 and 11 a.m. at 14-day intervals. The animals were not taken off water and feed prior to weighing. Hay that had been refused was weighed and the amount subtracted from the total quantity fed during the 14-day period. The data were summarized on individual record forms for each period and included initial weight and total grain and hay consumed.
All the calves were scored at weights of 500 and again at 800 pounds. Scoring was done by three or more animal husbandmen and the average of these scores for each calf was considered as the official score.

Feed efficiency or economy of gain as used in this study is pounds of total digestible nutrients required per 100 pounds gain in body weight. Digestible nutrients were computed from Morrison’s table of average composition of feeding stuffs (Morrison 1948).

The statistical methods used on the 1949 and 1950 groups of purebred Angus and Hereford bulls and heifers were analysis of variance, multiple classification, two x two, with unequal subclasses and multiple regression as outlined by Snedecor (1946).

The 5 per cent significance level is used throughout in all statistical analyses.

Results

The effect of sex on rate and economy of gains

One phase of the present study was to determine the effect of sex on rate and economy of gain in the feed lot. The data on purebred Hereford bull and heifer calves covering 2 years were analyzed using analysis of variance, multiple classification, with unequal subclasses.

Within the Herefords there was found a significant sex difference in rate of gain in the feed lot. The bulls gained significantly more per day than the heifers; thus, bulls gain faster than heifers. The average daily gain (Table 2) during the test was 2.3 pounds

Table 2. Average Daily Gain (500 to 800 Pounds) and Economy of Gains—Pounds Total Digestible Nutrients (TDN) Required per 100 Pounds Gain—of Purebred Hereford Calves by Year, Breed, and Sex.

<table>
<thead>
<tr>
<th>Sex</th>
<th>1949 Average daily gain</th>
<th>1949 TDN per 100 pounds gain</th>
<th>1950 Average daily gain</th>
<th>1950 TDN per 100 pounds gain</th>
<th>2-year average Average daily gain</th>
<th>2-year average TDN per 100 pounds gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bull</td>
<td>2.4 Pounds</td>
<td>372 Pounds</td>
<td>2.2 Pounds</td>
<td>410 Pounds</td>
<td>2.3 Pounds</td>
<td>391 Pounds</td>
</tr>
<tr>
<td>Heifer</td>
<td>2.1 Pounds</td>
<td>471 Pounds</td>
<td>1.9 Pounds</td>
<td>495 Pounds</td>
<td>2.0 Pounds</td>
<td>483 Pounds</td>
</tr>
</tbody>
</table>
for bulls and 2.0 pounds for heifers. There was also a significant year difference (Table 3) in rate of gain while on test.

Table 3. SUMMARY OF ANALYSIS OF VARIANCE FOR RATE OF GAIN IN HEREFORD BULL AND HEIFER CALVES.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>d.f.</th>
<th>Mean square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>0.580</td>
<td>12.01*</td>
</tr>
<tr>
<td>Year</td>
<td>1</td>
<td>0.345</td>
<td>7.14*</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>0.009</td>
<td>0.02</td>
</tr>
<tr>
<td>Error</td>
<td>25</td>
<td>0.048</td>
<td></td>
</tr>
</tbody>
</table>

* Significant.

A significant sex difference was also found in economy of gain while on test. The heifers required significantly more TDN (total digestible nutrients) to gain 100 pounds live weight than the bulls. Bulls required an average of 391 pounds TDN to gain 100 pounds in body weight; whereas, heifers required an average of 483 pounds TDN to gain 100 pounds in body weight during the test period (Table 2). Therefore, bulls are more efficient, requiring less TDN per 100 pounds gain than heifers in the feed lot. It was found, however, (Table 4) that year had no statistically significant effect on feed efficiency during the test period.

Table 4. SUMMARY OF ANALYSIS OF VARIANCE FOR ECONOMY OF GAIN IN HEREFORD BULL AND HEIFER CALVES.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>d.f.</th>
<th>Mean square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>56,418.8</td>
<td>32.86*</td>
</tr>
<tr>
<td>Year</td>
<td>1</td>
<td>6,359.9</td>
<td>3.70</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>292.3</td>
<td>0.17</td>
</tr>
<tr>
<td>Error</td>
<td>25</td>
<td>1,716.8</td>
<td></td>
</tr>
</tbody>
</table>

* Significant.

Effect of birth weight, suckling rate of gain, age put on test, and weaning score on rate and economy of gain

Two multiple regressions were computed using data from two years of test feeding a total of 50 purebred Angus and Hereford bull and heifer calves.

One multiple regression was set up to test the effects of $X_1$ (birth weight), $X_2$ (suckling rate of gain), $X_3$ (age put on test), and $X_4$ (weaning score) on rate of gain. The regression equation was

\[ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \epsilon \]

Where $Y$ is the rate of gain, $X_1$ is birth weight, $X_2$ is suckling rate of gain, $X_3$ is age put on test, and $\epsilon$ is the error term.
(weaning score) on $Y_1$ (rate of gain during the test period). The results of tests of significance are presented in Tables 5 and 6.

Table 5. Test of Significance of the Multiple Correlation Coefficients of Rate of Gain During Test on the Four Other Variates, Birth Weight, Suckling Gains, Age Put on Test, and Weaning Score.

\[ R = 0.641031 \]

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>d.f.</th>
<th>Mean square</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>4</td>
<td>0.171</td>
<td>6.63*</td>
</tr>
<tr>
<td>Residual</td>
<td>38</td>
<td>0.026</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant.

Table 6. Test of Significance of the Multiple Correlation Coefficients of Rate of Gain During Test on the Two Variates, Birth Weight, and Age Put on Test.

\[ R = 0.6311 \]

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>d.f.</th>
<th>Mean square</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>2</td>
<td>0.330</td>
<td>13.24*</td>
</tr>
<tr>
<td>Residual</td>
<td>40</td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant.

The other multiple regression was set up using the same variates $X_1$, $X_2$, $X_3$, and $X_4$ on $Y_2$ (economy of gains during the test). Economy of gain was computed as pounds TDN required to gain 100 pounds live weight during the test period. The results of tests of significance are presented in Tables 7 and 8.

Table 7. Test of Significance of the Multiple Correlation Coefficients of Economy of Gain During Test on the Four Other Variates, Birth Weight, Suckling Gains, Age Put on Test, and Weaning Score.

\[ R = 0.551557 \]

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>d.f.</th>
<th>Mean square</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>4</td>
<td>4,526.65</td>
<td>4.15*</td>
</tr>
<tr>
<td>Residual</td>
<td>38</td>
<td>1,089.81</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant.
Table 8. Test of Significance of the Multiple Correlation
Coefficients of Economy of Gain During Test on the
One Variate, Birth Weight.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>d.f.</th>
<th>Mean square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>10,664.57</td>
<td>8.88*</td>
</tr>
<tr>
<td>Residual</td>
<td>41</td>
<td>1,201.23</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant,

After the effects of sex, breed and year were eliminated, the partial regression coefficients, b, of \( Y_1 \) (rate of gain during test) on \( X_1 \) (birth weight), \( X_2 \) (suckling rate of gain), \( X_3 \) (age put on test) and \( X_4 \) (weaning score) were calculated.

Only \( b_1 \) (birth weight) and \( b_3 \) (age put on test) are significantly different from zero; therefore, only birth weight and age put on test have a significant effect on rate of gain during the test. Suckling rate of gain and weaning score do not significantly affect the rate of gain in the feed lot. The multiple correlation coefficient \( R \) of rate of gain during the test on birth weight and age put on test is 0.6311. This multiple correlation coefficient results in \( R^2 = 0.40 \). This indicates that 40 per cent of the variation in gains during the test period is accounted for by variations in birth weight and age put on test. The partial regression coefficient of rate of gain during test on birth weight is 0.01. This indicates that for each deviation of 1.0 pound in birth weight there is associated 0.01 pound in gain per day during the feeding period. Thus calves that are 10 pounds heavier than the average at birth would be expected to gain 0.1 pound per day more than the average; whereas, the partial regression coefficient of rate-of-gain-during-the-test on age-put-on-test is 0.0046. This shows that for each difference of 10 days in age at start of the test, there is a difference of 0.05 pounds in gain per day during the test period. The partial regression coefficients are presented in Table 9.

Table 9. Effect of Birth Weight (Pounds) and Age Put on Test (Days) on Rate of Gain During Test.

<table>
<thead>
<tr>
<th>Variate</th>
<th>Partial regression coefficient</th>
<th>Standard deviation of B</th>
<th>95 per cent confidence interval of B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age put on test, days</td>
<td>0.0046</td>
<td>.001</td>
<td>.0028 to .0065</td>
</tr>
<tr>
<td>Birth weight, pounds</td>
<td>0.010</td>
<td>.004</td>
<td>.0022 to .0179</td>
</tr>
</tbody>
</table>
In the case of the regression of \( Y_z \) (economy of gain on test) on the variates \( X_1 \) (birth weight), \( X_2 \) (suckling rate of gain), \( X_3 \) (age put on test) and \( X_4 \) (weaning score), only \( b_1 \) of birth weight is significantly different from zero; thus, only birth weight has a significant effect on economy of gain in the feed lot. The partial regression coefficient of \(-2.096\) shows that, for every pound of birth weight above the mean, there is required 2 pounds less TDN (total digestible nutrients) per 100 pounds gain in live weight. Suckling rate of gain, age put on test and weaning score have no significant effect on economy of gain during the feeding period. The correlation coefficient of economy of gain with birth weight is 0.4219. This gives a value for \( R^2 \) of 0.18 which indicates that 18 per cent of the variation in economy of gain is accounted for by variations in birth weight. The partial regression coefficient of economy of gain during test on birth weight is presented in Table 10.

Table 10. **Effect of Birth Weight (Pounds) on Economy of Gain During Test.**

<table>
<thead>
<tr>
<th>Variate</th>
<th>Partial regression coefficient</th>
<th>Standard deviation of B</th>
<th>95 per cent confidence interval of B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth weight, pounds</td>
<td>(-2.096)</td>
<td>0.7036</td>
<td>(-0.675) to (-3.518)</td>
</tr>
</tbody>
</table>

The confidence intervals calculated for all \( b \)'s are quite wide due to the small size of sample. For greater accuracy the confidence intervals should be narrow. This would be possible, however, by increasing the size of the sample.

**Discussion**

The findings in this study further prove that beef animals possessing similar breeding and being exposed to the same environment show marked sex differences in growth rate and efficiency. Bulls gained faster than heifers. The average daily gain of bulls was 2.3 pounds as compared to 2.0 pounds for heifers. Also, bulls were much more efficient than heifers; the former required an average of 391 pounds TDN, while the latter required an average of 483 pounds TDN per 100 pounds gain in body weight during the feeding period.

This is in harmony with the findings of Blackwell (1951) who also found that bulls gain faster and are more economical feed converters than heifers.
When progeny testing, it would be of utmost importance to have equal numbers of offspring of the same sex from all sires being tested. Because of the sex difference in both rate and economy of gain, it would seem unfair to the sires being tested if their offspring were being compared on an unequal sex basis.

The findings obtained from the phase of study using multiple regression, after the effects of sex, breed, and year were eliminated, revealed that birth weight had a significant effect on both rate and economy of gain in the feed lot. This would indicate that calves which were largest at birth would tend to reach a slaughter weight of 800 pounds at the youngest age. This is in agreement with Dawson, Phillips, and Black (1947) since they found that the largest calves at birth and those with the highest prenatal growth rates tended to reach 500 pounds (weaning weight) and 900 pounds (slaughter weight) at the youngest age. They found practically no association, however, between birth weight and economy of gain in the feed lot; whereas, in this present study, birth weight was found to have a significant effect on economy of gain while on the test. The calves that are largest at birth gain faster and the faster gaining calves are more efficient; therefore, the largest calves at birth are the most efficient. This would seem quite possible, however, because it was found by Blackwell (1951) that a high correlation existed between rate and economy of gain in the feed lot; the faster gaining calves being the most economical gainers.

Since the multiple correlation coefficient obtained in this study of the effect of birth weight on rate of gain during the test is fairly high, it seems that birth weight should be given consideration in selection in view of the fact that it had an influence on the time required for calves to attain a slaughter weight of 800 pounds. Also, the trend to market cattle at younger ages, rather than older ages, will increase the importance of birth weight rather than diminish it.

The variance in suckling daily gains in this study had no significant effect on either rate or economy of gain in the feed lot.

Birth weight is taken into account by using a weight for age figure; whereas, the use of gains from birth to weaning and from weaning to slaughter ignore birth weights entirely.

Since suckling gains do not affect gains in the feed lot, they have their importance only in their value in measuring milk production of the dam. This, of course, is highly important and needs to be stressed; therefore, the use of gains during the suckling period in a selection index is worthwhile.

When considering age-put-on-test as a factor affecting rate and economy of gain, it was found that age-put-on-test had a significant
effect on rate of gain during the test. This would seem quite logical when one considers that the calf having the greater age when reaching 500 pounds weaning weight might not have received enough milk from its dam to permit maximum gain in weight. However, this same calf may have received enough milk from its dam to facilitate adequate skeletal growth and digestive tract development, yet very little fat and other body substance has been deposited during the suckling period. Then, when the calf is put on test in the feed lot, it already has adequate skeletal growth; consequently, a greater opportunity for the production of additional body substance, including fat. This reasoning coincides with the statement of Knapp and Black (1941) that approximately 80 per cent of the mature skeletal size of cattle has been attained by the end of the suckling period, whereas, only about 40 per cent of the mature weight has been reached. Age put on test did not significantly affect economy of gain during the test period.

Weaning score did not have a significant effect on either rate or economy of gain during the test; furthermore, it was found that the appearance of these calves was not reliable as an indication of efficiency or capacity for growth. This may be related to the finding that there was a greater variation among those scoring than total score variation among the calves scored. Thus, scoring technique is subject to considerable error and is of doubtful value when animals are quite similar. This may be the case when dealing with this particular sample because both the dams and sires, including their ancestors, had been developed by selecting for type and conformation on a phenotypic basis. Consequently, these calves were, no doubt, quite similar. According to Lush, (1932, 1931) Knapp et al, (1941) and Roubicek, Hilston, and Wheeler (1951), scoring technique is subject to considerable error and is of doubtful value when animals are quite similar.

Blackwell (1951) indicated that conformation score at 500 pounds was negatively correlated with both gains and efficiency during the feeding period. His evidence indicates that selection for weaning score would interfere with progress of improvement if also selecting for rate and economy of gains. However, the present study indicates that since score is independent from rate and economy of gain selection for either type and conformation or rate and economy of gain could be accomplished without hindrance to progress in either. Thus, it appears possible that a cattleman may select for type and conformation; yet, within this desired type and conformation, select for the faster gaining and more efficient cattle as an additional step in beef cattle improvement.
Summary and Conclusions

- Bulls gain faster than heifers. The average daily gain for bulls during the test was 2.3 pounds as compared to an average daily gain of 2.0 pounds for heifers.
- Bulls are more efficient feed utilizers than heifers. The bulls required an average of 391 pounds TDN (total digestible nutrients) to gain 100 pounds body weight during test, while the heifers required an average of 483 pounds TDN per 100 pounds gain.
- Birth weight has a significant effect on both rate and economy of gain, indicating that calves larger at birth would tend to reach slaughter weight of 800 pounds at the youngest age and with the least feed.
- Birth weight should be given consideration in selection in view of the fact that it has an influence on the time required for calves to attain a slaughter weight of 800 pounds.
- The trend to market cattle at younger ages, rather than older ages will increase the importance of birth weight rather than diminish it.
- No relationship was found between suckling gains and gains in the feed lot.
- Suckling gains do have their importance in their value of measuring the milking ability of the dam; therefore, the use of gains during the suckling period in a selection index is worthwhile.
- The age of a calf when put on test at 500 pounds live weight had a significant effect on rate of gain during the test. The older calf having a greater proportion of skeletal growth than the younger animal when put on test has a greater opportunity for the production of additional body substance, including fat.
- Age (in days) when put on the test did not significantly affect feed efficiency during the test period.
- Weaning score did not have a significant effect on either rate or economy of gain during the test; furthermore, it was found that the appearance of these calves was not reliable as an indication of efficiency or capacity for growth.
- It appears that selection for either type and conformation or rate and economy of gain may be accomplished without hindrance to progress in the other.
Bibliography


Donald, H. P. The Relative Importance of Sow and Litter During the Growth of Suckling Pigs: A Comparison of Foster With Normally Reared Pigs. Empire Journal of Experimental Agriculture 7: 32-42. 1939.


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Snell, M. G. The Utilization of Feed by Range Steers of Different Ages. New Mexico Agricultural Experiment Station. Station Bulletin 140. December 1923. 7p.


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 No. 695)