SOME GENETIC AND ENVIRONMENTAL FACTORS AFFECTING
"NET EFFICIENCY" OF BEEF CATTLE

by

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SOME GENETIC AND ENVIRONMENTAL FACTORS AFFECTING
"NET EFFICIENCY" OF BEEF CATTLE

INTRODUCTION

The principal function of beef cattle in producing
wealth and promoting human welfare is to harvest and convert
into useful products the pastures and roughages of farms and
ranches, and also to share with sheep in the conversion of
the annual forage crops from vast areas of range, forest and
desert lands that comprise a large percentage of the land
area of the nation.

Cattle and sheep are able to utilize both roughages and
concentrates, where swine and poultry must depend largely
upon concentrates. Since physiological processes of con­
verting feed into milk are more efficient than the produc­
tion of meat through growth and fattening (8, p.56), dairy
are more efficient than beef cattle in utilizing the better
roughages, pastures and concentrates, provided such feeds
are located strategically for the marketing of dairy prod­
ucts. In the future, as in the past, dairy cattle will
probably increase in a fairly definite ratio to the human
population, whereas beef-cattle numbers per capita decrease.
Since dairy cattle have a longer productive life than
slaughter cattle and generally utilize concentrates throughout this productive life, they require relatively more of these feeds than do beef cattle, as the latter use concentrates mainly in the final fattening process, and then only in the case of a portion of those marketed.

In the long run, as the population increases, the expansion in numbers of animals becomes more and more limited, and a continual high level of nutrition in its population will require a shift toward the more efficient converters. If the beef-cattle industry, facing the challenges and competition of the future, is to continue fulfilling its functions of contributing to essential food supply and to human welfare, production must become increasingly efficient. Such efficiency might come through more extensive use of low-quality roughage materials.

The efficiency of feed utilization is a very involved phenomenon that is influenced by a great number of physiological and environmental factors as well as by individual differences. Fortunately, a portion of the variation in efficiency is controlled by genetic factors, thus permitting progress from selection for high efficiency of feed utilization.

The animal breeder of the future is faced with the task of maintaining and improving the genotype of his herd.
Whether selections be made on the basis of progeny tests or feeding trials, productive traits must be used to predict future performance. To make any real improvement, the characteristics must represent to as great an extent as possible that portion of variation capable of reproduction in the genetic constitution. Selection on individual merit may not reflect the inherited ability of an animal to perform due to the role environment plays. An outstanding animal is produced when superior genetic material is exposed to optimum environmental conditions. While environment does not change the genotype, it may alter genetic expression.

The animal breeder has further restrictions. No new genes can be created by selection, so the effectiveness of his selections depend upon the sorting and rearranging of the genes available into efficient combinations.
Investigators generally agree that one of the major tasks in beef cattle production is improvement in feed efficiency. That efficiency of feed utilization is inherited has been shown by several studies. It appears that the attainment of a relatively large size is more closely associated with efficiency of feed conversion than is type or appearance.

Hess and Jull (28, p.38), working with fowl, found a definite inherent difference in efficiency of feed utilization between individuals that could not be explained on the basis of body weight, rate of gain or time. They concluded that the mode of inheritance of feed efficiency is a complicated phenomenon and a problem which would probably require several years to solve.

Morris, et al. (50, p.53) selected two lines of rats for different levels of efficiency in feed utilization. By applying an efficiency index they were able to show that their low efficiency line was about 40 per cent less efficient and was more variable than the high efficiency line. Palmer (54, pp.24,50) also compared high and low efficiency strains of rats to determine the genetic differences in the biochemistry and physiology influencing food utilization. They found that the high efficiency strain of rats exhibited
greater efficiency in the storage of food energy. They concluded that the over-all efficiency of food utilization in growing rats is controlled by inheritance factors. The difference between the two strains was not due to differences in ability to digest and metabolize the ration.

The utilization of food energy, according to Kleiber (35, p.250), is the result of various physiological functions which are interrelated in many ways; thus, the genetics of efficiency is far from simple. Brody (8, p.1) and Wright (74, pp.93-94) consider growth and its efficiency complex to involve innumerable genetic, physiological and environmental factors. Therefore, difficulty arises when one studies these factors separately because of the existing close relationships and interactions.

Birth Weight

In the selection of breeding animals it is important to determine their prospective value at an early age. A study of birth weight as a measure of the prospective value of the calf is therefore justified since it is one of the first measurements that can be obtained and also one of the easiest to record with reasonable accuracy.

Knapp, Lambert and Black (38, p.284) have shown that birth weight is of limited value as an index of a calf's growth potentialities. They found 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 (12, p.256), however, found that the largest calves at birth tended to reach weaning weight and slaughter weight at the youngest age. Correlation coefficients between birth weight and economy of gain during the feeding period showed practically no association. They found male calves heavier at birth than females, as did Gregory, Blunn and Baker (23, p.345).

Heritability estimates of 0.11, by Dawson, Phillips and Black (12, p.256), and 0.23 by Knapp and Nordskag (39, p.66) for birth weight have been reported, indicating it is relatively low.

Dahmen and Bogart (11, p.20) found that birth weight had a significant effect on both rate and economy of gain. They concluded that it should be given consideration in selection in view of the fact that it had an influence on the time required for calves to attain slaughter weight. While Pierce (68, p.57) found economy of gain was not affected by birth weight, it did have a significant effect on rate of gain.

Age on Test

Age is an important factor to consider in production-
testing beef cattle. As an animal increases in age and size, there are corresponding changes in the physiological functions governing the utilization and disposition of nutrients. After maintenance requirements are met, young cattle can use feed for both growth and fattening, whereas the mature animals use the ration above maintenance largely for the production of fat.

Williams and Wood (71, p.29) state that if a relatively young animal is to lay on fat, it is obvious that a greater share of its feed will be used to produce this fat, leaving less for growth. A greater degree of fat in a young animal would mean either a greater appetite and increased food intake or a lower inherited growth potential.

In comparative performance tests, it is important that environmental variation be reduced to a minimum. Variation due to differences in age and weight may be reduced by feeding on either an age-constant or weight-constant basis. Williams and Wood (71, p.30) determined graphically that each individual 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 in view of this, animals should be compared at identical weights.

The age an animal should be placed on a feed test is probably affected most by the milking ability of the dam,
provided the feed test is started shortly after weaning. Knapp and Black (36, p.254) have shown 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 produced by the dam; while Gifford (20, p.606) concludes that the rate of growth during the pre-weaning period is controlled by the capacity of the calf to take the milk rather than being restricted by the milk yield of the dam.

Dickerson (13, p.524) 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. Donald (16, p.41) in working with pigs found no correlation between weaning weight and post weaning growth. He suggests that this may be due to growth limitations of some of the pigs during the suckling period and partly to different genes controlling growth during suckling and post suckling periods.

Black and Knapp (4, p.77) found no correlation between efficiency of gain before and after weaning in their study of record of performance steers. They suggested that the lack of correlation 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.

Blackwell (5, p.43) concluded that suckling gains were not related to performance during the feed test, and, likewise, Dahmen and Bogart (11, p.20) found age when placed on test lacked significance in affecting efficiency during the test period. They stated that suckling gains should be included in the selection in that it measures the suckling ability of the dam. Pierce (58, p.57) found economy of gain was not affected by suckling gains or age-on-test.

Effects of Sex on Efficiency of Gains

It has been shown that animals, possessing similar breeding, and exposed to the same environment, have exhibited marked sex differences in their growth and efficiency of gain.

Bogart, et al. (7, p.180) found that ovariectomized female rats grew more rapidly early in life than virgins or breeding animals, but the growth period is no longer than for the virgins. Slonaker (63, p.317) found normal rats of each sex were more active, consumed more food and had less energy available for growth and metabolism than gonadectomized animals. Mendel and Cannon (49, p.780) have reported that in the growth of the Albino rat, except for a short early period, males grow faster than females and reach a
larger adult body size; both sexes being held under similar environment. Kellerman (31, p.331) reported that male rats made more efficient use of their food than females.

Palmer, et al. (54, p.23), 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 carcasses from the males. Discrepancies in quantity of food consumed accounted for part of the difference in efficiency between strains, but when animals representing the two strains were compelled to consume equal quantities of the same ration, the rate of growth and efficiency of food utilization were still in favor of the high efficiency strain. Morris, Palmer and Kennedy (50, p.53) stated that the maintenance cost was probably the largest item involved in the efficiency of food utilization by these rats.

In the growing chicken Hess and Jull (28, p.38) found males were slightly more efficient than females in utilizing feed, and the differences between sexes, although small at low weights, progressively increased in favor of the males. The males had a smaller "k" value, indicating either a lower
maintenance requirement for males or a more rapid decrease in efficiency in females due to a lower mature weight.

Comstock, Winters and Cummings (10, p.12) found that in certain lines of swine barrows grew faster than gilts; therefore it became necessary to consider sex as a factor in making progeny comparisons.

As early as 1920, Hammond (26, p.256) reported that steers were heavier than heifers at 22 months-of-age, and further that this sex difference increased with age. Lush, et al. (46, p.33), Schutte (61, p.582), Knapp, et al. (40, pp.11-12) and Koger and Knox (42, pp.18-19) reported that steer calves were heavier at weaning than heifers.

Trowbridge and Moffett (68, p.23) reported that steer calves fullfed for 182 days gained more than heifers of similar quality, type and age that were fed the same way. Daily feed consumption was about equal for the heifers and the steers; therefore, the heifers required more feed than the steers to produce a unit of gain.

Gramlich (22, pp.52-53) noted that heifers fattened faster than steers, due to the greater skeletal growth of the steers, or more precisely to a lower mature weight of the heifers.

Blackwell (5, p.43) noted at the same age bulls were larger and gained faster than heifers, but there was no difference in their feed efficiency. However, at a constant
weight the bulls still gained faster and were more efficient than the heifers. He concluded that in order to test animals for feed efficiency it is more accurate when they are fed to make a given amount of gain rather than for a given period of time. Dahmen and Bogart (11, p.20) found that bulls gained faster than heifers by 0.3 pounds per day and likewise were more efficient than heifers by 92 pounds total digestible nutrients per 100 pounds of gain.

Effect of Rate of Gain on Efficiency

A relatively close positive correlation between rate of gain and economy of gain has been demonstrated by many workers: Winters and McMahon (73, p.27), Bogart and Blackwell (6, p.2), Blackwell (5, p.44), Roubicek (59, p.17), Black and Knapp (4, p.77), and Pierce (58, p.57). In studies with Shorthorn steers, Roubicek (59, p.10) observed a positive correlation of 0.55 on rate of gain with initial height at withers. He also found that the correlation of efficiency with initial height, 0.52, was the same as that for initial weight and rate of gain. Pierce (58, p.57) observed that an increase of 0.1 pound per day in gain on test resulted in a saving of 23 pounds of total digestible nutrients for each 100 pounds gain in live weight.

Guilbert and Gregory (24, p.153) observed that two lots of steers having the same rate of gain differed significantly
in economy of gain, while two other groups having the same efficiency differed significantly in rate of gain. From this they concluded that absolute rate of gain was not a satisfactory index of economy of gain in groups differing in potential size and earliness of maturity; but rather than rate of gain in relation to metabolic size was more closely associated with efficiency of food utilization. Knapp and Baker (36, pp.222-223) concluded that the correlation is reduced in a time-constant population and the high correlation is applicable only between animals of the same size; therefore, selection in time-constant tests should be made for rate of gain rather than observed gross efficiency, in that gross efficiency would generally be misleading in a test of this type.

Hess and Jull (28, p.38), working with chickens, noted that fast-growing individuals utilize their feed more efficiently than slow-growing individuals. At the same weight the fast-growing males required 16.3 per cent less feed than the slow-growing males, and the fast-growing females required 55.0 per cent less feed than the slow-growing females.

Baker, et al. (3, p.6), working with young beef steers, studied the degree of correlation between feed efficiency and digestion coefficients, between the rate of gain and feed efficiency, and between rate of gain and digestion
coefficients. They found that digestion of crude fiber was related to feed efficiency but that there was no significant relation between efficiency and other food nutrients. This would indicate that the digestion of crude fiber is possibly one of the most important factors involved in economy of gain. They also found a positive correlation between feed efficiency and rate of gain.

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

Maintenance

Henry Prentiss Armsby (1853-1921), one of the first American investigators, emphasized the importance of the maintenance requirements in the nutrition of farm animals (2, p.268):

"A very considerable fraction of the feed actually consumed by farm animals--on the average probably fully one-half--is required simply for maintenance. But if half of the farmer's feed bill is expended for maintenance, it is clearly important for him to know something of the laws of maintenance--how its requirements vary as between animals, how they are affected by conditions under which animals are kept, how different feeding stuffs compare in value for maintenance, etc.--as well as to understand the principles governing the production of meat, milk, or work from the other half of his feed."
It is generally agreed that there are at least two components, growth and maintenance, that contribute to the gross efficiency or the utilization of feed by growing animals. From a practical point of view, of course, there is more interest in the gross efficiency than in each component. From a scientific point of view, however, it is advisable to determine growth and maintenance requirements separately, for they may yield valuable information concerning the extremely complicated problem of efficiency of feed utilization.

Klieber (32, p.257) discussed some of the problems in breeding for efficiency of feed utilization. He pointed out that one must use a uniform feed and must have a well defined characteristic for selection, such as total energy efficiency. He suggested that one must study the different factors which influence feed utilization, and then investigate the genetics of each separate factor. He presented a very complex diagram in which he succeeded in impressing this reader with the complexity of the problem. He referred to such factors as appetite, eating capacity, absorption capacity, stimulus for growth, fasting catabolism, heat requirement and cooling power.

Lambert, et al. (45, p.242) emphasized that the development of strains of livestock that are more efficient meat producers than those now existing is one of the basic
problems in animal production. They further pointed out that geneticists have largely neglected this problem because of the inherent difficulties involved in such a study.

It is a common practice to express the efficiency of growing or fattening animals in terms of the food required to secure a unit of gain in body weight. The value of rations are also compared in the same manner. However, when applied to animals this does not take into consideration differences between their maintenance requirements and is therefore strictly valid for comparative purposes only when animals of the same species, sex and initial weight are growing or gaining at the same rate.

Many studies have been made to determine the energy requirement for maintenance of farm animals. The usual procedure for adult animals has been to feed a sufficient amount of a ration, containing the necessary nutrients, over a long period of time so that the animal neither gains nor loses weight, as described by Titus (19, pp.448-449).

Spillman (66, p.160) pointed out the fact that the equation of the curve of diminishing increment expresses with a high degree of accuracy the relationship between live weight and feed consumption. On the basis of this, Titus, et al. (67, p.834) developed a method which they considered to show promise in growth studies. The equation of the curve of diminishing increment, as applied to the relation-
ship, may be written:

\[ E = c - kw \]

where \( E \) is the efficiency of feed utilization for growth, i.e., the gain in the live weight per unit weight of feed consumed; \( c \) is the maximum efficiency of feed utilization for growth; \( k \) is a measure of the rate of decrease in the efficiency of feed utilization; and \( w \) is the live weight at which the efficiency of feed utilization is being measured.

Hess and Jull (28, p. 28) have applied this method to growth studies in chickens. They imply that the \( k \) value might be used to indicate the maintenance requirement per unit of weight.

Another method of studying the maintenance requirements for energy is to determine in a respiration apparatus or calorimeter the amount of heat produced by an animal when at rest, and when a sufficient time has elapsed since the last meal so that there is no longer an increased production of heat due to the digestion and assimilation of food. This is called basal metabolism, or fasting metabolism, of the animal.

The basal metabolism of an animal does not represent the total amount of nutrients or energy required for maintenance, but only the minimum amount of energy expended by the animal when at rest and in a post-absorptive state.
To this amount must be added the amount represented in heat increment. Also, the amount of energy expended in the normal motion of the animal must be added to the basal metabolism.

Brody (8, p. 475) has concluded that the maintenance requirements of mature animals are about twice those of basal metabolism.

It has long been recognized that some relation existed between body size and metabolism, and between body surface and metabolism. Since the smaller animals have a larger surface in proportion to their body weight, their metabolism must be greater per unit of body weight in order to replace the extra heat lost. Brody and his associates (8, p. 403) and Kleiber (31, pp. 352-353), who have made significant recent contributions on this subject, are in approximate agreement on the relation between body weight and metabolism.

Brody (8, p. 397) observed the basal metabolism of animals varying in size from mice to elephants. He found basal metabolism in calories was proportional to the 0.734 power of the live weight in kilograms. When the equation \( Y = ax^b \) was applied to the data, \( a \) was found to have the value of 70.2 when body weight \( (x) \) was in kilograms or 39.5 when body weight was in pounds. Thus, the equation was obtained:

\[ B.M. = 70.2 \times x^{0.734} \]

where B.M. is basal metabolism and \( x \) is
body weight in kilograms. Kleiber (31, p. 350) obtained similar results, using 0.75 for the value of $b$, a value of 72.0 was obtained for $a$. Marston, working with sheep, obtained almost the identical figure of Brody, in that the basal metabolic heat production was 70 W.73.

Winchester and Hendricks (72, p. 17) obtained data on growth rates and levels of energy intake of 16 pairs of identical twin calves during periods when one member of each pair received a reduced energy allowance as low, in some cases, as 80 per cent of a ration sufficient to maintain body weight, and its twin received a more liberal energy allowance. From these data, equations were derived for the determination of energy requirements for growth and for maintenance. The energy requirement of a growing animal was found to be:

$$\text{Energy requirement in pounds of TDN} = 0.0553 \times \text{body weight in pounds}^{2/3} (1 + 0.805 \times \text{gain per day in pounds})$$

This equation can also be used to determine maintenance requirements (growth = 0) of young cattle.

The amount of nutrients that Morrison (51, p. 179) recommends for maintaining dairy cows of various sizes is proportional to the 0.87 power of live weight. He feels that body weight$^{0.87}$ more closely agrees with the methods of feeding dairy cows that have proven satisfactory in
practice. It is obvious that he has included a safety margin and that his allowances are not the minimum maintenance requirements. In the case of a performance test where environmental conditions are held to a minimum, a figure of this type would be of little value.

Other methods involve the determination of urinary constituents and correlating these values with the metabolism of specific nutrients. For example, Smuts (64, pp.432-433) measured the basal metabolism and total endogenous nitrogen excretion of several species and found that in mature animals an average of 2 milligrams of nitrogen were lost from the body for every calorie of basal heat. Since 2 milligrams of nitrogen are approximately equivalent to 12.5 milligrams of protein (nitrogen x 6.25) it is possible to calculate from the basal heat the amount of protein catabolized by the body equivalent to the endogenous nitrogen losses.

Similar studies on the relation of endogenous urinary nitrogen and neutral sulfur excretion in adult animals indicated that these substances tend to vary with the 0.72 and 0.74 powers of body weight, respectively. Since the difference in the numerical value of the exponent of body weight for each of the relationships studied is remarkably small, Brody and his associates (8, pp.384-387) concluded that the ratio between body weight and basal metabolism and the relationship between endogenous nitrogen and neutral
sulfur excretion tend to remain constant for mature warm-blooded animals. These workers (8, pp.384-387) have assembled extensive prediction tables on the basis of these findings, as well as a feeding standard for maintenance that includes total digestible nutrients, digestible crude protein and calories for animals of widely different body weights.

The interesting relations revealed by these studies have contributed some substantial progress toward scientific evaluation of feeds and consequently toward the economical feeding of animals.
MATERIALS AND METHODS

The data used in this study are from 43 calves individually fed at the Oregon Agricultural Experiment Station under the Western Regional Beef Cattle Improvement Project. The calves were purebred Hereford and Aberdeen Angus bulls and heifers. All were produced at this station and dropped during the spring of 1952. They were weaned at 450 pounds body weight, or in the first week of December, whichever came first, and placed under experimental conditions immediately.

The animals were fed individually twice daily at uniform times and remained tied by neck chains for a total of approximately seven hours. Mangers were constructed such that calves had access to water at all times through automatic drinking cups. Pens, in which wood shavings were used for bedding, housed the calves in monosexual groups of six. The feeding period was from a weight of 500 pounds to a weight of 800 pounds. The ration used has been described by Nelms, et al. (53, pp.1-2). It was composed of 2 parts chopped alfalfa and 1 part concentrate, mixed thoroughly and pelleted in a one-inch pellet about one and one-half inches long. This permitted accurate determination of feed consumption. All animals were full-fed so that there was some weigh back after each feeding.
All calves were weighed once weekly at a uniform time, and feed consumption was calculated after each weighing.

Gross feed efficiency as used in this study is pounds of total digestible nutrients per pound of gain in body weight. Digestible nutrients were determined by a digestibility trial (53, pp.1-2). "Net efficiency" as used in this study is the gross efficiency less maintenance. Maintenance is calculated as twice basal metabolism \( (B.M. = 70.5 \times 0.735) \) as described by Brody (8, p.475).

The analyses measure the effects of three independent variables--birth weight, age-on-test, and gain-per-day during test--on two dependent variables--gross efficiency and net efficiency, within lines, sex and breed. Birth weights were taken within 12 hours after birth. Age-on-test is the age at which the calf reached 500 pounds. Age-on-test is a measure of the suckling gains in that calves were placed under experimental conditions immediately upon weaning. Gain-per-day during test is the gain made per day from a weight of 500 pounds to a weight of 800 pounds. These analyses were carried out by the least squares analysis applying a regression model as described by Anderson and Bancroft (1, pp.191-203).

The regression of feed efficiency on body weight was calculated by a method similar to that presented by Titus, Jull and Hendricks (67, pp.817-835). The regressions of
intake of total digestible nutrients on time, body weight on time and the correlation coefficients were calculated as outlined by Snedecor (65, pp. 214-239, 340-373).
RESULTS

A total of 43 purebred Hereford and Aberdeen Angus bulls and heifers were individually fed during 1952-1953 and records of production were taken. Records which were studied include birth weights, weaning weights, age-on-test, weekly weights, feed consumption by weeks, gain-per-day during test period, gross efficiency (total digestible nutrients per 100 pounds gain), and calculated net efficiency (gross efficiency less maintenance) for individual calves.

Correlations Between Gross Efficiency, Net Efficiency Gains-on-Test, Age-on-Test, Birth Weight, Scores at 500 and 600 Pounds Body Weight, and Feed Intake

Correlations between some traits and efficiency of gains were computed to determine those of most significance. Sex and line variations were eliminated by analyzing within sex and within lines. The Aberdeen Angus were considered as one line, thereby accounting for breed variation. It may be seen from the coefficients of correlation (Table 1) that gains-per-day during test, age-on-test and birth weight were significantly related to efficiency of gains.

It is also interesting to note a lack of correlation of scores at 800 pounds with scores at 800 pounds in the case of bulls, while in the case of heifers these two scores were
**TABLE 1**

Correlations between some traits of Purebred Hereford and Aberdeen Angus males and females

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age-on-test : Birth weight : Score at 500 : Score at 800 : Feed intake : Gross efficiency : Net efficiency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>days : pounds : pounds : pounds : TDN/week : TDN/100# gain : TDN/100# gain</td>
<td></td>
</tr>
<tr>
<td><strong>Males</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gains-on-test</td>
<td>.0645</td>
<td>-.0475</td>
</tr>
<tr>
<td></td>
<td>-.2905</td>
<td>.1004</td>
</tr>
<tr>
<td></td>
<td>.6501**</td>
<td>-.8118**</td>
</tr>
<tr>
<td></td>
<td>-.5185*</td>
<td>.1547</td>
</tr>
<tr>
<td></td>
<td>.2919</td>
<td>.4609*</td>
</tr>
<tr>
<td></td>
<td>-.5569*</td>
<td>.1431</td>
</tr>
<tr>
<td></td>
<td>.3240</td>
<td>-.4595*</td>
</tr>
<tr>
<td></td>
<td>.3897</td>
<td>.1431</td>
</tr>
<tr>
<td></td>
<td>-.6259**</td>
<td>.4170*</td>
</tr>
<tr>
<td></td>
<td>-.1236</td>
<td>-.5231**</td>
</tr>
<tr>
<td></td>
<td>-.2266</td>
<td>-.5326*</td>
</tr>
<tr>
<td></td>
<td>-.0694</td>
<td>.0248</td>
</tr>
<tr>
<td></td>
<td>-.0117</td>
<td>.9034**</td>
</tr>
<tr>
<td><strong>Females</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gains-on-test</td>
<td>-.3136</td>
<td>.3336</td>
</tr>
<tr>
<td></td>
<td>-.3240</td>
<td>.1369</td>
</tr>
<tr>
<td></td>
<td>.3897</td>
<td>-.3528</td>
</tr>
<tr>
<td></td>
<td>-.5760**</td>
<td>-.0349</td>
</tr>
<tr>
<td></td>
<td>-.4595*</td>
<td>.1431</td>
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<td></td>
<td>.4170*</td>
<td>.4188*</td>
</tr>
<tr>
<td></td>
<td>-.0712</td>
<td>.3611</td>
</tr>
<tr>
<td></td>
<td>-.1754</td>
<td>-.3526*</td>
</tr>
<tr>
<td></td>
<td>.6449**</td>
<td>.0829</td>
</tr>
<tr>
<td></td>
<td>-.2906</td>
<td>-.1542</td>
</tr>
</tbody>
</table>
Table 1, continued

<table>
<thead>
<tr>
<th>Age-on-Birth test weight:</th>
<th>Feed intake:</th>
<th>Gross efficiency:</th>
<th>Net efficiency:</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 days: pounds: pounds:</td>
<td>: pounds TDN/week: TDN/100# gain: TDN/100# gain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>800 pounds</td>
<td>.0130</td>
<td>-.0936</td>
<td>-.0822</td>
</tr>
<tr>
<td>Feed intake</td>
<td>.3903</td>
<td>.6870**</td>
<td></td>
</tr>
<tr>
<td>Gross</td>
<td></td>
<td>.9384**</td>
<td></td>
</tr>
</tbody>
</table>

* significant at 5% level
** significant at 1% level
significantly correlated. This may indicate that the heifers look more nearly mature at 500 pounds body weight than do the bulls. The significant correlation between 500-pound score and efficiency only in the bulls is interesting. This probably means that the bulls which have a tendency to lay on fat at an early age (and consequently score higher) are less efficient. In the case of females, all probably have started to lay on fat at 500 pounds body weight since the score at this weight is highly correlated with score at 800 pounds body weight only in the heifers. The positive correlation between feed intake and net efficiency in the case of heifers might be expected, because the increase in feed intake takes place faster than efficiency decreases. The correlation between gross and net efficiency is high, which indicates that selection for net efficiency on a gross basis is possible with a high degree of accuracy.

It can be noted from Table 2 that there exists some very interesting line and, especially, sex differences.

When considered within lines, bulls were heavier at birth in every case than heifers; however, Hereford heifers were heavier than the Angus bulls. The Angus heifers were 10.2 pounds lighter at birth than the Hereford heifers.

Bulls reached 500 pounds at a younger age than did the heifers, with the exception of Line 1. Note here that the
<table>
<thead>
<tr>
<th>Line and Sex</th>
<th>No. of Animals</th>
<th>Average Birth Weights</th>
<th>Average Age-on-Test</th>
<th>Average Daily Gain-on-Test</th>
<th>Gross Efficiency</th>
<th>Net Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(pounds)</td>
<td>(days)</td>
<td>(pounds/day)</td>
<td>TDN/100# gain</td>
<td>TDN/100# gain</td>
</tr>
<tr>
<td>Line 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>8</td>
<td>76.1</td>
<td>233</td>
<td>3.12</td>
<td>372</td>
<td>241</td>
</tr>
<tr>
<td>Females</td>
<td>4</td>
<td>75.5</td>
<td>229</td>
<td>2.37</td>
<td>526</td>
<td>356</td>
</tr>
<tr>
<td>Line 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3</td>
<td>74.0</td>
<td>220</td>
<td>2.43</td>
<td>404</td>
<td>238</td>
</tr>
<tr>
<td>Females</td>
<td>4</td>
<td>67.0</td>
<td>265</td>
<td>2.20</td>
<td>497</td>
<td>314</td>
</tr>
<tr>
<td>Line 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>1</td>
<td>77.0</td>
<td>246</td>
<td>2.75</td>
<td>396</td>
<td>257</td>
</tr>
<tr>
<td>Females</td>
<td>6</td>
<td>68.8</td>
<td>254</td>
<td>2.26</td>
<td>528</td>
<td>346</td>
</tr>
<tr>
<td>All Hereford</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>12</td>
<td>75.7</td>
<td>231</td>
<td>2.91</td>
<td>382</td>
<td>242</td>
</tr>
<tr>
<td>Females</td>
<td>14</td>
<td>69.6</td>
<td>250</td>
<td>2.27</td>
<td>518</td>
<td>339</td>
</tr>
<tr>
<td>Line 4 (Angus)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>6</td>
<td>63.5</td>
<td>215</td>
<td>2.87</td>
<td>404</td>
<td>260</td>
</tr>
<tr>
<td>Females</td>
<td>11</td>
<td>58.8</td>
<td>264</td>
<td>1.95</td>
<td>608</td>
<td>403</td>
</tr>
</tbody>
</table>
Angus bulls reached 500 pounds at a younger age than any other group even though they were lighter at birth. The Angus heifers were the oldest group to reach 500 pounds.

Bulls gained faster than heifers during the test period. Line 2 bulls had a lower gain-per-day than bulls of any other group. Angus heifers had the lowest gain-per-day of any group. Bulls gained approximately 0.70 pounds more per day than the heifers.

Bulls were more efficient than heifers. The gross efficiency figures for bulls are worthy of noting in that they required only about 4 pounds of TDN per pound of gain, while in heifers required more than 5 pounds of TDN per pound of gain. Line 1 bulls were more efficient than any other group, while Line 4 heifers were less efficient than any other group on a gross basis. It is interesting, indeed, that Line 2 bulls had the best net efficiency, while they had only a mediocre gross efficiency and had the lowest gain-per-day during the test of any of the bulls. This would have to mean that they had a lower feed intake. The Angus heifers again were the least efficient of any group included in this study.

Line 1 bulls and heifers were outstanding in almost every case. They were heavier at birth, had less than average age-on-test, had higher gain-per-day, and were only slightly above the average in efficiency. The Angus heifers
stand out also; they were lighter at birth, older at 500 pounds body weight, had a lower gain-per-day, and were less efficient than any other group of animals here considered.

**Effects of Birth Weight, Age-on-Test and Gain-per-Day During Test on Efficiency Within Sex and Within Lines**

A multiple regression was designed to test the effects of birth weight, age-on-test, gain-per-day during test, sex, lines and sex x line interaction on efficiency. The partial regression coefficients of the independent variables and their confidence intervals are presented in Table 3, with test of significance indicated.

The least square method of estimation was used for the analysis of the data. Each observation for efficiency was assumed to be the sum of the influence or effects of the identifiable variables as follows, using efficiency as an example:

\[
\text{Efficiency} = \text{general mean} + \text{line effects} + \text{sex effect} + \text{line x sex interaction effect} + \text{birth weight effect} + \text{age-on-test effect} + \text{effects due to gain-per-day} + \text{effects peculiar to each calf}
\]

This linear combination of effects is referred to hereafter as the mathematical model.

The general mean of the mathematical model includes in its basis the fundamental likeness of the observations, due
to the fact that all individuals were of the same genus and species and were grown in the same general environment. Superimposed upon the general mean are other factors which are not alike for all calves. Potential sex effects are perhaps due to difference in metabolic and endocrine patterns and, hence, to differences in rates of maturity. The effects peculiar to individual calves included such effects as milk production of the dam before weaning and accidents or other environmental incidents as colds, bloat, etc. not measurable for analysis.

Restrictions are imposed upon the mathematical model in that the effects of calves from Line 1, Line 2, Line 3 and males are indicated by constants representing deviations from the general mean. The effect of the continuous variables represents the average change in the dependent variable for each unit of change of the independent continuous variables. Furthermore, no constants were obtained to measure the effect of calves which are from Line 4 and are females, since the general mean includes the estimate of the average Line 4 female, irrespective of birth weight, age-on-test or gain-per-day during test which are the continuous independent variables in this analysis. The constants estimated represent deviations from the general mean which must be added to it to estimate a given value. For example, the most efficient, unbiased estimate of the net efficiency
of a Line 4 female with a 60 pound birth weight, 260 days age-on-test and a gain of 2.0 pounds per day on test would be as follows:

Estimated Net Efficiency = general mean + 60 (regression coefficient of net efficiency on birth weight) + 260 (regression coefficient of net efficiency on age-on-test) + 2.0 (regression coefficient of net efficiency on gain-per-day during test);

whereas the most efficient estimate of net efficiency of a Line 1 male with a 75 pound birth weight, 210 day age-on-test and a gain of 3.5 pounds per day while on test would be:

Estimated Net Efficiency = general mean + constant for Line 1 + constant for males + constant for Line 1 x sex interaction + 75 (regression coefficient for net efficiency on birth weight) 210 (regression coefficient for net efficiency on age-on-test) + 3.5 (regression coefficient for net efficiency on gain-per-day during test).

A test of significance for each of the constants necessitated obtaining the standard errors of the estimates.

Estimates of the deviations from the mean efficiency of the mathematical model of the line groups and environmental effects are presented in Table 3. The difference in
## TABLE 3
Summary of Analysis of Variance (1); Estimates (with other variables adjusted) of Deviations from the Mean Efficiency of the Mathematical Model (2)

<table>
<thead>
<tr>
<th></th>
<th>Net Efficiency</th>
<th></th>
<th>Gross Efficiency</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sum of Squares</td>
<td>Degrees of Freedom</td>
<td>Sum of Squares</td>
<td>Degrees of Freedom</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>232,771.117</td>
<td>42</td>
<td>441,783.070</td>
<td>42</td>
</tr>
<tr>
<td><strong>Regression</strong></td>
<td>208,470.402</td>
<td>10</td>
<td>414,829.768</td>
<td>10</td>
</tr>
<tr>
<td><strong>Residual</strong></td>
<td>24,300.715</td>
<td>32</td>
<td>26,953.302</td>
<td>32</td>
</tr>
<tr>
<td><strong>R²</strong></td>
<td>.896</td>
<td></td>
<td>.939</td>
<td></td>
</tr>
<tr>
<td><strong>(2)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>General Mean¹</strong></td>
<td>512.86*</td>
<td>+ 185.40</td>
<td>844.24*</td>
<td>+ 195.06</td>
</tr>
<tr>
<td><strong>Line 1 (Lionheart)</strong></td>
<td>18.93</td>
<td></td>
<td>8.61</td>
<td></td>
</tr>
<tr>
<td><strong>Line 2 (Prince)</strong></td>
<td>-59.79*</td>
<td></td>
<td>-67.24*</td>
<td></td>
</tr>
<tr>
<td><strong>Line 3 (David)</strong></td>
<td>-17.01</td>
<td></td>
<td>-21.05</td>
<td></td>
</tr>
<tr>
<td><strong>Sex (Males)</strong></td>
<td>-55.07*</td>
<td></td>
<td>-62.90*</td>
<td></td>
</tr>
<tr>
<td><strong>Line 1 x Sex</strong></td>
<td>-8.94</td>
<td></td>
<td>4.07</td>
<td></td>
</tr>
<tr>
<td><strong>Line 2 x Sex</strong></td>
<td>24.52</td>
<td></td>
<td>28.51</td>
<td></td>
</tr>
<tr>
<td><strong>Line 3 x Sex</strong></td>
<td>15.21</td>
<td></td>
<td>8.79</td>
<td></td>
</tr>
<tr>
<td><strong>Birth Weight</strong></td>
<td>-1.63*</td>
<td></td>
<td>-1.68*</td>
<td></td>
</tr>
<tr>
<td><strong>Age-on-Test</strong></td>
<td>-64.63*</td>
<td>+ 38.13</td>
<td>-124.06*</td>
<td>- 35.91</td>
</tr>
<tr>
<td><strong>Gains-on-Test</strong></td>
<td>42</td>
<td></td>
<td>.41</td>
<td></td>
</tr>
</tbody>
</table>

* significant at 5%

¹ includes estimate for Line 4 (Angus) female calves
efficiency between Line 2 and the remaining lines, as indicated in Table 2, was significant. Also the sex difference noted in Table 2 was significant.

The calculated partial regression coefficients (Table 3) of efficiency on the three continuous independent variables—birth weight, age-on-test and gain-on-test—indicate that all three have a significant effect on efficiency of feed utilization in all cases with the exception of the effect of age-on-test on gross efficiency.

The regressions (-1.63) of net efficiency on birth weight and (-1.68) of gross efficiency on birth weight indicate that for each difference from the mean in birth weight of 10 pounds there would be a difference of 16.3 and 16.8 pounds total digestible nutrients (TDN) per 100 pounds gain, respectively, with the heavier calves at birth being more efficient. The regression (0.42) of net efficiency on age-on-test indicates that for each 10 days difference from the mean in age-on-test there is a difference of 4.2 pounds TDN per 100 pounds gain with the younger calves being more efficient. The regression coefficient of gross efficiency on age-on-test was not significant at the 5 per cent level.

The regressions (-64.63) of net efficiency on gains-on-test and (-124.06) of gross efficiency on gains-on-test indicate that for each difference from the mean of one pound per day in gain, there will be a difference of 64.63 and 124.06
pounds TDN per 100 pounds gain, respectively, with the faster gaining calves being more efficient.

The value, \( R^2 = 0.896 \), for net efficiency and, \( R^2 = 0.939 \), for gross efficiency means that 89.6 and 93.9 percent of the variations in net efficiency and gross efficiency, respectively, are accounted for by variations in the variables tested.

**Effects of Increased Weight on Efficiency**

Net efficiency and gross efficiency were calculated for males and females within lines and are presented in Figure 1.

It can be seen that the males decrease in efficiency at a much greater rate than do females. The regressions of \(-.000697\) of net efficiency and \(-.000328\) of gross efficiency on body weight for the females indicates that for each additional 100 pounds live weight the efficiency decreased 6.97 and 3.28 pounds gain for each 100 pounds TDN, respectively. The regressions of \(-.0014766\) of net efficiency and \(-.0007432\) of gross efficiency on body weight for the males indicate that for each additional 100 pounds of live weight the efficiency decreased 14.766 and 7.432 pounds gain for each 100 pounds TDN, respectively. It can be seen (Figure 1) that even though the males decreased in efficiency faster they are still more efficient at 800 pounds body weight than
Figure 1. The regression of net efficiency and gross efficiency on body weight for males and females.
the females.

**Effects of Increased Body Weight on Amount of Total Digestible Nutrients (TDN) Available for Storage**

Brody (8, p.83) has found that specific dynamic action (SDA) energy, fecal energy, urine energy and methane energy account for approximately 60 per cent of the gross available energy when an animal is eating 2.5 to 3.0 times the amount required for basal metabolism (full feed). When this need for energy plus the need for basal metabolism is satisfied, the remaining can, theoretically, be stored. These figures have been calculated for all individuals (Figure 2), for the period of 500 to 600 pounds and for the period of 700 to 800 pounds live weight for males and females within lines. The length of the lines indicates the time required to gain the respective 100 pounds of weight. For example, it took approximately 7 weeks for the females to gain from 500 to 600 pounds, while it took them 6½ weeks to gain from 700 to 800 pounds body weight. In the case of males it took only 5 weeks to gain from 500 to 600 pounds body weight and approximately 4½ weeks to gain from 700 to 800 pounds body weight. The regressions represent the amount of TDN per week for the indicated variable.

Figure 3 represents a similar situation for the regression of gain on time. The regression represents the amount
Figure 2. The regression of TDN consumed (1), TDN remaining after SDA, fecal, urine and methane losses are taken out (2), and TDN available for storage (3) on time for the period of 500 to 600 pounds body weight. The same applies for the regressions (4), (5) and (6) for the period 700 to 800 pounds live weight.
Figure 3. The regression of body weight on time for the periods of 500 to 600 pounds live weight and 700 to 800 pounds live weight for males and females.
of gain made per week for the periods of 500 to 600 pounds body weight and for the period of 700 to 800 pounds body weight. Bulls were gaining 19.838 pounds per week and heifers were gaining 13.55 pounds per week for the period of 500 to 600 pounds body weight. While during the period of 700 to 800 pounds body weight the bulls gained 19.519 pounds per week and heifers gained 13.01 pounds per week.

The regressions of total digestible nutrients (TDN) consumed on time (Figure 2) and body weight on time (Figure 3) have been tabulated (Table 4).

From Table 4, it can be seen that the females were consuming 3.36 pounds TDN per week more than the males and had 3.55 pounds TDN available per week for storage than the males, yet they gained 6.29 pounds per week less for the period of 500 to 600 pounds. During the period from 700 to 800 pounds, the males consumed 4.00 pounds TDN more per week, had 5.11 more pounds TDN per week for storage and gained 6.51 pounds more per week than did the females.

It is very interesting that both groups of animals (males and females) were gaining at approximately the same rate in the two periods (500 to 600 pounds body weight and 700 to 800 pounds body weight). When the weekly TDN consumption data (Table 4) are compared with the weekly rate of gain for the two periods it is found that considerably
### TABLE 4

Regressions of TDN consumed and TDN available for storage on time and body weight on time for the periods of 500 to 600 pounds and 700 to 800 pounds

<table>
<thead>
<tr>
<th></th>
<th>500 to 600 pounds</th>
<th></th>
<th>700 to 800 pounds</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TDN consumed per week</td>
<td>TDN available for storage per week</td>
<td>pounds gained per week</td>
<td>TDN consumed per week</td>
</tr>
<tr>
<td>Males</td>
<td>67.22</td>
<td>12.26</td>
<td>19.84</td>
<td>94.38</td>
</tr>
<tr>
<td>Females</td>
<td>70.58</td>
<td>15.81</td>
<td>13.55</td>
<td>90.38</td>
</tr>
</tbody>
</table>
more TDN was required for the same amount of gain; bulls required 27.16 pounds TDN more and heifers required 19.80 pounds TDN more than for the same amount of gain.

The comparison of weekly feed consumption between bulls and heifers during the period of 500 to 600 pounds body weight is apparent. This probably is due to heifers being older at the same weight and, therefore, having a larger rumen capacity. This difference had reversed during the period of 700 to 800 pounds, probably due to increased activity of the bulls over the heifers and in turn increased appetites.
DISCUSSION

If basal metabolic rate is constant in that it varies with the 0.734 power of body weight, it appears possible to make accurate selections for efficiency by using gross efficiency. The correlating coefficient between net efficiency and gross efficiency ($r = 0.903$) shows that 81.6 percent ($r^2 = 0.816$) of the variation in net efficiency is due to variations in gross efficiency.

The significant correlation between 500-pound score and efficiency (Table 1) for bulls is unfortunate, in that it is at this time many calves are culled. There might be a tendency for keeping the good-looking calves and culling the others without a performance test, which would result in inefficient calves being kept. This is not the case with females because there is a significant correlation between scores at 500 and 800 pounds body weight and no relation of scores at 500 pounds to efficiency.

There was a significant negative correlation between age-on-test and score at 800 pounds body weight and the lack of a significant correlation between score at 500 pounds body weight and age-on-test in the case of the heifers. This suggests that the "better-doing" calves during the suckling period may not necessarily be the "better-looking" calves at 500 pounds, probably due to type of growth which
is largely skeletal and muscular at that age. However, the calves doing better in early life have the stimulus to do better later and in turn to look better at a heavier weight due to the greater degree of finish, largely fat, that they lay on at heavier weights.

The significant positive correlation between 500-pound score and 800-pound score for the females indicates that heifers have already started laying down fatty tissue at this lighter weight. They would tend, therefore, to score at 500 pounds in the order as they would at 800 pounds.

The significant positive correlation between feed intake and net efficiency for the females is not too surprising, since the ration is designed for growing and not a fattening ration. The heifers have a tendency to fatten after reaching test weight of 500 pounds; consequently, the more they eat the less efficient they become due to their not making the most efficient use of a growing ration as do the bulls.

The negative correlation between age-on-test and birth weight might be expected. That larger calves at birth reach weaning size at a younger age has been shown by Sawyer, Li and Bogart (60, p.5), Gregory, Blunn and Baker (23, p.345), Kohli, et al. (43, p.364), Galgan, et al. (20, p.1), Dahmen and Bogart (11, p.16), and Pierce (58, p.57). Also calves which were heavier at birth were significantly more
efficient during the performance test. The regression coefficient (Table 3) of -1.63 of net efficiency on birth weight indicates that for each 10 pounds additional weight at birth there would be a decrease in 16.3 pounds TDN required for each 100 pounds gain in live weight.

Cow size has been quite well established as one of the more important factors affecting birth weight of calves; Gregory, et al. (23, p.345) and Knapp, et al. (38, p.284). As the calf retains this advantage to maturity, it appears that the importance of birth weight, as a factor in beef cattle improvement through selection, can hardly be overemphasized. Sawyer, et al. (60, p.6) suggest that the hereditary factors controlling "growthiness" and milk production may be the same or closely associated.

The analysis reveals that age-on-test did have a significant effect on efficiency. The older calves at 500 pounds were less efficient. This is contrary to results by Dahmen and Bogart (11, p.19). They suggested that a calf which is slow to reach 500 pounds or weaning weight might have received only enough milk for skeletal growth and digestive tract development with little fat and other body substance deposited. However, the difference in their case was not significant for economy of gains. In the case of the present study the effect of age-on-test can probably be explained by the fact that pasture conditions were better than
in most cases, thus producing a good milk flow from the
dams. Therefore, the calves that made the best growth dur­
ing the suckling period continued to do so during the per­formance test and were also more efficient. Pierce (58, p. 57) found age-on-test did not affect efficiency of gains,
but the older calves placed on test the greater the gain per day.

Gain per day during the test had a significant effect on efficiency. The faster gaining calves were the most
efficient. This has been shown to be true by Blackwell (5, p.43), Pierce (58, pp.57-58), Knapp, et al. (40, p.19),
Winters and McMahan (73, p.27), Roubicek, et al. (59, p.17),
and Black and Knapp (4, p.77).

This study is in harmony with the findings of Blackwell
(5, p.43) and Dahmen and Bogart (11, pp.17-18) that males
are more efficient than heifers at the same body weight.
Even though they were exposed to the same environment and
possessed similar breeding, there was a marked sex differ­ence. Because of this large sex difference it seems unfair
to compare the progeny of one sire with that of another,
unless comparisons are made within sex.

This study has presented a number of facts which in­
dicate that the type of tissue being lain down is not the
same for both sexes. First of all the correlations between
500-pound and 800-pound scores; in the case of heifers this
correlation was highly significant (Table 1), while in the case of bulls a significant correlation was lacking. Since finish is one of the determining factors in a calf's score, this would indicate that heifers already had a high degree of finish at 500 pounds body weight and therefore tended to score in the same order as at 800 pounds body weight. The lack of a significant correlation in the case of bulls certainly means that they did not look the same at the two weights. This could be due to lack of finish at 500 pounds and having a considerable amount of finish at 800 pounds body weight.

The fact that heifers were less efficient than bulls would indicate that the gains were not the same type of tissue. There was little difference in feed consumption, yet the difference in gains is tremendous.

Calves in Line 2 were significantly more efficient than the calves in the other 3 lines. This is interesting because the bulls of that line made lower gains than bulls in any other line. This may be partly explained on the basis that the feed intake for calves in Line 2 was less than for calves in the other lines. Had they had the appetite of the other lines, they probably would have exceeded the calves of the other lines in gain-per-day. Some of the difference could possibly be explained on the basis of less activity, since the bulls of that line had a tendency to be
lazy. It appears that calves of Line 2 had lower metabolic rates and were quite efficient in spite of the lower food intake and reduced rate of gain. According to Kleiber (32, p.251), the rate of production of body substance in growing animals depends not only on the stimulus for growth but also on the level of available energy. With two animals having the same stimulus, the one with the higher level of available energy will have the higher rate of production of body substance, because it either eats more or digests better. The power of digestion does not seem to differ greatly among similar animals, but their appetites vary considerably. With the same growth stimulus, therefore, the bigger eater will be the better utilizer because of the resultant higher available energy level.

If the TDN consumed and the gains made are converted to calories, some interesting figures are obtained. Assuming one pound of TDN is equivalent to 1814 Calories (1 gram is equal to 4 Calories) (8, p.56), gain of muscle which is 75 per cent water, is equivalent to 635 Calories per pound, and gain of fat which contains 1 part water to each 9 parts of fat is equivalent to 3800 Calories per pound of gain made as fat (71, p.29), some interesting calculations can be made.

From Figure 2 one notes that the bulls had available
for storage 12.26 pounds TDN or approximately 22,240 Calories per week during the period of 500 to 600 pounds body weight. If simple algebra is applied (example: 22,240 Cal. = (19.34 - pounds of fat) • 635 + pounds of fat(3800) Cal.), it is found that bulls were making 3.05 pounds of gain as fat (with associated water) and 16.79 pounds of gain as protein (with associated water) or 15.4 per cent of the gain was fat. The heifers during this same period had 15.81 pounds TDN or 28,672 Calories available for storage. Again applying algebra it is found that the heifers were making 6.34 pounds gain as fat (with associated water) and 7.21 pounds gain as protein (with associated water) or 46.8 per cent was fat. These figures are, of course, assuming that the entire decrease in efficiency is due to the degree of decomposition of fat.

If one looks at the figures during the period of 700 to 800 pounds body weight, it is noted that the bulls were making 59.2 per cent of the gain as fat and the heifers were making 73.2 per cent of the gain as fat.

These figures are by no means exact, but they show certain tendencies for which the nutrients are used. This points out some of the difficulties encountered when selecting a good-doing calf on type alone. Perhaps it would be better to select on efficiency first, then consider type,
instead of the reverse, for which there is a tendency to do so often.
SUMMARY AND CONCLUSIONS

A total of 43 purebred Hereford and Aberdeen Angus bulls and heifers were individually fed at the Oregon Agricultural Experiment Station during the fall and winter of 1952-1953. They were fed for the period from 500 pounds body weight to 800 pounds body weight. Weekly weights and feed consumption were obtained. A multiple regression was set up to test the effects of sex, lines, sex x line interaction, birth weight, age-on-test and gain-per-day on each of two dependent variables—gross efficiency and net efficiency. Some theoretical calculations were made concerning the type of tissue that was being laid down.

1. Bull calves decrease in efficiency more rapidly than heifers from a body weight of 500 to a body weight of 800 pounds. The bulls continue to be more efficient at 800 pounds body weight. With an increase of 100 pounds in body weight net efficiency decreased 14.7 pounds gain per 100 pounds TDN consumed for bulls. With each increase in body weight of 100 pounds net efficiency decreased 6.97 pounds gain for each 100 pounds TDN consumed in the case of the heifers. For each increase of 100 pounds in body weight, gross efficiency decreased at the rate of 3.28 pounds gain per 100 pounds TDN consumed for bulls, and 7.43 pounds gain per 100 pounds TDN consumed for heifers.

2. Birth weight had a significant effect on both net
efficiency and gross efficiency. An increase in birth weight of 10 pounds resulted in a saving in net efficiency of 16.3 pounds TDN per 100 pounds of gain and in a saving in gross efficiency of 16.8 pounds TDN per 100 pounds gain.

3. Age-on-test had a significant effect on net efficiency. It took 4.2 pounds more TDN per 100 pounds of gain for each increase of 10 days in age-on-test. Gross efficiency was not affected by age-on-test.

4. Net efficiency and gross efficiency were significantly affected by rate of gain. An increase of 1.0 pounds gain per day resulted in a saving in net efficiency of 64.6 pounds TDN per 100 pounds gain and a saving in gross efficiency on 124.1 pounds TDN 100 pounds gain.

5. The Prince line (Line 2) was significantly more efficient than the other lines tested, with there being no differences between any two of the remaining lines.

6. It appears that bulls and heifers are not laying on muscle and fat in the same ratio. Apparently bulls are storing more protein and less fat resulting in them being more efficient at the same body weight. Using calculated data and reserving certain assumptions, the increase in body weight of heifers (on the average) was 46.8 per cent fat from 500 to 600 pounds and that of bulls was 15.4 per cent fat at the same weight. While at 700 to 800 pounds body weight the gain made by heifers was 73.2 per cent fat and
that made by bulls was 59.2 per cent fat.

7. It appears that selection for net efficiency can be accomplished with a high degree of accuracy by selecting for gross efficiency.

8. This study indicates that using 0.734 power of body weight to calculate basal metabolism and maintenance is valid.


