ABSTRACT OF THESIS

A COMPARISON OF COMPREST AND CONVENTIONAL TYPES OF HEREFORD STEERS AS EVALUATED BY BODY AND CARCASS MEASUREMENTS

Submitted by

Carl E. Safley

In partial fulfillment of the requirements for

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Colorado

Agricultural and Mechanical College

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INTRODUCTION

This study explores: first, changes in body measurements of two different types of Hereford steer calves during fattening; second, interrelationships between body measurements and the feed lot efficiency and gains of these steers.

The visual method of comparing the conformation of one animal with another lacks the objectivity desired for research purposes. Because of this, linear measurements were used as a means of describing the two types and to show the interrelationships mentioned above.

The small type Hereford steers compared in this study with average size Herefords as found in most purebred herds, referred to as conventional type, appear shorter in head, neck, body, and legs than the conventional type Herefords and are designated as comprest type.

Some of the questions it is hoped may be at least partially answered in this study are:

1. Can body measurements be used to differentiate between comprest and conventional types of Hereford steers?

2. How do the measurements of the steers differ between the two types?

3. Can these measurements be used to predict feed lot performance?

4. What is the relationship of fat steer measurements to subsequent carcass measurements?

5. What is the relationship of slaughter grade to subsequent carcass measurements?

MATERIALS AND METHODS

This comparison was made during two growth-fattening periods, using for each period all the steer calves produced by a herd of purebred Hereford cows at the Fort Lewis A and M College each of the two years. The steers were fattened and slaughtered at Colorado A and M College.

Some of the steers were sired by conventional type bulls and some by comprest type bulls. All dams were of conventional type breeding.

The steers were individually fed in dry lots from shortly after weaning time until they were slaughtered. The length of feeding period varied from 151 to 241 days.

Nineteen different body measurements were taken on each steer at twenty-eight day intervals throughout the growth-fattening period each year. A twentieth measurement, depth of chest, was calculated. Twelve carcass measurements and two carcass cut-out measurements were taken. All measurements were recorded in centimeters.

FINDINGS

The largest differences in conformation were found for the following body measurements, listed in decreasing order:

Hip height

Circumference of paunch

Length of body

Wither height

Circumference of flank

Point of ilium around flank to tuber ischii

Height of chest

Patella to patella

The smallest differences were shown by width of head and circumference of cannon bone. The conventional type steers showed the larger measurement in all cases.

Four measurements, length of cannon bone, height of chest, hip height, and wither height were singled out as showing the smallest amount of overlapping of individual measurements between the two types. Considering these four measurements, the size of measurement suggested for differentiating the two types of steers at about one year of age are summarized as follows:

Length of cannon bone....... 20.1 centimeters

Height of chest............. 48.5 centimeters

Hip height.................. 107.3 centimeters

Wither height............... 101.8 centimeters

These differentiating sizes were not offered as definitely dividing the two types, rather, they were offered as possible guides to be used in classifying twelve month old Hereford steers as to whether they are of comprest type or of conventional type. It was suggested that at least three of the four measurements of the steers be less than the respective differentiating measurement in order to classify a steer as comprest type, or, greater than the differentiating measurement in order to classify a steer as conventional type.

There was very little difference between types in the relative increase or growth in any of the measurements between February and May. The largest relative increase in size of measurements for the two types was for width of loin. Circumference of heart girth and width at hooks also showed large relative increases for both types.

Conventional type steers showed the largest average ratio of weight to wither height but the comprest type steers showed the largest average ratio for all other ratios considered. There was some overlapping between types for the two years for all but two of the seven ratios, namely, weight to wither height and depth of chest to length of cannon bone.

Body measurements cannot be used as a reliable indication of the individual steers' capacity for growth and fattening. However, correlation studies of total digestible nutrients per pound gain with certain body measurements and ratios of these measurements indicated that feeder steers that are shorter legged, shorter in overall height, narrower in chest, shorter in body, and smaller around the paunch tend to be more efficient in the feed lot than those that were taller, longer in body, wider in chest, and larger in the paunch.

In general then, this study shows that the smaller steers tend to be more efficient in the feed lot than steers that are larger, and perhaps older.

A highly significant positive correlation for area of rib eye muscle with patella to patella indicates that the feeder steers with larger hind quarters tend to yield a finished carcass with a larger circumference of rib eye muscle, hence, possibly a higher proportion of lean meat to total bone and fat.

SUGGESTIONS FOR FURTHER STUDY

The relatively high correlation of total digestible nutrients per pound of gain in weight with width of chest as well as significant correlations with other body measurements is sufficiently informative to warrant further study along these lines. Perhaps something could be gained by making multiple correlation studies with some of the more interesting measurements from this standpoint. There also may be other measurements equally informative.

The fact that the comprest type steers show higher ratios of width and depth of body to wither height than the conventional type but that the conventional type steers show a higher ratio for weight to wither height is very interesting and appears to warrant further study. Perhaps something could be learned about this if comparisons of the two types of steers were made at periodic intervals from weaning age, or younger, to slaughter age.

The density of the two types of steers' bodies may not be the same. The work of Washburn, et al. (31), 1948, indicates that the "compact" type of Shorthorns have a slightly higher density of body than do the conventional type. Relationships of this nature relative to the comprest and conventional types of Herefords appears to warrant scientific investigations.

Variations in age may have considerable influence on variations in the different body measurements. Because of this it is suggested that perhaps a truer picture of the various body measurements could be presented in future studies of this nature if they were corrected for age.

The differences shown by some measurements appear to warrant further study, especially to ascertain just what the differences are due to, whether due to skeletal differences, muscular differences, or the degree of fatness. This is of particular interest in the case of width of chest since this measurement showed a high correlation with total digestible nutrients per pound of gain.

It appears that specific differences between the two types of Hereford steers would warrant further study, especially the skeletal measurements that might be used in differentiating the two types. Emphasis might well be placed along these lines on younger steers than were used in this study as it might be desirable to differentiate the two types of steers very soon after birth, or at least by weaning age.

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR

SUPERVISION BY CARL E. SAFLEY

ENTITLED A COMPARISON OF COMPREST AND CONVENTIONAL TYPES OF HEREFORD STEERS AS EVALUATED BY BODY AND CARCASS MEASUREMENTS

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

CREDITS

Committee on Graduate Work

H. H. Stonaker   H T Guard

Major Professor   Minor Professor

Head of Department   Homer J Henney
Dean of Division

Committee on Final Examination

Examination Satisfactory

C R Creek

H. H. Stonaker

H T Guard   R Patton

David H Morgan
Dean of the Graduate School

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Chapter I

INTRODUCTION

This is a study to explore: first, changes in body measurements of two different types of Hereford steer calves during fattening; second, interrelationships between body measurements and the feed lot efficiency and gains of these steers.

Comparative body form in animals is commonly described and evaluated as seen by experienced livestock judges with a more or less standardized terminology and score card for degree of excellence. This visual method and the use of score cards has also been relied upon in this and other studies as a means for differentiating types and sizes and as a basis for studying the importance of these body characteristics on the quality and economy of production of beef. However, the visual method of comparing the conformation of one animal with another lacks the objectivity desired for research purposes. Because of this, it was decided to attempt to use linear measurements as a means of differentiating the two types and possibly as causal factors influencing steer performance in the feedlot.

The small type Herefords compared in this study with average size Herefords as found in most purebred herds, hereafter referred to as conventional type, are apparently very similar in type to the "compact" Shorthorns described by Stonaker and Tom (27), 1944, as a type showing an extreme degree of compactness of body and shortness of bone. The small type of Herefords will hereafter be designated as comprest type. Concerning this comprest type, Ingalls (14), 1948, had the following to say:

> .....comprest type in the Hereford breed is believed to be a mutant, probably due to a single dominant gene. These cattle can be identified at birth; appearing shorter in head, neck, body, and legs than the conventional type Herefords. This identification is distinct throughout the life of the animals. (14:9).

Some of the questions it is hoped may be at least partially answered in this study are:

1. Can body measurements be used to differentiate between comprest and conventional types of Hereford steers?

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4. What is the relationship of fat steer measurements to subsequent carcass measurements?

5. What is the relationship of slaughter grade to subsequent carcass measurements?

This investigation has been limited to data taken during two growth-fattening periods. Twenty-seven and thirty head of steers, respectively, were used in this study in 1948 and 1949. The data consist of nineteen body measurements, initial and final weights, and the amount of feed individually consumed by these fifty-seven steers. The eighteen comprest steers were sired by two comprest bulls. The thirty-nine conventional type steers were sired by two comprest and five conventional type bulls.

Chapter II

LITERATURE REVIEWED

Early investigations

Animal measurements were made as early as 1779 when Daubenton (18) used a micrometer to measure the fineness of wool. A century later Meeh (11) published what is thought to be the first paper written concerning measurements of the body for use in calculating the surface area of an individual, in this case, humans. He suggested that the surface area of any individual could be calculated from linear body measurements.

Much of the early work on body measurement studies of cattle was done in Germany according to Lush (19), 1928, who summed up this early research as either a study of the changes that take place during growth after birth or as an objective means for describing certain races or breeds of cattle.

Descriptive measurements

Probably the most detailed and complex measurements of animals used are those made by animal sculptors who early recognized the necessity for some dependable method of measuring live animal bodies.

Bush-Brown (3), 1912, declared that for the purpose of reproducing an animal from non living material neither absolute measurements nor a comparative measurement based on the circumference of the animal, as unit, is of much value. He used instead, regardless of the size of the animal, height at withers as a basis to determine the unit of measure to be used in the particular animal in mind. The painter, Megargee, and the sculptor, Kawamura, for many years, according to Gulliver (10), 1926, used a system of measurement and proportion based on the length of the head. Swett, a dairy husbandman, et al. (28), 1937, likewise pointed out the importance of the use of body proportions or the relationship of each of the different measurements to one or more measurements thought to be most nearly representative of the true skeletal size of the animal.

Measurements as associated with type studies

In a 1927 report on a study of beef calves relative to type, as designated by ranginess or low-setness, Hultz (12) found that with but one exception, namely, body length in the final measurements, type appeared to be associated with height, body circumference, or body depth. The two most important ratios for indicating type were the chest depth to height at withers and paunch circumference to height at withers. However, they pointed out that the latter may not be particularly reliable as a visual determiner of type because of the tendency of the paunch to extend to the side as well as downward.

In the second experiment of this popular series concerning type in beef steers at the Wyoming Agricultural Experiment Station, Hultz and Wheeler (13), 1927, using two-year-old beef steers took the following five measurements:

1. Heart girth
2. Circumference of paunch
3. Width across hips
4. Height at withers
5. Chest, floor to ground

and calculated a sixth, depth of chest. From the results obtained with these measurements they concluded that the intermediate type steers demonstrated an intermediate growth in height as well as breadth but the low-set steers seemed to grow taller, rather than wider while the rangy steers appeared to grow broader rather than taller.

Ingalls (14), 1948, found that conventional type steers had a larger weight to wither height ratio than "compress" type steers. However, he also found that compress type steers had a greater average ratio of heart girth to wither height and a greater ratio of circumference of hind quarters to wither height than did the conventional type steers. He did not find a significant correlation between the ratios of these body measurements and efficiency of converting feed into beef.

Body measurements as affected by fattening

A study of 14 linear measurements of horses reported in 1912 by Cochel and Severson (4) indicated that a change in width of body is more apt to take place than a change in body depth in fattening horses.

The Missouri Agricultural Experiment Station has conducted an extensive series of detailed and integrating experiments on the use of feed by cattle, some of which incorporated many body measurements. In a report on one of these studies in 1918, Trowbridge, Moulton, and Haigh (30) said that by the use of a hinged wheel with adjustable points for getting the exact contour at the heart, flank, and paunch girths the increase in height as well as the increase or decrease in width could be determined. Later, in 1919, they (29) reported that a gain in the measurement of the heart girth of very young steers may show skeletal growth, whereas a gain in the same measurement in steers more than one year old is largely an indication of increase in flesh or fatness.

Of seven measurements taken in an experiment reported by Hultz (12), 1927, the greatest increases from the beginning to the end of the fattening period were shown in heart girth, width at hips, and paunch girth, although all of the seven measurements showed increases for the calves in this study.

Concerning a report on "Changes in Form and Weight on Different Planes of Nutrition" by Moulton, Trowbridge, and Haigh (22), 1921, Lush (19), 1928, had the following to say:

> .....a comparison of the average measurements for the steers on the good, medium, and poor rations, combined with a knowledge derived from slaughter tests that the steers differed much more in fatness than in quantity of muscle or of skeleton, does warrant the conclusion that the differences in the average measurements were largely caused by the differences in the fatness of the three groups of steers. On this basis it may be concluded that:
>
> (a) Height at withers is affected practically not at all by fatness
>
> (b) Height at hips is affected very little if at all by fatness
>
> (c) Length from shoulder to hips is slightly affected by fatness
>
> (d) Length from shoulder to ischium increases distinctly with fatness
>
> (e) Width at hips increases distinctly with fatness.
>
> (f) Heart girth increases very greatly with increases in fatness. (19:6).

Four measurements, heart girth, paunch girth, shoulder height, and rump height were taken in conjunction with some 120 and 210 day cattle feeding experiments at the Iowa Agricultural Experiment Station reported in 1926 by Evvard, Culbertson, Wallace, and Hammond (7) and in 1927 by Evvard, Culbertson, and Hammond (6) followed in the same year by Culbertson, Evvard, and Hammond (5). They used calves, yearlings and two-year-olds in these tests and all four measurements exhibited increases from the beginning to the end of the feeding trials. The greatest increases were made by the heart girth and paunch girth measurements. Their results also indicated that the measurements of the younger cattle increased more than did those of the older cattle.

Lush (19), 1928, reported on measurements taken on 185 steers at the Texas Agricultural Experiment Station. Eight different measurements were taken on each of the 185 steers. Each measurement showed the following percentage increase or decrease relative to live weight during the fattening process:

(a) Chest width............ ≁ 9.29%
(b) Loin width............. ≁ 5.18%
(c) Chest girth............ ≁ 1.55%
(d) Flank girth............ ≁ .97%
(e) Paunch girth........... - .35%
(d) Depth of chest......... - 1.95%
(e) Length of body......... - 3.53%
(f) Height over withers.... - 5.68%

He stated that, in general, there is a greater increase in width during fattening than in length or depth of body, and least of all in the height and head measurements. He found that the soft parts of the body increase most rapidly. Of the bony measurements, those of the pelvis showed the greatest increase. The ratio of chest girth to wither height appeared to be the most useful in general. He concluded that linear measurements should be regarded as supplementary to other means of description rather than as a substitute for them.

Predicting grades from body measurements

Correlating the appraisal price per pound of dressed carcass with the following variables:

(1) Caul and ruffle fats
(2) Estimated fatness
(3) Initial weight
(4) Final weight
(5) Gain
(6) Carcass weight
(7) Other
(8) Dressing percent

Lush (20), 1932, found the highest correlations to be .35 between appraisal price per pound and final weight and .32 between appraisal price per pound and carcass weight. The other correlations were all below .29. This, he pointed out, indicates that there is little hope of finding a high correlation between body measurements of feeder calves and the appraisal price of meat at the end of the feeding period. He showed that, using initial weight and gain as independent variables and appraisal as the dependent variable, the multiple correlation is only .279. He considered that, in this case, a correlation of .16 probably is significant and .21 is certainly significant.

Measurements for predicting rate of gain

In a search for an answer to the work of Mitchell and Grindley (21), 1913, which showed the importance of increasing the uniformity of gains within a given experimental lot of livestock, Severson and Gerlaugh (23), 1917, correlated rate of gain with fifteen different body measurements. They attempted to find some definite aid to supplement the empirical method of selecting animals as to their gaining capacity in the feed lot in order to lower the probable error of experimentation caused by individual differences between the animals under study. In general they found measurements of the hindquarters of a steer to have more predictive value as to gaining capacity than those of its forequarters. Of the twenty-three measurements taken the one showing the highest correlation with gains in live weight was the length from hip to buttock. They considered this correlation coefficient of .271 $\pm$ .053

to be of some value when selecting feeder steers. Severson, Gerlaugh, and Bentley assembled many individual measurements and weights in the same report (25) but they have not been summarized.

Hultz and Wheeler (13), 1927, calculated simple correlation coefficients between each of six measurements and the individual total gains per steer but none proved significant because of the accompanying error, consequently they were unable to predict gaining capacity from the initial measurements.

In studying the changes in body measurements during fattening, Watson (32), 1932, reported a correlation of .4190 $\pm$ .0348 of width between the eyes and rate of gain although practically no correlation between length of face and rate of gain. The correlation between circumference of shin bone and gain in weight was found to be .3630 $\pm$ .0378. The other body measurements considered showed practically no correlation to rate of gain.

The work of Lush (20), 1932, tended to confirm the idea that general size is the cause of much of the primary correlation of a measurement with gain in weight rather than a relation with that particular measurement. His calculations showed that neither the head length nor the head width indicated anything about gain, regardless of whether considered as dimensions or as ratios. The width of chest likewise had practically no value in connection with rate of gain. The five most important measurements from the standpoint of maximum gain in weight appeared to be:

(a) Body length, long
(b) Height at withers, tall
(c) Flank girth, small
(d) Width of loin, narrow
(e) Paunch girth, large

Other measurements that were on the borderline of statistical significance, or near it, are:

(a) Muzzle, small
(b) Chest, shallow
(c) Heart girth, large
(d) Hips, not tall

In view of these data he stated that there is very little association between conformation and rate of gain, except, that in general, large but thin steers tend to gain rapidly. He further stated that steers with wide differences in conformation might all be high in daily gains, and steers very similar in conformation may vary widely in gaining capacity.

In summarizing a considerable amount of data, Lush (20), 1932, said that, although conformation is very often the only means available for evaluating an animal, the data indicate that specifications based on conformation could never be used to accurately predict the future rate of gain of individual steers.

Black, Knapp, and Cook (2), 1938, found that, with weight nearly constant, length of body was more closely associated with efficiency and rate of gain than was height at withers. However, with weight not nearly constant, the reverse situation prevailed. They also pointed out that, when using ratios for supplementing other means of predicting future performance, one should make corrections for differences in fatness, weight, and age of the animal because of the changes in these factors throughout the course of the animal's life.

Some statistical comparisons of certain body measurements with daily gain were made on three groups of calves in a three year progeny testing study at the Arizona Agricultural Experiment Station. The results published in 1945 by Stanley and McCall (26) indicated that, before the measurements were corrected for size, circumference of cannon, length of body, width at the thurls, height at withers, and fullness at the stifle all had highly significant positive correlations with rate of daily gain in weight. After dividing the measurements by height at withers to eliminate the effect of size the modified correlation of circumference of cannon and length of body with daily gain barely showed significance. In relation to their height the shallowest bodied steers slightly out gained the deeper-bodied steers.

Measurements useful in predicting efficiency

In 1915, Moulton, Trowbridge, and Haigh (22) concluded that as the weight of cattle increases, the cost of maintenance in energy increases per unit of surface area.

In reporting an efficiency variation study of steers, Winters and McMahon (33), 1933, concluded that there is a marked difference in the abilities of steers judged to be of the same breeding, age, weight, market grade, and condition to make economical gains. They declared also, that the shape of any given animal cannot be used as an accurate indicator of that animal's efficiency of feed utilization.

Evidence reported by Black, Knapp, and Cook (2) in 1938 was based on a study of beef, dual purpose, and dairy breeding. A ratio of weight to height at withers was a better measure of efficiency of gain than was the ratio of heart girth to height at withers. Length of body gave a higher correlation with efficiency than did height at withers.

Relationship of type to rate of gain

Hultz and Wheeler (13), 1927, compared the gaining capacity of three different types of steers. They concluded that low-set type steers were slightly more rapid gainers than rangy or intermediate type steers. In the experiment reported the steers were fed for a period of 156 days.

In the four years that large and small type Hereford steers were compared by Woodward, Clark, and Cummings, (34), 1942, the large type steers made somewhat faster gains both as calves and as two-year-olds.

In Hereford type tests reported by Stanley and McCall (26), 1945, steers classified as low-set gained more than did those rated as medium type, but the up-standing steers showed the highest rate of gain. According to a progeny test study reported by the above workers, uncorrected height at withers correlated with gain showed that the tallest steers gained the most but a negative correlation of corrected height at withers to daily gain indicated that the low-set steers demonstrated the greatest rate of gain.

Knox and Koger (17), 1946, reported on a nine year type study of approximately 350 yearling Hereford steers very similar in breeding and raised in a similar environment. Rangy steers were equally as thick as compact steers but differed from them in the proportion of height and length to depth and in size due to greater height and length. The rangy type, with but one exception, ranked first in average daily gain each year although there was a non-significant tendency for the compact cattle to rank high when gain was expressed in percent of initial weight. Some compact steers made very rapid gains. In view of these facts, they pointed out that greater actual average gains made by the rangy cattle were due to size and associated feeding capacity and growth rate rather than to body form.

Relationship of type to efficiency

Using steer calves for the study, Hultz (12), 1927, reported that the most economical gains were made by very rangy calves as contrasted to very low-set calves. However, Hultz and Wheeler (13), 1927, using two-year-old steers in a 156 day feeding period reported that slightly more efficient gains were made by low-set type steers than by the rangy or intermediate type. Differences in efficiency as between types were not pronounced in either experiment.

One conclusion from a correlation of body measurements in a study of fifty record-of-performance steers made by Black, Knapp, and Cook (2), 1938, was that, with weight constant, the type of animal that is shorter in height, shorter legged, and shallower in the chest is a little higher in efficiency than the taller, longer legged, deeper bodied animal.

Research at the Montana Agricultural Experiment Station concerning large and small type Hereford cattle was reported in 1942 by Woodward, Clark, and Cummings (34). They found that the large type steers were slightly more efficient in utilizing their feed in three years of the four-year investigation.

Using "compact" and conventional type Shorthorn steers in a study of efficiency reported in 1948, Washburn et al. (31) showed that there was a slightly lower efficiency of feed utilization but also a lower rate of decline in efficiency of conversion exhibited by the "compact" animals than by the conventional type. In spite of this difference in rate of decline of efficiency both types reached the same efficiency level by the time they were visually judged finished. This was demonstrated by plotting efficiency on both weight-constant andage-constant bases although they believe that physiologic data can be adequately compared on an age-constant basis.

Correlation of rate of gain with efficiency of gain

Gerlaugh (8), 1931, reported on the feeding of five lots of twenty steer calves each. The cattle that made the most rapid gains and sold at the top price returned 63 cents a bushel for the corn they ate while the slowest gaining lot that sold for fifty cents less per hundred pounds returned 65 cents for each bushel of corn fed them. In another Ohio test with two lots of steers that showed .4 pound difference in daily gain the more rapid gaining lot outsold the other lot 65 cents per hundred weight but only returned a cent more per bushel for the corn they consumed.

As pointed out by Knapp et al. (20), 1941, it is expected that the correlation between rate of gain and efficiency of gain will be approximately .50 in a time constant population. This is in harmony with Snedecor (25), 1946, namely, that any correlation that has the numerator or the denominator common to both factors is a spurious correlation. He qualified this fact by stating that it is the interpretation that may be spurious.

A correlation of .34 between rate and efficiency of gain before being corrected for mean live weight and .71 after being corrected for mean live weight was reported by Winters and McMahon (33), 1933. Relative to the same two factors the high correlation of .88 was reported by Black and Knapp (1), 1936, as studied in a time variable population. With time constant, Knapp et al. (16), 1941, reported correlations of .436 and .527 between daily gain and efficiency in the feed lot. Knapp and Baker (15), 1944, found the correlation between the observed rate and gross efficiency to be .49. They thought this correlation indicated a relatively high error in selection for efficiency based on rate of gain. The lot means of rate and efficiency showed a low relationship. The fastest gaining sire group was most efficient. The next fastest gaining group was next to the poorest in efficiency. The slowest gaining lot was fourth in efficiency. Except for the fastest gaining group, none of the nine sire groups were in the same rank of efficiency that they were ranked in rate of gain.

Guilbert and Gregory (9), 1944, attempted to feed to an equal degree of fatness. Under these conditions two lots having the same rate of gain differed significantly in economy of gain. Thus they concluded that absolute rate of gain was not a satisfactory index of economy of gain in groups differing in potential mature size and in earliness of maturity.

Summary of literature reviewed

The literature relative to descriptive measurements (Bush-Brown (3), 1912; Gulliver, (10), 1926; Swett et al. (28), 1937) indicates that the relationship of each of the different measurements to one or more measurements thought to be most nearly representative of the true skeletal size of the animal is of paramount importance.

Hultz (12), 1927, found that the most reliable ratio for indicating type was chest depth to height at withers.

In general, heart girth is the measurement that increases most during fattening according to the data (Hultz (12), 1927; Lush (19), 1928; Evvard, Culbertson, Wallace, and Hammond, (7), 1916; Culbertson, Evvard, and Hammond, (5), 1927; Evvard, Culbertson, and Hammond (6), 1927). The general conclusion seems to be that body measurements should be regarded as supplementary to other means of description rather than as substitute for them.

Lush (20), 1932, pointed out that there is little hope of finding a high correlation between body measurements of feeder calves and the appraisal price of meat at the end of the feeding period. He also concluded that specifications based on conformation could never be used to accurately predict the future performance of individual steers. The latter was confirmed by Winters and McMahon (33), 1933.

Some of the literature (Woodward, Clark and Cummings (34), 1942; Stanley and McCall (26), 1945; Knox and Koger (17), 1946) indicates that the rangy or large type cattle make the most rapid gains. In regard to efficiency some research (Hultz (12), 1927; Woodward, Clark, and Cummings (34), 1942; Washburn et al. (31), 1948) indicates that larger type cattle are slightly more efficient than smaller type. However, Hultz and Wheeler (13), 1927, found that, with two-year-old steers in a 156 day feeding period, the low-set type steers were slightly more rapid gainers and slightly more efficient than the rangy or intermediate type.

Severson and Gerlaugh (23), 1917, found that measurements of the hindquarters of a steer had more predictive value as to gaining capacity than those of its forequarters. Hultz and Wheeler (13), 1927, were unable to predict gaining capacity from initial measurements. When considering maximum gain in weight, Lush (18), 1932, found that the desirable type of steer would be one that was tall with a long body, small flank girth, a large paunch, and a narrow loin. He stated that there is very little association between conformation and rate of gain, except that in general, large but thin steers tend to gain rapidly.

Gerlaugh (8), 1931, showed that the fastest gaining steers are not always the most efficient converters of feed. Ten years later Knapp et al. (16) reported that the correlation between rate of gain and efficiency of gain is expected to be approximately .50 in a time constant population since this is a spurious correlation.

Chapter III

MATERIALS AND METHODS

The steers were good to fancy quality purebred Hereford beef calves. They consisted of all the male calves produced by fifty-eight Hereford cows in 1947 and all the male calves produced by sixty-four Hereford cows in 1948. These calves were castrated while still nursing and later used in this experiment. No culling was practiced. Some of the calves were sired by conventional type bulls and some were sired by comprest type, while all dams were of conventional type breeding.

The calves were all raised to weaning age at the San Juan Basin Substation associated with Fort Lewis A and M College, Hesperus, Colorado. Each of the two years the calves were weaned early in December and transported to Fort Collins, Colorado where they were unloaded at the experimental feeding yards of the Colorado A and M College.

Feeding lots

The calves were individually fed in the dry lots until they were slaughtered. For details concerning the feeding lots the reader is referred to Ingalls

(14), 1948.

Weighing

All steers were weighed the morning they went on feed and periodically at twenty-eight day intervals from that time until slaughter day. They were withheld from feed for twenty-four hours prior to the final weighing at eight a.m. on the morning they were to be slaughtered.

Method of individual feeding

The steers were randomly assigned to feeding lots and also randomly assigned to stanchions. Although the stanchions were of the lock type the calves were locked in them only long enough to fasten a short tie chain to a numbered neck chain on each animal or to unfasten the tie chain. The calves were fed at 5 p.m. and had free choice of the ration until 8 a.m. the following morning. The short tie chains allowed some freedom of movement during this time.

The steers were hand fed throughout the feeding periods although the method used approximated self feeding in that each animal was given slightly more than he would eat by 8 a.m. the following morning. Feed was weighed into individual, numbered barrels that were kept in front of each steer's stanchion. Uneaten feed was weighed back into the barrel every fourteen days until a month preceding slaughter when weekly weighbacks were necessitated.

Grading and classifying at beginning of feeding period

Each calf was graded and then classified as to type, either conventional or comprest, on the day that the initial feed lot weights were taken. The grading and classifying was done by judges from the Animal Husbandry staff. The results of the grading were recorded by using a numerical value for each feeder grade; using six for fancy, five for choice, four for good, and three for medium. An average of the judges' ratings was used as the final recorded grade.

Grading at end of feeding period

Judges from the Animal Husbandry staff graded the steers on the morning they were to be slaughtered. The reader is referred to Ingalls (14), 1948, for a sample of the chart used as an aid to arrive at the grade.

Body measurements

Nineteen different body measurements were taken on each steer at twenty-eight day intervals throughout the growth-fattening period each year. All measurements were made with a steel tape, small arm calipers, and large arm calipers with a built-in spirit level and were recorded in centimeters.

While being measured, each steer was allowed to stand in as nearly a natural position as possible on the concrete floor behind their respective stanchions. Each measurement was taken twice at intervals of about fifteen minutes and an average of the two measurements was used. A recorder was provided for the person taking the measurements.

The nineteen measurements taken were:

1. Length of head
2. Width of head
3. Circumference of muzzle
4. Circumference of cannon bone
5. Length of cannon bone
6. Circumference of heart girth
7. Circumference of paunch
8. Circumference of flank
9. Anterior point of ilium around the flank to posterior point of tuber ischii
10. Patella to patella
11. Hip height
12. Wither height
13. Height of chest
14. Length of body
15. Width of chest
16. Length of pelvis
17. Width at hooks
18. Width of loin

19. Pelvis width

For details as to how each of these nineteen measurements was taken the reader is referred to Ingalls (14), 1948. A twentieth measurement, depth of chest, was calculated by subtracting the height of chest from wither height.

Carcass measurements

All measurements were taken on the right side of split carcass. The first measurement listed below was taken as the right side of carcass hung from a hook in normal position, neck down. Measurements numbered 6 and 7 were taken at time of slaughter. All other measurements were taken after the side was cut between the twelfth and thirteenth ribs. Carcass measurements taken were as follows:

1. Length of body from first rib to pelvic bone - this measurement was taken with a steel tape, measuring from the anterior edge of first rib to the highest anterior point of pelvic bone.

2. Length of leg from pelvic bone to square shank joint - this measurement was taken with small arm calipers, measuring from the highest point of pelvic bone to the highest point of hock joint.

3. Depth of body from shoulder to chest floor - small arm calipers were used to measure from the lower edge of flesh below breast bone (sternum) across the first rib to outer edge of flesh above the spinous

processes.

4. Thickness through chuck at first rib - this measurement was made with large arm calipers pivoting on first dorsal vertebra.

5. Length of arm bone from scapula to square shank joint - small arm calipers were used to take this measurement from ventral (external tuberosity of radius) surface of radius bone to dorsal edge of knee joint (joint between fused second and third carpal bones and metacarpal tuberosity).

6. Length of front cannon bone - a steel tape was used to measure distance from dorsal edge of knee joint to upper edge of dewclaw.

7. Circumference of front cannon bone - a steel tape was used to measure the circumference of skinned shank at the smallest point between dewclaw and the dorsal edge of knee joint.

8. Length of cross section of rib eye muscle (longissimus dorsi) - for this and the following measurement, the rib eye muscle (longissimus dorsi) was first cross sectioned by a cut crowding the eleventh rib and then a tracing was made of this cross section of rib eye muscle. From this tracing the length of the cross section of rib eye muscle was measured with a centimeter ruler.

9. Width of cross section of rib eye muscle

(longissimus dorsi) - width was measured with a centimeter ruler from the same tracing as used for the previous measurement.

10. Width of cross section of round - for this and the following two measurements, the rump was removed by cutting just posterior to pelvic bone, the round then being laid with flat side on the table. Width was then measured with small arm calipers held perpendicular to table measuring from bottom of round across large round bone to top of round.

11. Length of cross section of round - a short arm caliper was used to measure from a point opposite round bone, parallel to table top and at right angles to the previous measurement, across round bone to the opposite edge of round.

12. Circumference of round - a systematic method of determining the point of round at which circumference would be measured was determined in the following manner.

a. A short arm caliper was used to measure the distance from the highest anterior point of pelvic bone to the highest anterior point of hock joint.

b. This distance was multiplied by 61.50 percent to determine the point at which the circumference would be measured.

c. This calculated distance was set on the small arm caliper which was used to locate three points; one on top of round and one on either side of round equi-distant from hock joint, where skewers were inserted for markers.

The circumference of round at these three points was then measured with a steel tape.

13. Area of rib eye muscle (longissimus dorsi) - for this and the following measurement the tracing used for measurement number eight was used. The area was measured with the use of a planimeter.

14. Fat over the rib - the average of two points, arbitrarily picked as being representative of the thickness of fat over the eleventh rib, was used for this measurement.

Carcass measurements numbered six and seven were developed by members of the Animal Husbandry staff at Colorado A and M College. All other carcass measurements were developed with the aid of suggestions in private communications with O. G. Hankins, senior animal husbandman in charge of meat investigations, Bureau of Animal Industry, United States Department of Agriculture.

1947-48 Fattening Period

Arrival of calves

The calves were weaned December 15, 1947 and sent directly to Fort Collins by truck. The calves were then dehorned and after allowing ample time for healing, they were started on feed.

Ration

The ration fed was a mixture of 25 percent ground alfalfa hay, 30 percent dried beet pulp, 15 percent cracked yellow corn, 15 percent rolled barley, and 15 percent soy bean meal. Percentage figures are by weight. Total digestible nutrients per pound of feed were calculated by Ingalls (14), 1948. Salt was fed ad libitum between 8 a.m. and 5 p.m.

One thousand pounds of the mix was prepared at a time and thoroughly mixed in a vertical auger type mixer for twenty minutes.

Length of feeding period

There was a difference in length of time on feed varying between 173 and 212 days for the reason it was desired that all animals grade high good or better before being slaughtered.

Problems encountered

Two steers were eliminated from the experiment because of constant bloating. One of these was a conventional type steer and the other a comprest type. All cases of footrot were treated by veterinarians with 50 grams of Sodium-Sulfathiazole intravenously. Most symptoms disappeared within twenty-four hours after treatment.

Feeder steer measurements used were actually taken one month after the steers had been on feed due to lack of some specialized measuring equipment the first time of measuring.

1948-49 Fattening Period

Arrival of calves

The calves arrived at Fort Collins, December 7, 1948, by truck. All calves contracted shipping fever, consequently they were not put on feed until it had been checked.

Ration

The steers were put on feed December 17, 1948. Four slightly different rations were fed during the growth-fattening period. The percent of the ration by weight for the different feeds are as follows:

	Feeds o/o by Weight in Ration					
	Rolled Barley	Cracked Yellow Corn	Dried Beet Pulp	Soy Bean Oil Meal	Alfalfa	Molasses
12/17/48 to 2/25/49	13.99	13.99	27.97	13.99	23.31	6.76
2/25/49 to 4/8/49	12.50	12.50	25.00	10.00	40.00	0.00
4/8/49 to 5/6/49	12.16	12.16	24.32	12.16	33.31	5.88
5/6/49 to 8/14/49	15.00	15.00	30.00	15.00	25.00	0.00

Salt was fed ad libitum from 8 a.m. to 5 p.m. throughout the growth-fattening period.

Length of feeding period

There was a difference in length of time on feed varying from 151 to 241 days for the reason it was desired that all animals have a slaughter grade of high good before being slaughtered.

Problems encountered

Two steers were eliminated from the experiment. One died early in the period from impaction. The other was eliminated because, as a chronic bloater it was thought that his record would not present a reasonable picture of a growth-fattening period. Another steer, a semichronic bloater was left in the experiment. There were several cases of bloat in the early part of the experiment but most of it was eliminated when the percent of concentrates in the ration was changed. One steer was lame for a short time as a result of an accident while dipping for lice. One steer had coccidiosis two different times and one steer had scours once.

Method of analysis

Using all nineteen body measurements and the ratios as listed, line graphs have been made to be used as an aid in showing the differences in types and years. For those data where line graphs would have failed to reveal much, tables have been used.

For certain selected measurements and characteristics, correlation coefficients have been calculated in accordance with Snedecor (25), 1946.

Covariance analyses have been calculated, using as the dependent variable those characteristics which seem to be of paramount interest in this study.

Chapter IV

ANALYSIS OF DATA

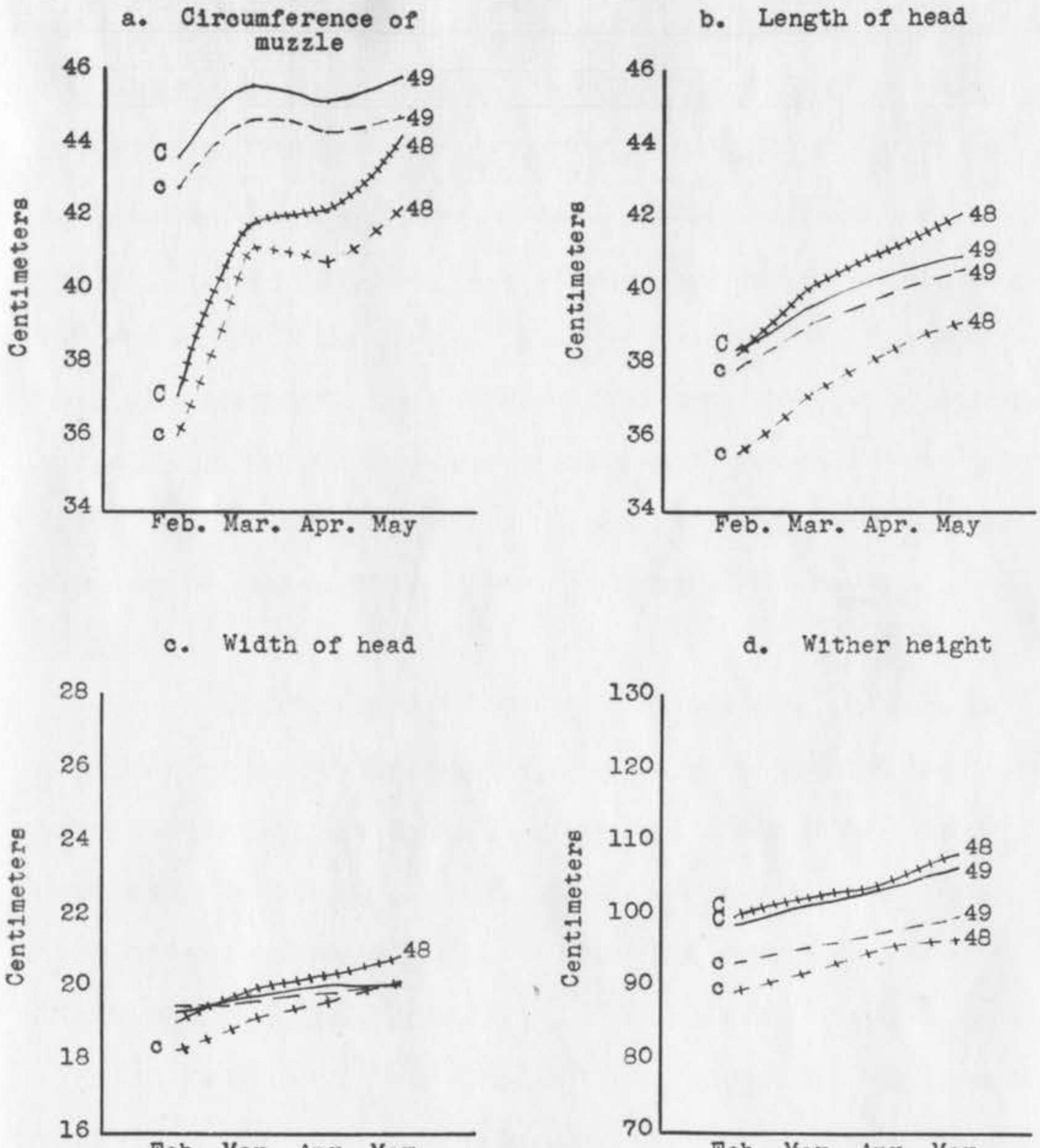
Differences in measurements

During the two years that measurements were taken on the steers in this study there were only four months, February, March, April, and May, in which measurements were taken on all steers on feed both years. The day the measurements were taken in February, 1948, the steers on feed had an average age of 245 days. The day the measurements were taken in February, 1949, the steers on feed had an average age of 257 days.

All nineteen body measurements, as well as one calculated measurement, and ratios of certain of these measurements were averaged individually by types and by seasons for each of the four months previously mentioned. The averages of ratios will be shown later. The averages of all measurements, including the calculated measurement, are summarized on line charts numbered 1 through 5.

Chart 1a shows very little difference in circumference of muzzle between types. The conventional type steers have slightly larger muzzles. There is a

Chart 1.—AVERAGE BODY MEASUREMENTS OF STEERS ON FEED



C ++++++++ 48 Conventional type steers 1948
C ———— 49 Conventional type steers 1949

c + + + + + + 48 Comprest type steers 1948
c – – – – – – 49 Comprest type steers 1949

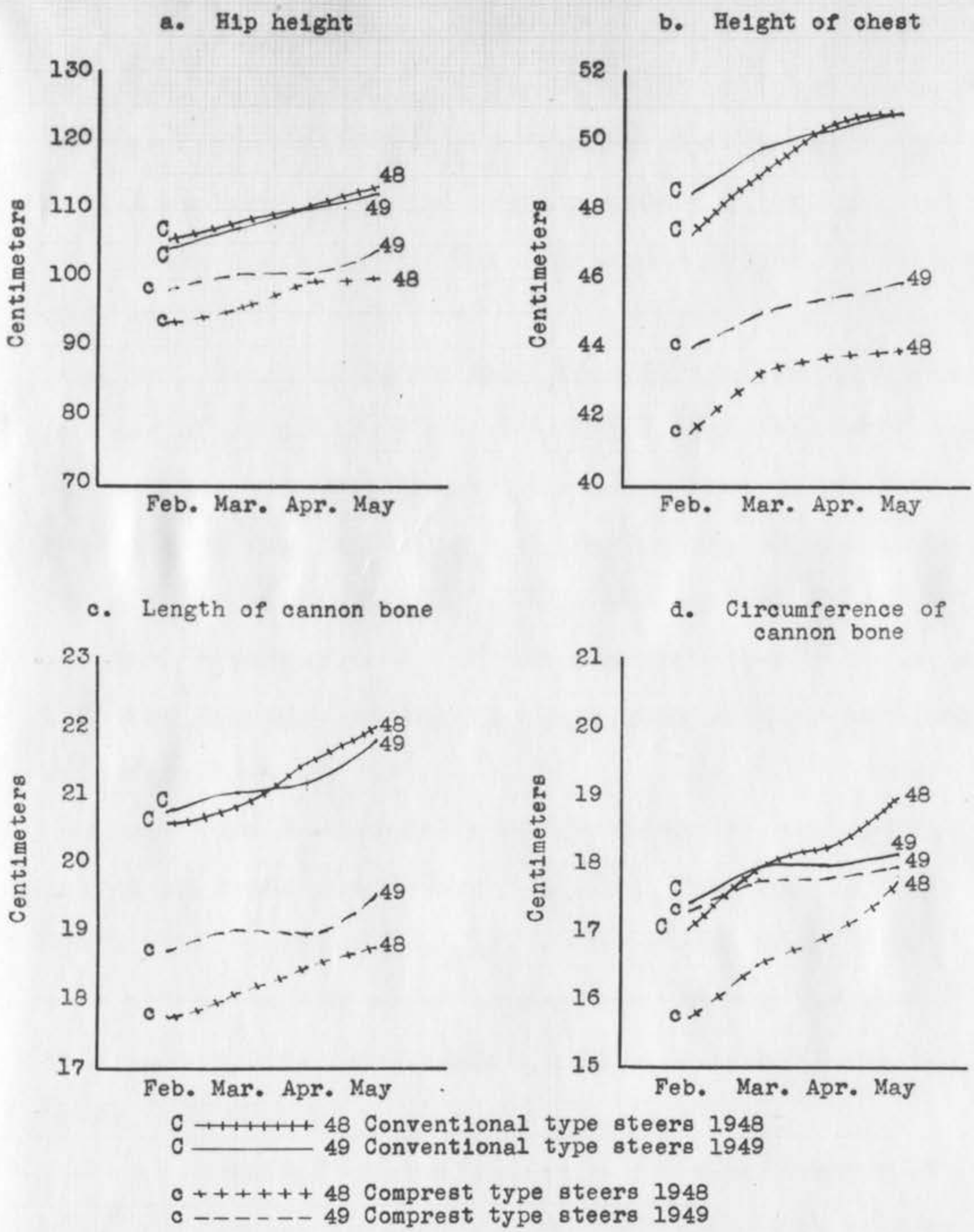
difference of about three centimeters for this measurement between years.

For the year 1948, as shown on chart 1b, conventional type steers have longer heads by approximately two centimeters. However, in 1949, although the conventional type steers had longer heads, the difference was only about one-half centimeter. The measurements of width of head for the 1948 steers, as shown on chart 1c, indicates that the conventional type steers were wider than the comprest type steers for each of the four months compared. The 1949 measurements were inconsistent in differences between the two types, but in general were similar to those differences between the two types for 1948.

Charts 1d, wither height, and 2a, hip height, show that the two measurements are very similar both in actual measurement and the increase during the growth-fattening period. In both instances the conventional type steers averaged taller than the comprest steers. There was a slightly wider spread between the two types for the year 1948 than for 1949. In general the conventional type steers are shown to average about ten centimeters taller than the comprest type steers.

Average height of chest, as shown by chart 2b, is nearly six centimeters greater for the conventional type steers than for the comprest type each of the two

Chart 2.--AVERAGE BODY MEASUREMENTS OF STEERS ON FEED



years compared. There was a general increase in height of chest from the ground throughout the four months considered.

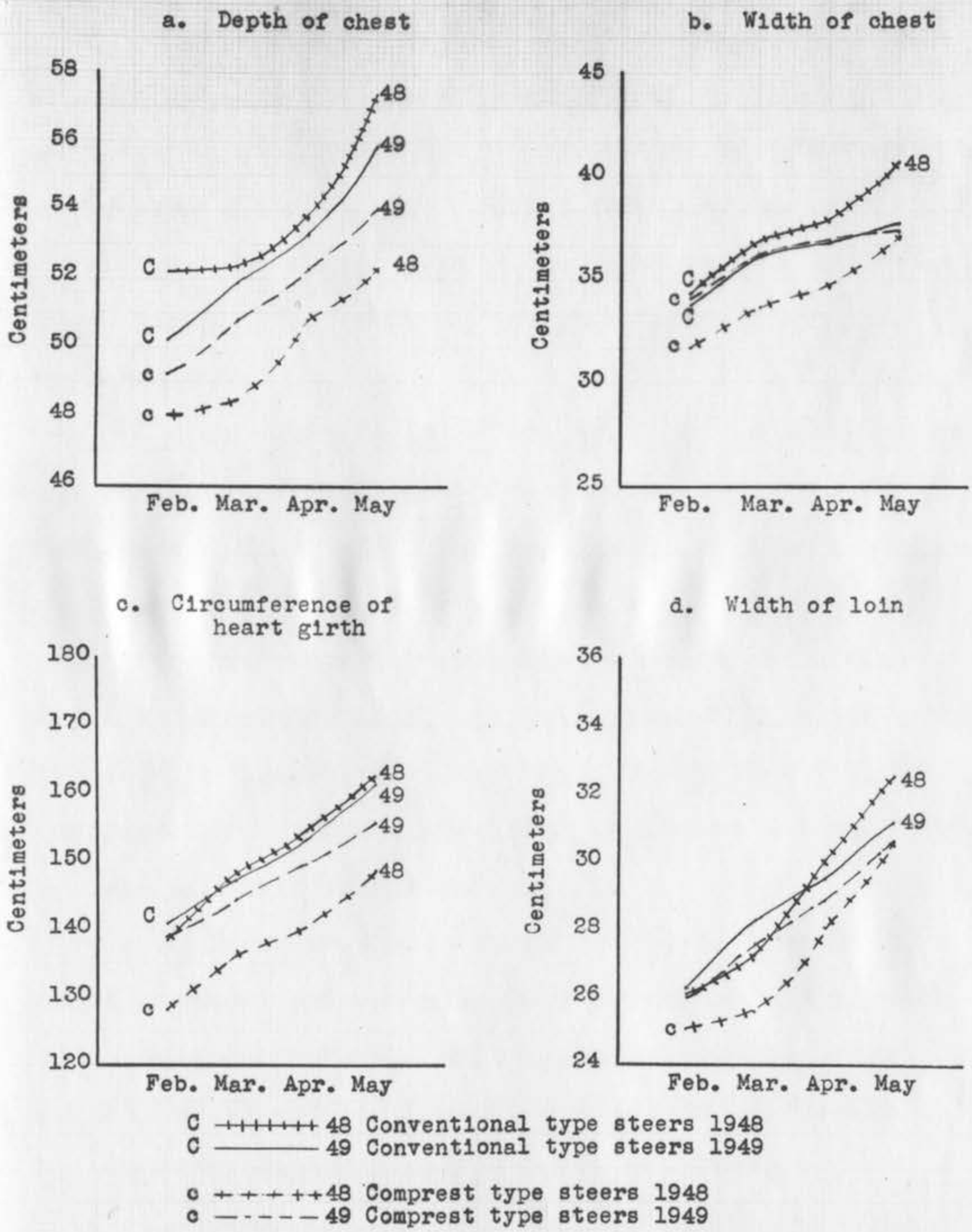
Average differences in length of cannon bone are shown in chart 2c. There is a definite difference between types of about three centimeters for all four months compared. The 1949 measurements do not show as uniform an increase for the four month period as do those for 1948.

Chart 2d shows that the differences in circumference of cannon bone between types were uniform throughout the four months that measurements were taken each year. However, in 1948 the circumference of cannon bone for the conventional type steers averaged about one centimeter larger than for the comprest steers while in 1949 the average difference was approximately one-tenth of a centimeter.

Depth of chest was calculated by subtracting height of chest from wither height. The results are summarized on chart 3a. The conventional type steers were deeper in the chest during both years, the spread being about four centimeters in 1948 and about one centimeter in 1949.

Chart 3b shows the relative measurements of width of chest. In 1948 the conventional type steers averaged about three centimeters wider than the comprest

Chart 3.--AVERAGE BODY MEASUREMENTS OF STEERS ON FEED



type steers while in 1949 there was a certain amount of overlapping of this measurement, the two types being very close together.

Chart 3c shows very little difference between types for circumference of heart girth in 1949 with some overlapping of the two types. However, the 1948 measurements show a difference of about five centimeters, conventional type steers having the largest circumference of heart girth. The increase is gradual for both types both years.

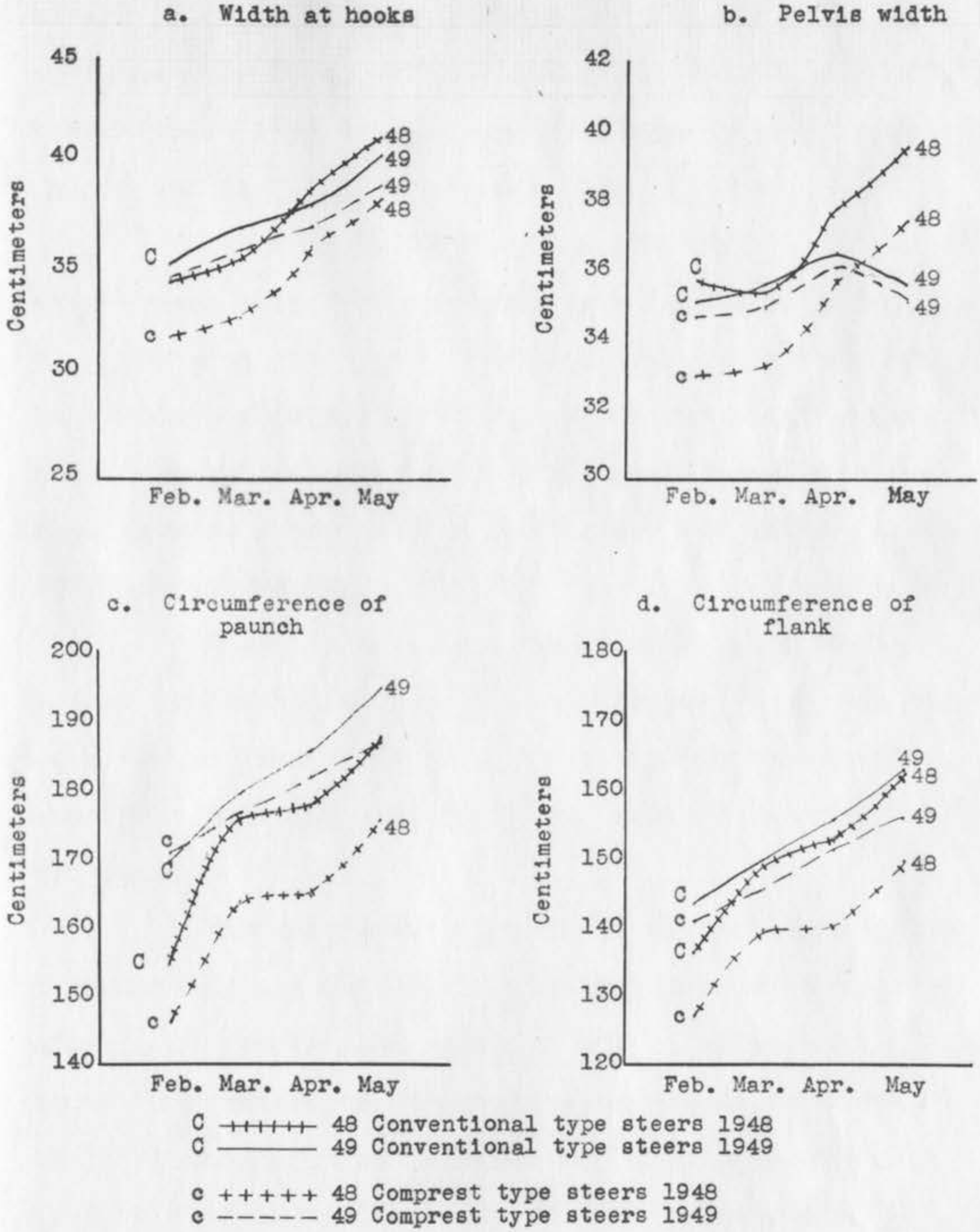
As shown by chart 3d, width of loin was about one centimeter greater for the conventional type steers each year. There was some overlapping of this measurement for the two types between years.

The average measurement of width at hooks, as shown by chart 4a, is about two and one-half centimeters greater for the conventional type steers than for the comprest type while in 1949 the difference was only about one and one-half centimeters.

Chart 4b shows a rather erratic picture of month by month pelvis width measurements. The differences between types are uniform throughout the four months but do not show a steady increase or decrease. No plausible explanation for this is offered.

Chart 4c, circumference of paunch, and 4d, circumference of flank, show a larger difference between

Chart 4.---AVERAGE BODY MEASUREMENTS OF STEERS ON FEED



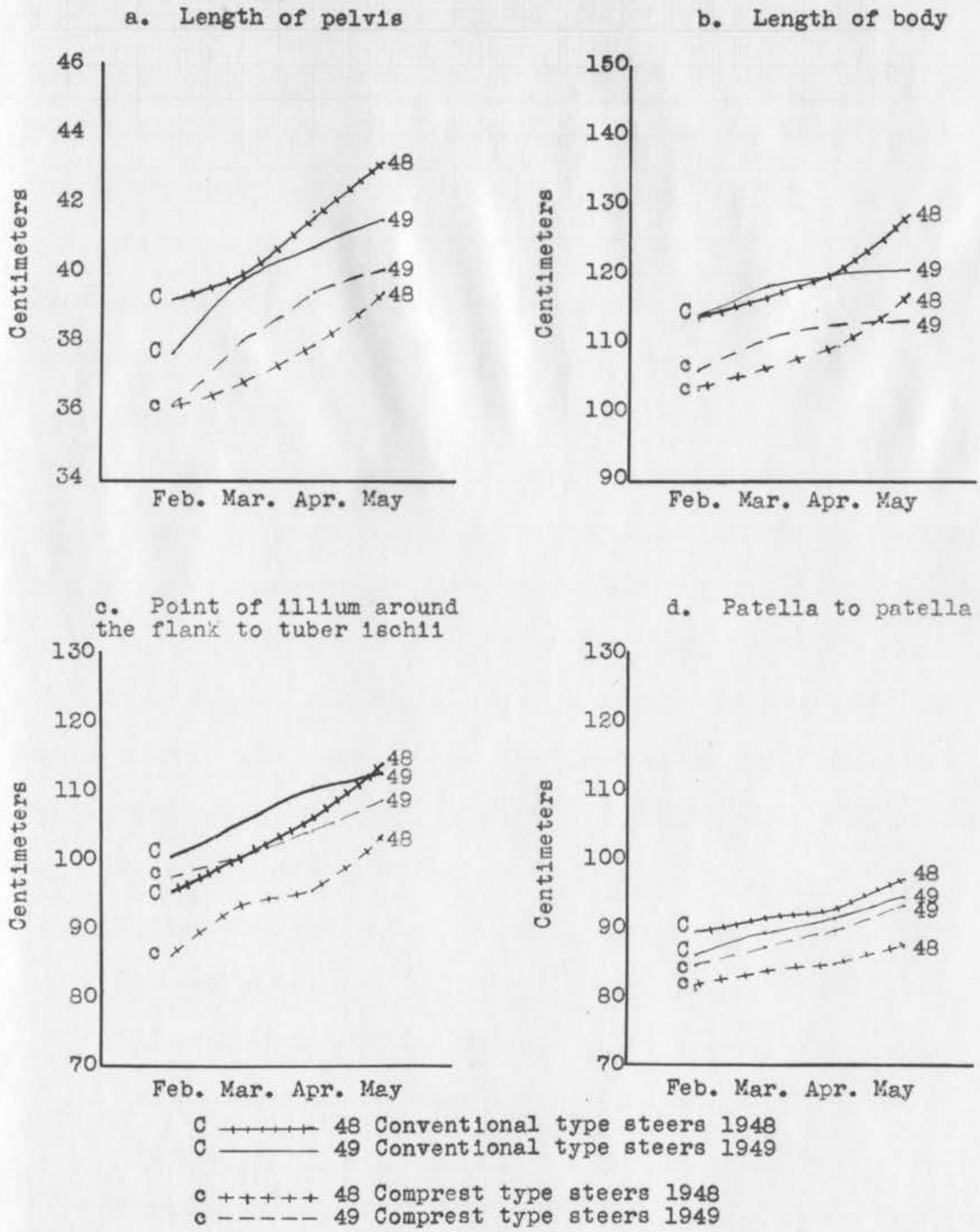
types for 1948 than for 1949 and a certain amount of overlapping between years. The average differences demonstrated between types in 1948 were about eight centimeters while in 1949 the average differences were approximately three centimeters. The measurements of the conventional type steers show the larger circumference of paunch and the larger circumference of flank.

Chart 5a shows that the conventional type steers were about three centimeters longer in the pelvis than the comprest type in 1948 and about one centimeter longer in the pelvis in 1949. There was a difference of about one-half centimeter in this measurement for each type between years but the difference was not consistent for all four months.

There is a difference of about nine centimeters in length of body each of the two years compared as shown on chart 5b. This difference is uniform for each year, showing a slightly different trend for the two years.

The measurement, point of hip (ilium) around the flank to pin bone (tuber ischii) was taken in an attempt to get an indication of the relative size of the round. The averages of these measurements as shown on chart 5c indicate that the conventional type steers in 1948 were about six centimeters larger from point to point than the comprest type steers and in 1949 they were

Chart 5.--AVERAGE BODY MEASUREMENTS OF STEERS ON FEED



about four centimeters larger from point to point than the comprest type steers.

The measurement, patella to patella, likewise was taken to get an indication of the relative size of the hind quarters and, indirectly, the round. The conventional type steers, in 1948, as shown on chart 5d, measured about six centimeters farther from patella to patella than did the comprest type steers. In 1949 the spread between the two types averaged only about one centimeter, conventional type again having the larger measurement.

The differences between the conventional type steers and the comprest type steers, as shown by each of the nineteen measurements and the one calculated measurement for May of the two years and the differences in weight and age, are summarized in table 1. As seen in this table, the conventional type steers are larger in all measurements. The measurements that show difference of five centimeters or more are:

Wither height........................	9.3	cm.
Hip height...........................	11.0	cm.
Circumference of paunch..............	10.0	cm.
Circumference of flank...............	9.3	cm.
Length of body.......................	9.7	cm.
Circumference of heart girth.........	9.0	cm.
Point of ilium around flank to tuber ischii.........................	7.2	cm.

Table 1.--AVERAGE DIFFERENCES BETWEEN TYPES AS SHOWN BY BODY MEASUREMENTS, WEIGHT, AND AGE AS OF MAY 7, 1948 AND 1949

	Conventional Type		Comprest Type		Differences
	Range	Average	Range	Average	
Age in days	334.0-385.0	359.9	334.0-374.0	358.0	1.7
Weight in pounds	490.0-900.0	713.0	490.0-685	600.0	113.0
Measurements in centimeters:					
1. Circumference of muzzle	42.0- 50.2	45.0	40.5- 47.3	43.5	1.5
2. Length of head	38.8- 44.5	41.5	38.3- 42.0	39.8	1.7
3. Width of head	19.0- 22.0	20.4	19.0- 21	20.1	0.3
4. Wither height *	99.5-114.5	107.4	93.3-104.0	98.1	9.3
5. Hip height *	106.0-125.3	113.1	95.0-108.5	102.1	11.0
6. Height of chest *	48.0- 55.5	50.8	41.5- 49.0	44.9	5.9
7. Length of cannon bone *	20.0- 24.0	21.9	18.0- 20.3	19.2	2.7
8. Circumference of cannon bone	17.1- 20.0	18.5	17.0- 19.1	17.9	0.6
9. Depth of chest	50.5- 62.5	56.6	49.5- 57.0	53.2	3.4
10. Width of chest	31.0- 43.0	39.2	32.5- 40.5	37.4	1.8
11. Circumference of heart girth	144.8-176.5	161.9	139.7-162.6	153.0	8.9
12. Width of loin	26.5- 37.0	31.9	27.0- 32.8	30.7	1.2
13. Width at hooks	35.0- 45.0	41.1	37.0- 41.5	39.0	2.1
14. Pelvis width	31.0- 42.0	37.6	32.5- 38.5	36.3	1.3
15. Circumference of paunch	169.5-215.3	191.3	163.2-197.5	181.3	10.0
16. Circumference of flank	146.7-174.5	162.6	146.5-163.8	153.3	9.3
17. Length of pelvis	38.0- 46.5	42.4	37.5-42 .0	39.8	2.6
18. Length of body	107.0-135.3	124.8	101.5-121.5	115.1	9.7
19. Point of ilium around flank to tuber ischii	100.7-126.0	113.3	99.5-113.0	106.1	7.2
20. Patella to patella	82.6-106.8	95.9	86.0-113.0	90.3	5.6

* Very little overlapping between types

Height of chest........................ 5.9 cm.

Patella to patella...................... 5.6 cm.

The measurements that show less than one centimeter difference are:

Width of head........................... 0.3 cm.

Circumference of cannon bone............ 0.7 cm.

All other measurements show differences of from one to five centimeters between the two types of steers.

Table 1 also shows the range in size for each measurement for the two types of steers being compared. There is some overlapping of individual measurements between types for each of the twenty measurements considered.

The measurements showing the smallest amount of overlapping between the two types have been singled out and are:

a. Length of cannon bone - only one conventional type steer shows a measurement less than 20.3 centimeters, the largest measurement of length of cannon bone for the comprest type steers. Only two of the comprest type steers show a length of cannon bone higher than 20.0, the lowest of these measurements for the conventional type steers.

b. Height of chest - only three conventional type steers show a height of chest lower than 49.0 centimeters, the greatest height of chest shown for the compress type steers. Only one compress type steer shows a height of chest greater than 48.0 centimeters, the smallest height of chest shown for the conventional type steers.

c. Hip height - only five conventional type steers show a hip height less than 108.5 centimeters, the hip height of the compress type steer measuring the tallest at the hips. Only three of the compress type steers are taller at the hips than 106.0 centimeters, the shortest hip height shown by the conventional type steers.

d. Wither height - there are four conventional type steers that show a wither height less than 104.0 centimeters, the tallest wither height shown for the compress type steers. Eight compress type steers show wither heights of higher than 99.5 centimeters, the shortest wither height for the conventional type steers.

Most of the so called skeletal measurements show very little overlapping between the two types of steers for any one year, the overlapping that is shown being mostly between years. All other measurements show more overlapping between types than is demonstrated by the previously mentioned four skeletal measurements.

<u>Relative change in measurements as an indication of comparative growth</u>

In order to see the relative increase in each measurement during the four months considered, the ratio of the average measurement in May to the average measurement in February for each type each year have been calculated for each measurement. These ratios have been summarized in table 2. In this table the largest ratios indicate the measurements with the greatest increase or growth from February to May. The largest relative increase in size of measurement for both types is shown by width of loin, followed closely by circumference of heart girth and width at hooks. In comparing the average growth ratio of the two years for the conventional type steers to the average growth ratio for the comprest type steers it can be seen that there is very little difference in the relative growth, the greatest difference being only .03 and that difference is shown for only one ratio. There are four other ratios that show a difference of .02 while the remaining fifteen ratios show a difference of .01 or less. Three measurements, length of head, circumference of heart girth and pelvis width show slightly larger ratios for the comprest steers than for the conventional type; six measurements show the same relative increase and the other eleven all show slightly higher relative increases for the conventional type

Table 2.-- RELATIVE INCREASE IN BODY MEASUREMENTS FROM FEBRUARY TO MAY

	RATIO OF $\frac{\text{MAY MEASUREMENT}}{\text{FEBRUARY MEASUREMENT}}$					
	Conventional			Compress		
Measurement	1948	1949	Ave.	1948	1949	Ave.
1. Circumference of muzzle	1.191	1.048	1.12	1.173	1.044	1.11
2. Length of head	1.101	1.063	1.08	1.100	1.072	1.09
3. Width of head	1.093	1.041	1.07	1.102	1.030	1.07
4. Wither height	1.086	1.080	1.08	1.079	1.072	1.08
5. Hip height	1.072	1.077	1.07	1.066	1.062	1.06
6. Height of chest	1.071	1.047	1.06	1.058	1.043	1.05
7. Length of cannon bone	1.066	1.055	1.06	1.055	1.045	1.05
8. Circumference of cannon bone	1.111	1.043	1.08	1.130	1.036	1.08
9. Depth of chest	1.099	1.112	1.11	1.089	1.098	1.09
10. Width of chest	1.186	1.113	1.15	1.182	1.086	1.13
11. Circumference of heart girth	1.170	1.145	1.16	1.161	1.121	1.14
12. Width of loin	1.248	1.187	1.21	1.225	1.180	1.20
13. Width at hooks	1.203	1.152	1.18	1.210	1.134	1.17
14. Pelvis width	1.105	1.015	1.06	1.134	1.012	1.07
15. Circumference of paunch	1.214	1.149	1.18	1.199	1.095	1.15
16. Circumference of flank	1.191	1.137	1.16	1.177	1.112	1.14
17. Length of pelvis	1.101	1.101	1.10	1.091	1.109	1.10
18. Length of body	1.132	1.055	1.09	1.128	1.058	1.09
19. Point of illium around flank to tuber ischii	1.192	1.123	1.16	1.206	1.109	1.16
20. Patella to patella	1.084	1.101	1.09	1.073	1.096	1.08

steers. The greatest difference in ratios is shown for each type between years, this difference ranging up to .143 as shown by the conventional type steer ratio for circumference of muzzle. Most of the other ratios show much smaller differences between years.

The steers are approximately the same age but as table 1 shows, there is a difference of 113 pounds in weight.

Type differences in ratios of selected measurements

The averages by types and years of all ratios of measurements calculated are summarized on tables 3 and 4.

Table 3a shows the averages of the ratio of the patella to patella measurement to wither height. The greatest change in this ratio for the four months was only .02 as demonstrated by the 1949 steers, and the greatest difference between types was only .04.

The ratio of width of head to length of head as shown in table 3b is very similar to the ratio previously mentioned in that there is practically no change in the ratio from one month to the next and practically no difference demonstrated between types or between years.

The width of chest to wither height ratio averages are shown in table 3c. There is considerable overlapping both between types and between years and

Table 3.-- RATIOS OF SELECTED BODY MEASUREMENTS FOR A FOUR MONTH COMPARISON PERIOD

(a)	Patella to Patella / Wither Height				(b) Width of Head / Length of Head			
Type	Feb.	Mar.	Apr.	May	Feb.	Mar.	Apr.	May
Conventional 1948	0.90	0.90	0.89	0.90	0.50	0.50	0.50	0.49
Conventional 1949	0.87	0.88	0.88	0.89	0.50	0.50	0.50	0.49
Comprest 1948	0.91	0.91	0.89	0.91	0.51	0.52	0.51	0.52
Comprest 1949	0.91	0.91	0.92	0.93	0.52	0.50	0.49	0.50

(c)	Width of Chest / Wither height				(d) Weight / Wither Height			
Type	Feb.	Mar.	Apr.	May	Feb.	Mar.	Apr.	May
Conventional 1948	0.35	0.36	0.36	0.38	5.20	5.61	6.41	6.88
Conventional 1949	0.34	0.36	0.33	0.35	5.14	5.57	5.95	6.31
Comprest 1948	0.36	0.37	0.36	0.39	4.58	4.84	5.47	5.98
Comprest 1949	0.37	0.38	0.38	0.37	4.98	5.35	5.77	6.10

Table 4.-- RATIOS OF SELECTED BODY MEASUREMENTS FOR A FOUR MONTH COMPARISON PERIOD

(a) $\frac{\text{Length of Body}}{\text{Wither Height}}$; (b) $\frac{\text{Circumference of Heart Girth}}{\text{Wither Height}}$

Type	(a) Feb.	(a) Mar.	(a) Apr.	(a) May	(b) Feb.	(b) Mar.	(b) Apr.	(b) May
Conventional 1948	1.14	1.15	1.15	1.19	1.39	1.46	1.48	1.50
Conventional 1949	1.16	1.17	1.16	1.13	1.43	1.45	1.48	1.51
Comprest 1948	1.16	1.15	1.15	1.22	1.44	1.49	1.47	1.65
Comprest 1949	1.15	1.16	1.16	1.13	1.49	1.51	1.53	1.56

(c) $\frac{\text{Depth of Chest}}{\text{Length of Cannon Bone}}$; (d) $\frac{\text{Depth of Chest}}{\text{Wither Height}}$

Type	(c) Feb.	(c) Mar.	(c) Apr.	(c) May	(d) Feb.	(d) Mar.	(d) Apr.	(d) May
Conventional 1948	2.53	2.55	2.50	2.61	.52	.52	.52	.53
Conventional 1949	2.42	2.46	2.52	2.56	.51	.51	.51	.52
Comprest 1948	2.70	2.67	2.75	2.79	.54	.53	.53	.54
Comprest 1949	2.63	2.67	2.77	2.76	.53	.53	.54	.54

there is no consistent increase or decrease in this ratio.

The ratio, weight to wither height, in table 3d, demonstrates a consistent increase for the four months compared for both types both years. The average differences between types are certain but not large. The conventional type steers show the larger ratio.

The ratio, length of body to wither height, is shown in table 4a. This ratio is erratic in both increase and decrease but not pronounced in either. There is considerable overlapping between types as well as between years.

According to table 4b, the comprest type steers showed a higher ratio of circumference of heart girth to wither height than did the conventional type steers. There was a consistent increase in this ratio for both types for each month that it was compared for the two years.

The ratio of depth of chest to length of cannon bone is shown in table 4c. This ratio was larger for the comprest type steers than for the conventional type each of the two years compared, although the differences were not great.

Table 4d shows the ratio of depth of chest to wither height to be greater for the comprest type steers each year.

The average differences between types as shown by the eight ratios are summarized in table 5. One of the ratios, length of body to wither height, shows an equal value for the two types of steers. With the exception of one of the remaining ratios, weight to wither height, the values are larger for the comprest type steers than for the conventional type. This indicates that on the average the comprest type steers are deeper in the chest in relation to length of cannon bone and in relation to wither height than the conventional type steers. They are also slightly wider in the chest and slightly larger around the heart girth in relation to wither height. In addition the comprest steers are slightly larger in the hind quarters in relation to wither height and slightly wider in the head in relation to length of head.

Correlation and regression studies

Correlations between selected observations were calculated from the different classes and subclasses in covariance analyses. This made it possible to check the manner in which two variables were correlated in the total sample of fifty seven steers and what effect removing the influence of seasons, types, and sires had on the correlation between the variables.

Thus, variance and covariance studies on measurements, ratios of measurements, grades, rate of gain, and total digestible nutrients per pound of gain

Table 5.--FOUR MONTH AVERAGE DIFFERENCES BETWEEN TYPES AS SHOWN BY RATIOS OF SELECTED BODY MEASUREMENTS.

	Two year average		
Ratio	Conventional	Comprest	Differences
Patella to patella / Wither height	.89	.91	.02
Width of head / Length of head	.50	.51	.01
Width of chest / Wither height	.35	.37	.02
Weight / Wither height	5.88	5.38	.50*
Length of body / Wither height	1.16	1.16	.00
Circumference of heart girth / Wither height	1.46	1.52	.06
Depth of chest / Length of cannon bone	2.52	2.72	.20
Depth of chest / Wither height	.53	.54	.01

* Conventional type steers have the larger ratio.

were broken down into the following categories:

a. Totals

b. Between seasons

c. Within seasons

d. Between types within seasons

e. Within types within seasons

f. Between sires within types within seasons

g. Within sires within types within seasons

These correlation studies were not made between all combinations of the various measurements because of the large possible number. Certain measurements are frequently considered to be indicative of feeding performance. The measurements used were selected largely from those measurements. Circumference of muzzle circumference of cannon bone, and width of chest especially fall in this category. The other three, circumference of paunch, wither height, and length of body, sometimes thought to be associated with good feeding qualities, were selected because of their possible influence on the capacity of the digestive organs, and hence, possibly feed lot performance.

The correlations between these measurements and two possibly dependent variables, total digestible nutrients per pound of gain and daily rate of gain in weight, are shown in tables 6 and 7.

As an example of the interpretation of these

Table 6.--CORRELATIONS BETWEEN TOTAL DIGESTIBLE NUTRIENTS (T.D.N.) PER POUND OF GAIN AND SIX INITIAL BODY MEASUREMENTS OF FEEDER STEER CALVES.

	Degrees of freedom.	T.D.N. per lb. gain (y) with circumference of muzzle (x)	T.D.N. per lb. gain (y) with circumference of cannon bone (x).	T.D.N. per lb. gain (y) with circumference of paunch (x).	T.D.N. per lb. gain (y) with wither height (x).	T.D.N. per lb. gain (y) with length of body	T.D.N. per lb. gain (y) with width of chest (x).
Totals	56	.17	.52**	.40**	.39*	.49**	.61**
Between seasons	1	-1.0	1.0	1.0	1.0	1.0	1.0
Within seasons	55	.35*	.37**	.42**	.14	.29*	.64**
Between types within seasons	2	.82	.20	.73	-.39	- .39	.02
Within types within seasons	53	.30*	.40**	.38**	.32*	.43**	.71**
Between sires within types within seasons	7	.53	.24	.50	.04	.32	.55
Within sires within types within seasons	46	.27	.43**	.37*	.36*	.45**	.76**

** Significant at .01 level.

* Significant at .05 level.

Table 7.-- CORRELATIONS BETWEEN DAILY RATE OF GAIN IN WEIGHT AND SIX INITIAL BODY MEASUREMENTS OF FEEDER STEER CALVES

	Degrees of freedom	Rate of gain (y) with circumference of muzzle (x).	Rate of gain (y) with circumference of cannon bone (x).	Rate of gain (y) with circumference of paunch (x).	Rate of gain (y) with wither height (x).	Rate of gain (y) with length of body (x).	Rate of gain (y) with width of chest (x)
Totals	56	.02	.34**	.10	.57**	.45**	.14
Between seasons	1	-1.0	1.0	1.0	1.0	1.0	1.0
Within seasons	55	.07	.31*	.09	.60**	.44**	.12
Between types within seasons	2	-.17	.56	-.02	.93	.93	.70
Within types within seasons	53	.15	.22	.14	.31*	.20	-.04
Between sires within types within seasons	7	.26	.57	.24	.68	.54	.26
Within sires within types within seasons	46	.10	.10	.11	.19	.10	-.18

** Significant at .01 level.

* Significant at .05 level.

tables the correlations between total digestible nutrients per pound of gain and the feeder calf measurement, width of chest, will be discussed.

a. Totals - the correlation of .61 is highly significant. This means that, for the entire population of fifty-seven steers, on the average the ones that are wider in the chest tend to have a higher feed requirement per pound of gain.

b. Between seasons - this correlation is unity since only two seasons are being compared.

c. Within seasons - the correlation here of .64 is highly significant. Elimination of the effect of seasons has had a slight but positive effect on this correlation. Again it means that on the average, the steers that are wider in chest tend to have a higher feed requirement per pound of gain.

d. Between types within seasons - there is a very low, nonsignificant correlation here which means that between types each year there apparently is very little tendency for the feed requirement per pound of gain to be larger for those with wider chests. Compress steers while not so wide as conventional type, have in this case about the same feed requirements per unit of gain.

e. Within types within seasons - here, within a type, there is a still slightly greater tendency, as shown by a correlation of .71, for the steers wider in chest to have a greater feed requirement per pound of gain.

f. Between sires within types within seasons - the relatively high correlation of .55 for this category is not significant since there are only seven degrees of freedom.

g. Within sires within types within seasons - the highest correlation, .76, for the seven categories is shown here and is highly significant. This means that, in a population consisting of progeny from one sire and of the same type classification, there is a general tendency for the steers with wider chests to have a slightly higher feed requirement per pound of gain, in other words, to be less efficient.

Table 7 indicates that the correlations between rate of gain in weight and body measurements are low and insignificant for populations of feeder steer calves in which season, type, and sire effects are held constant. On the other hand, table 6 shows the feed requirements per unit of gain are very closely correlated with width of chest. The other highly significant correlations were those between total digestible nutrients per pound of gain and length of body, circumference of cannon bone, circumference of paunch, and wither height. All showing that smaller initial measurements were associated with greater efficiency in feed utilization.

Table 8 shows correlations between certain ratios and the two possibly dependent variables previously mentioned. These ratios were selected as examples of some relationships of width to height or length, and depth of body to length of leg representing proportions frequently considered to be indicative of feeding performance. The ratios used are:

a. $\frac{\text{Weight}}{\text{Wither height}}$

b. $\frac{\text{Width of head}}{\text{Length of head}}$

c. $\frac{\text{Width of chest}}{\text{Wither height}}$

d. $\frac{\text{Depth of chest}}{\text{Length of cannon bone}}$

This table is used in the same manner as was exemplified for width of chest with total digestible nutrients per pound of gain. In each of the seven categories, correlations between total digestible nutrients per pound of gain and the ratio, width of head to length of head, fail to show significance. This indicates that the relation of head width to head length is not necessarily an indication of future efficiency in the feed lot. When season, type, and sire effects are held constant, total digestible nutrients per pound of gain correlated with the three ratios, weight to wither height, width of

Table 8.-- CORRELATIONS OF TOTAL DIGESTIBLE NUTRIENTS (T.D.N.) PER POUND OF GAIN AND RATE OF GAIN IN WEIGHT WITH SELECTED RATIOS OF FEEDER STEER CALF MEASUREMENTS

	Degrees of freedom	T.D.N. per lb. gain (y) with the ratio weight / wither height (x).	T.D.N. per lb. gain (y) with the ratio width of head / length of head (x).	T.D.N. per lb. gain (y) with the ratio width of chest / wither height (x).	T.D.N. per lb. gain (y) with the ratio Depth of chest / length of cannon bone (x)	Rate of gain (y) with the ratio weight / wither height (x)	Rate of gain (y) with the ratio width of head / length of head (x)	Rate of gain (y) with the ratio width of chest / wither height (x)	Rate of gain (y) with the ratio depth of chest / length of cannon bone (x)
Totals	56	.61**	.18	.10	.52**	.13	-.38**	-.44**	-.42**
Between seasons	1	1.0	-1.0	-1.0	1.0	1.0	-1.0	-1.0	1.0
Within seasons	55	.55**	.22	.43**	.42**	.09	-.38**	-.42**	-.52**
Between types within seasons	2	.26	.75	.81	.84	.51	-1.00*	-.98	-.97
Within types within seasons	53	.58**	.12	.38**	.34*	-.01	-.07	-.26*	-.12
Between sires within types within seasons	7	.68	-.08	.67	.03	.09	-.34	.01	.10
Within sires within types within seasons	46	.58**	.14	.35*	.39**	-.05	-.03	-.37*	-.21

** Significant at .01 level.

* Significant at .05 level.

chest to wither height, and depth of chest to length of cannon bone, shows significance in all cases. These correlations indicate that the steers that are wider and heavier in relation to height and deeper bodied in relation to length of leg tend to have a higher feed requirement per unit gain in weight. However, considering daily rate of gain in weight with each of these four ratios in the same table shows significance within each sire group only with the ratio, width of chest to wither height, and then only at the .05 level. Daily rate of gain in weight correlated with the ratio, weight to wither height does not show any significance in any of the seven categories, although the other three ratios show significance at the .01 level for totals and for within seasons. This indicates that in general there may be a tendency for steers that are wider in relation to height, deeper bodied in relation to length of leg, and that have a wider head in relation to length of head to have a slower rate of gain than those that are narrower in relation to height, shallower bodied in relation to length of leg, and that have a narrower head in relation to length of head. However, when the effect of types and of seasons is removed, the only significant correlation at the .05 level is between daily rate of gain in weight and the ratio, width of chest to wither height.

Table 9 shows that when season, type, and sire effects are held constant there is a highly significant correlation between length of body and length of carcass from first rib to pelvic bone; the same is true for the measurement patella to patella with the carcass measurement, area of rib eye muscle; likewise, the same is true for slaughter grade of fat with the actual measurement of fat over the rib.

Use of regression coefficients

The significance and size of some of the correlations between measurements or ratios of measurements and total digestible nutrients per pound of gain or daily rate of gain make it appear that some of these initial measurements may be useful for indicating future feed lot performance.

Regression coefficients have been calculated in order that prediction equations may be developed. These are summarized in tables 10 and 11, having been developed from the covariance analyses as seen in the appendix.

The regression coefficient for a sample of paired variates represents an increase expected in Y for a given increase in X. Thus, using table 10, it can be seen that .13 pound is an estimate of the average increase in total digestible nutrients per pound of gain in weight with an increase of one centimeter in

Table 9.-- CORRELATIONS OF CARCASS MEASUREMENTS WITH FAT STEER BODY MEASUREMENTS AND SLAUGHTER GRADE.

	Degrees of freedom	Length from first rib to pelvic bone (y) with length of body (x).	Area of rib eye muscle (y) with width of loin (x).	Area of rib eye muscle (y) with patella to patella (x).	Area of rib eye muscle (y) with slaughter grade of loin (x).	Area of rib eye muscle (y) with slaughter grade of round (x).	Fat over rib (y) with slaughter grade of thickness of fat (x).
Totals	56	.88**	.33*	.54**	-.30*	-.23	.53**
Between seasons	1	1.0	1.0	1.0	-1.0	-1.0	1.0
Within seasons	55	.87**	.32*	.53**	-.24	-.18	.53**
Between types within seasons	2	1.00	.88	.93	-.38	-.47	.92
Within types within seasons	53	.63**	.17	.36**	-.22	-.04	.53**
Between sires within types within seasons	7	.22	.17	.12	-.59	-.42	.79*
Within sires within types within seasons	46	.71**	.18	.43**	-.13	.03	.47**

** Significant at .01 level.

* Significant at .05 level.

Table 10.--REGRESSION COEFFICIENTS FOR PREDICTING FEED LOT PERFORMANCE FROM INITIAL FEEDER CALF MEASUREMENTS

	Dependent Variable			
	Total digestible nutrients per lb. gain		Daily rate of gain in weight	
Experimental Mean	4.98		2.00	
	Regression Coefficient	Standard Error of Estimate	Regression Coefficient	Standard Error of Estimate
Circumference of muzzle	.06 lb.	.36	.01 lb.	.17
Circumference of cannon bone	.21 lb.	.34	.02 lb.	.17
Circumference of paunch	.02 lb.	.35	.00 + lb.	.17
Wither height	.04 lb.	.35	.01 lb.	.16
Length of body	.03 lb.	.33	.00 + lb.	.17
Width of chest	.13 lb.	.25	- .01 lb.	.16
$\frac{\text{Weight}}{\text{Wither height}}$	.43 lb.	.30	- .02 lb.	.17
$\frac{\text{Width of head}}{\text{Length of head}}$	3.98 lb.	.37	- .40 lb.	.17
$\frac{\text{Width of chest}}{\text{Wither height}}$	.67 lb.	.35	-3.14 lb.	.16
$\frac{\text{Depth of chest}}{\text{Length of cannon bone}}$	1.25 lb.	.34	- .03 lb.	.16

Table 11.--REGRESSION COEFFICIENTS FOR PREDICTING CARCASS MEASUREMENTS FROM OBSERVATIONS AND MEASUREMENTS OF LIVE SLAUGHTER STEERS.

	Dependent Variable					
	Length from first rib to pelvic bone		Area of rib eye muscle		Fat over rib	
Experimental Mean	121.91		55.07		.28	
	Regres - sion Co-efficient	Standard Error of Estimate	Regres-sion Co-efficient	Standard Error of Estimate	Regres-sion Co-efficient	Standard Error of Estimate
Length of body	.57 cm.	2.38				
Width of loin			.62 sq. cm.	5.22		
Patella to patella			.74 sq. cm.	4.78		
Slaughter grade of loin			-2.60 sq. cm.	5.26		
Slaughter grade of round			.45 sq. cm.	5.30		
Slaughter grade, thickness of fat					.62 cm.	.28

width of chest.

Multiple regressions were not run since the correlations throughout the study were generally low, thus indicating that dispersion of the variates about the estimated average would be quite wide. Likewise, knowledge that the standard deviations for the variates are relatively large indicates that many of them would fall far from the predicted average.

Variance and covariance studies, significance of differences

The effect which the total sample or isolated segments of the sample have on correlation studies was presented in the preceding section. Covariance studies also make it possible to test the statistical significance of differences in seasons, types, and sires as they may affect measurements. In addition, it is possible to isolate the effect of variation of the dependent variable from that of the variable upon which it may be dependent. For example, in table 12 it is observed that when rate of gain between types is adjusted for differences in each of the six feeder steer measurements, F values are scarcely influenced. On the other hand, differences in total

Table 12.--SIGNIFICANCE OF F VALUES FOR INITIAL MEASUREMENTS, TOTAL DIGESTIBLE NUTRIENTS (T.D.N.) PER POUND OF GAIN, AND RATE OF GAIN BETWEEN SEASONS, TYPES AND SIRES.

			Circumference of muzzle	Circumference of cannon bone	Circumference of paunch	Wither height	Length of body	Width of chest
		Variance	Covariance (adjusted means)					
T.D.N. per lb. gain y	Between seasons	**	**	*	**	*	*	**
	Between types within seasons	ns	ns	*	ns	*	**	**
	Between sires within types within seasons	ns	ns	ns	ns	ns	ns	ns
Daily rate of gain y	Between seasons	ns	ns	ns	ns	*	ns	ns
	Between types within seasons	**	**	**	**	**	**	**
	Between sires within types within seasons	**	**	**	**	*	**	**
			Variance					
	Between seasons		ns	**	ns	**	**	ns
	Between types within seasons		ns	**	ns	**	**	ns
	Between sires within types within seasons		ns	ns	ns	ns	ns	ns

** Significant at .01 level.
* Significant at .05 level.
ns Not significant.
y Dependent variable for covariance.

digestible nutrients per pound of gain between types have an F value that is not significant. However, when the values are adjusted for differences in each of the six measurements there is significance at the .05 level for circumference of cannon bone and for wither height and significance at the .01 level for length of body and width of chest. All levels of significance from the variance and covariance studies in this investigation are summarized in tables 12, 13, and 14.

Table 13.--SIGNIFICANCE OF F VALUES OF RATIOS OF BODY MEASUREMENTS, TOTAL DIGESTIBLE NUTRIENTS (T.D.N.) PER POUND OF GAIN, AND RATE OF GAIN BETWEEN SEASONS, TYPES, AND SIRES.

			$\frac{\text{Weight}}{\text{Wither height}}$	$\frac{\text{Width of head}}{\text{Length of head}}$	$\frac{\text{Width of chest}}{\text{Wither height}}$	$\frac{\text{Depth of Chest}}{\text{Cannon bone length}}$
		Variance	Covariance (adjusted means)			
T.D.N. per lb. gain y	Between seasons	**	**	**	**	**
	Between types within seasons	ns	*	ns	ns	ns
	Between sires within types within seasons	ns	ns	ns	ns	ns
Daily rate of gain y	Between seasons	ns	ns	ns	ns	**
	Between types within seasons	**	**	**	**	**
	Between sires within types within seasons	**	**	**	**	**
			Variance			
	Between seasons		*	ns	**	**
	Between types within seasons		ns	ns	*	**
	Between sires within types within seasons		ns	ns	ns	ns

** Significant at .01 level.
* Significant at .05 level.
ns Not significant.
y Dependent variable for covariance.

Table 14.-- SIGNIFICANCE OF F VALUES OF SLAUGHTER STEER MEASUREMENTS AND GRADES, AND CARCASS MEASUREMENTS AND GRADES BETWEEN SEASONS, TYPES, AND SIRES.

** Significant at .01.
* Significant at .05.
ns Not significant
y Dependent variable for covariance.

			Length of body	Width of loin	Patella to Patella	Slaughter grade of loin	Slaughter grade of round	Slaughter grade of thickness of fat
		Variance	Covariance (adjusted means)					
Length from first rib to pelvic bone y	Between seasons	*	ns					
	Between types within seasons	**	**					
	Between sires within types within seasons	ns	**					
Area of rib eye muscle y	Between seasons	ns		ns	ns	ns	ns	
	Between types within seasons	**		**	ns	**	**	
	Between sires within types within seasons	*		*	*	ns	*	
Fat over rib y	Between seasons	ns						ns
	Between types within seasons	ns						ns
	Between sires within types within seasons	*						ns
			Variance					
	Between seasons		**	ns	ns	**	*	ns
	Between types within seasons		**	**	**	*	**	ns
	Between sires within types within seasons		ns	ns	ns	ns	ns	ns

Chapter V

DISCUSSION

The conformation of the two types of steers differ primarily in that the conventional type steers in all cases have a larger average measurement, for each measurement taken in this study, than that of the comprest type steers. There is, however, a certain amount of overlapping of certain measurements between individuals of the two types. Some measurements show much more overlapping between types than other measurements. Because of this overlapping of measurements between the two types no clean cut differentiation of the two types has been found for any measurement or ratio of measurements. However, it seems reasonable to believe that a certain size selected measurement, or combination of selected measurements, could be designated as a dividing line between conventional type Hereford steers and the comprest type Hereford steers. Some of the so-called skeletal measurements would probably be of more value in this respect than those measurements usually thought of as fleshy measurements.

Some of the more interesting skeletal measurements from the standpoint of differentiating the two types are length of cannon bone, height of chest, hip height, and wither height. In order to accurately distinguish between the two types with the use of a single measurement or simple combination of measurements it appears that the differentiation should be made when each animal becomes a certain standard age.

It appears from this study, as shown by table 1, that comprest steers of about twelve months of age seldom exceed 20.1 centimeters in length of cannon bone, and more typically average 19.2 centimeters, whereas the conventional type steers seldom measure less than 20.1 centimeters in length of cannon bone and more typically average 21.9 centimeters. The next most accurate measurement from the standpoint of differentiating the two types of steers appears to be height of chest from the ground. For steers that are about twelve months of age, 48.5 centimeters seems to be the height of chest that separates the two types of steers with but very little overlapping of this measurement. The average height of chest for the conventional type of steers is about 50.8 centimeters and for the comprest type steers is about 44.9 centimeters. For hip height the smallest amount of overlapping between the two types of steers seems to be at about 107.3 centimeters, while for wither height the smallest amount of overlapping is at 101.8 centimeters.

In view of this it would seem that if a twelve month old steer has a cannon bone length that is less than 20.1 centimeters the probability that it is of the comprest type is very great, while if this steer has a cannon bone length that is greater than 20.1 centimeters the steer is probably of the conventional type. If the four measurements, length of cannon bone, height of chest, hip height, and wither height are taken on a twelve month old steer and all four, or at least three of the four, measurements are less than the differentiating measurement set down above one would be more sure that the steer is of the comprest type. Conversely, if all, or at least three of the four, measurements are greater than the differentiating measurement one would be more sure that the steer is of the conventional type.

Although the definition of "comprest", Ingalls (14), 1948, says that they appear "shorter in head, neck, body, and legs than the conventional type Herefords" the term "comprest" infers that they are also shorter in these respects in relation to height. Table 11 shows that the comprest type steers have a slightly wider average head width in relation to length of head; they average slightly wider and deeper in the chest in relation to wither height and slightly larger in circumference of heart girth in relation to wither height; they also average slightly deeper in the chest in relation to length of cannon bone and slightly larger in the hind quarters than do the conventional type Hereford steers. However, when the ratio, weight to wither height, is considered, the opposite relationship prevails.

Since the ratios of measurements to wither height show the comprest type steers to average slightly wider and deeper in relation to height than the conventional type steers, one would expect them to average slightly heavier in relation to wither height. However, as shown by the ratio of weight to wither height, this is not true. The conventional type steers are heavier in relation to wither height than the comprest type steers. The following explanation of this is offered:

First it must be realized that mass (weight) is dependent on more than one measurement, and that mass for material of a given density is dependent on volume. Then it can be seen that:

$$V \times D = \text{Mass (weight)}$$

and

$$V = l\,w\,d$$

where V = volume

l = length

w = width

d = depth

D = density

Then, assuming that density is approximately equal for the two types of steers (to the thousandth part per cubic centimeter) they can be compared on the basis of estimated volume.

For the sake of comparison then

Estimated V = l w d

where

l = length of body

w = width of chest

d = depth of chest

Substituting average measurements for the conventional type steers, found in table 1, in the above formula

$$\text{Estimated V} = (124.8)\ (39.2)\ (56.6)$$

$$= 276896.26 \text{ cubic centimeters}$$

Then the ratio of estimated volume of the conventional type steers to wither height is

$$\frac{\text{estimated V}}{\text{Wither height}} = \frac{276896.26}{107.4} = 2578.2$$

Substituting average measurements for the comprest type steers, found in table 1, in the same formula

$$\text{Estimated V} = (115.1)\ (37.4)\ (53.2)$$

$$= 229012.17$$

Then the ratio of estimated volume of the comprest type steers to wither height is

$$\frac{\text{estimated V}}{\text{wither height}} = \frac{229012.17}{98.1} = 2334.4$$

Thus it can be seen that the ratio of estimated volume to wither height for the conventional type steers is greater than the ratio of estimated volume to wither height for the comprest type steers. Because of this relationship it would be expected (assuming density to be approximately equal for the two types) that the conventional type steers would be heavier per unit height than the comprest type steers.

This comparison actually shows approximately the same relationship between types as is shown by the relationship of weight to wither height. For example, the ratio of weight to wither height for the conventional type steers as shown in table 5 is 5.88, or 1.09 times as great as 5.38, the value of the same ratio for the comprest type steers. In harmony with this the ratio of estimated volume to wither height for the conventional type steers has a value of 2578.2 which is 1.10 times greater than 2334.4, the value of the same ratio for the comprest type steers. The difference of .01 as shown here could be due to sampling error, the fact that the bodies are not exactly rectangular, the fact that the head, neck, legs, and tail are not included in the measurements of the body, possible human error in the experiment, or perhaps because of a difference in density of the steers' bodies or even a combination of two or more of these possibilities.

On the basis of this explanation perhaps a ratio of a single linear measurement to wither height for the two types of steers compared to the ratio of weight to wither height for the two types is not a fair comparison since weight is more nearly proportional to the product of three linear dimensions, hence a cubical measurement, than to a single linear dimension.

It must be remembered that the equations used above were based on linear measurements which represent the steers as cubical in shape which, of course, is not the case. The results are merely computed figures calculated for the sole purpose of arriving at some means of comparing the relative weights and volumes of comprest type Hereford steers to those of the conventional type of steers. These equations are applicable only to a comparison such as this and then only if the animals are of a nearly equal physiological age and have had a similar environmental background.

This, then, indicates that perhaps the popular opinion among livestock men that cattle that are lower set, blockier, more compact, and thicker are heavier in relation to height, may not always be true. It does not indicate anything specific concerning actual density of the steers' bodies.

Most measurements taken on these feeder steers do not appear to be a very accurate guide to either daily rate of gain in weight or total digestible nutrients per pound of gain. This is true since the association of body measurements with daily rate of gain in weight and feed requirements per pound of gain is in general low. However, the significant correlations between total digestible nutrients per pound of gain and five body measurements, circumference of cannon bone, circumference of paunch, wither height, length of body, and width of chest indicate that in general the steers that are narrower and shallower bodied, shorter in height, shorter in body, smaller around the paunch, and that have a smaller circumference of cannon bone tend to have a lower feed requirement per pound of gain than those steers that are wider and deeper bodied, taller, longer in body, and that have a larger circumference of cannon bone. This is in agreement with Black, Knapp, and Cook (2), 1938. This is further substantiated by similar results for the correlations of ratios of body measurements with total digestible nutrients per pound of gain. Especially this is true for the ratio weight to wither height, indicating that the narrower, shallower bodied steers tend to be more efficient converters of feed into body weight.

The regression coefficients in tables 10 and 11 can be used in regression equations to estimate future average requirements per unit gain in weight for feeder steers but since standard errors of estimate of the variates are relatively large and most of the correlations of body measurements are relatively small or very small the dispersion of the characteristics about the predicted average would be so great that nothing more than a tendency of the average can be successfully estimated. Considering the whole sample of cattle there was a tendency for the steers that were longer in body, taller at the withers, and that had a larger circumference of cannon bone to be more rapid gainers than those that were shorter in body, shorter at the withers, and that had a smaller circumference of cannon bone. However, contrary to this and the findings of Lush (20), 1932, after the effect of season, type and sire were removed no significant correlations between daily rate of gain in weight and any of the body measurements considered were found. This indicates that perhaps the common opinion among livestock men that body size and proportion is an indication of future gaining capacity in the feed lot is not well founded.

Analysis of the data in this study shows that there is more association between the size of the hind quarters of feeder steers and circumference of rib eye muscle at the end of the fattening period than there is between the slaughter grade given the hind quarters and circumference of the rib eye muscle. This is as might be expected since it seems logical to assume that if an animal is heavily muscled in one part of the body he would be in the other parts of the body, too. It indicates that a feeder steer that will develop a carcass that will yield a higher proportion of lean meat is one that is heavily muscled. Likewise, there was, as expected, a fairly close association between slaughter grade of thickness of fat on the carcass and the actual thickness of fat over the rib.

Suggestions for further study

The relatively high correlation of total digestible nutrients per pound of gain in weight with width of chest as well as significant correlations with other body measurements is sufficiently informative to warrant further study along these lines. Perhaps something could be gained by making multiple correlation studies with some of the more interesting measurements from this standpoint. There also may be other measurements equally informative.

The fact that the comprest type steers show higher ratios of width and depth of body to wither height than the conventional type but that the conventional type steers show a higher ratio for weight to wither height is very interesting and appears to warrant further study. Perhaps something could be learned about this if comparisons of the two types of steers were made at periodic intervals from weaning age or younger, to slaughter age.

The density of the two types of steers' bodies may not be the same. The work of Washburn, et al. (31), 1948, indicates that the "compact" type of Shorthorns have a slightly higher density of body than do the conventional type. Relationships of this nature relative to the comprest and conventional types of Herefords appears to warrant scientific investigation.

Variations in age may have considerable influence on variations in the different body measurements. Because of this it is suggested that perhaps a truer picture of the various body measurements could be presented in future studies of this nature if they were corrected for age.

The differences shown by some measurements appear to warrant further study, especially to ascertain just what the differences are due to, whether due to skeletal differences, muscular differences, or the degree of fatness. This is of particular interest in the case of width of chest since this measurement showed a high correlation with total digestible nutrients per pound of gain.

It appears that specific differences between the two types of Hereford steers would warrant further study, especially the skeletal measurements that might be used in differentiating the two types. Emphasis might well be placed along these lines on younger steers than were used in this study as it might be desirable to differentiate the two types of steers very soon after birth, or at least by weaning age.

Chapter VI

SUMMARY

This was a study to investigate the differences in conformation and changes in conformation of two different types of purebred Hereford steer calves as shown by body measurements. The interrelationships between certain body measurements and the feed lot efficiency and gains of these steers were also investigated.

The visual method of comparing the conformation of one animal with another lacks the objectivity desired for research purposes. Because of this, linear measurements were used as a means of describing the two types and to show the interrelationships mentioned above.

Large or intermediate type Herefords, as found in most purebred herds, have been called conventional type and compared to comprest type of Herefords, or those that appear to be shorter in head, neck, body, and legs than the conventional type Herefords.

This comparison was made during two growth-fattening periods, using for each period all the steer calves produced by a herd of purebred Hereford cows at the Fort Lewis A and M College each of the two years, where the calves were raised to weaning age. The steers were fattened and slaughtered at the Colorado A and M College.

Some of the steers were sired by conventional type bulls and some by comprest type bulls. All dams were of conventional type breeding.

Nineteen body measurements were taken and a twentieth, depth of chest, was calculated. Twelve carcass measurements were taken and two carcass cut-out measurements were used.

The largest differences in conformation were found for the following body measurements, listed in decreasing order:

Hip height
Circumference of paunch
Length of body
Wither height
Circumference of flank
Point of ilium around flank to tuber ischii
Height of chest
Patella to patella

The smallest differences were shown by width of head and circumference of cannon bone. The conventional type steers showed the larger measurement in all cases.

Four measurements, length of cannon bone, height of chest, hip height, and wither height were singled out as showing the smallest amount of overlapping of individual measurements between the two types. Considering these four measurements, the size of measurement suggested for differentiating the two types of steers at about one year of age are summarized as follows:

Length of cannon bone.......	20.1 centimeters
Height of chest.............	48.5 centimeters
Hip height..................	107.3 centimeters
Wither height...............	101.8 centimeters

These differentiating measurement sizes were not offered as definitely dividing the two types, rather, they were offered as possible guides to be used in classifying twelve month old Hereford steers as to whether they are of comprest type or of conventional type. It was suggested that at least three of the four measurements of the steers be less than the respective differentiating measurement in order to classify a steer as comprest type, or, greater than the differentiating measurement in order to classify a steer as conventional type.

There was very little difference between types in the relative increase or growth in any of the measurements between February and May. The largest relative increase in size of measurements for the two types was for width of loin. Circumference of heart girth and width at hooks also showed large relative increases for both types.

Conventional type steers showed the largest average ratio of weight to wither height but the comprest type steers showed the largest average ratio for all other ratios considered. There was some overlapping between types for the two years for all but two of the seven ratios, namely, weight to wither height and depth of chest to length of cannon bone.

Body measurements cannot be used as a reliable indication of the individual steers' capacity for growth and fattening. However, correlation studies of total digestible nutrients per pound gain with certain body measurements and ratios of these measurements indicated that feeder steers that are shorter legged, shorter in overall height, narrower in chest, shorter in body, and smaller around the paunch tend to be more efficient in the feed lot than those that were taller, longer in body, wider in chest, and larger in the paunch.

In general then, this study shows that the smaller, steers tend to be more efficient in the feed lot than steers that are larger, and perhaps older.

A highly significant positive correlation for area of rib eye muscle with patella to patella indicates that the feeder steers with larger hind quarters tend to yield a finished carcass with a larger circumference of rib eye muscle, hence, possibly a higher proportion of lean meat to total bone and fat.

A P P E N D I X

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Table 1.--ANALYSIS OF COVARIANCE OF T.D.N. PER # GAIN (Y) ON CIRCUMFERENCE OF MUZZLE (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	186.25	7.20	9.99	0.17	55	9.71			
Between seasons	1	13.04	-5.48	2.30	-1.00	1	2.96	2.96**	13.04	2.30**
Within seasons	55	173.21	12.69	7.68	0.35*	54	6.75	0.13	3.15	0.14
Between types within seasons	2	12.45	2.64	0.82	0.83	2	0.52	0.26	6.23	0.41
Within types within seasons	53	160.76	10.05	6.86	0.30*	52	6.23	0.12	3.03	0.13
Between sires within types within seasons	7	34.58	2.35	0.57	0.53	7	0.41	0.06	4.94	0.08
Within sires within types within seasons	46	126.18	7.70	6.29	0.27	45	5.82	0.13	2.74	0.14

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares.

ms: Mean square

Table 2.--ANALYSIS OF COVARIANCE OF T.D.N. PER # GAIN (Y) ON CIRCUMFERENCE OF CANNON BONE (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	51.38	11.79	9.99	0.52**	55	7.28			
Between seasons	1	12.63	5.39	2.30	-1.00	1	0.66	0.66*	12.63**	2.30**
Within seasons	55	38.76	6.39	7.68	0.37**	54	6.63	0.12	0.70	0.14
Between types within seasons	2	6.87	0.47	0.82	0.20	2	0.86	0.43*	3.44**	0.41
Within types within seasons	53	31.89	5.92	6.86	0.40**	52	5.76	0.11	0.60	0.13
Between sires within types within seasons	7	5.95	0.45	0.57	0.24	7	0.62	0.09	0.85	0.08
Within sires within types within seasons	46	25.94	5.47	6.29	0.43**	45	5.14	0.11	0.56	0.14

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares.

ms: Mean square

Table 3.--ANALYSIS OF COVARIANCE OF T.D.N. PER # GAIN (Y) ON CIRCUMFERENCE OF PAUNCH (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	4434.69	84.17	9.99	0.40**	55	8.39			
Between seasons	1	22.97	7.28	2.30	-1.00	1	2.05	2.05**	22.97	2.30**
Within seasons	55	4411.72	76.90	7.68	0.42**	54	6.34	0.12	80.21	0.14
Between types within seasons	2	435.21	13.80	0.82	0.73	2	0.48	0.24	217.60	0.41
Within types within seasons	53	3976.51	63.09	6.86	0.38**	52	5.86	0.11	75.03	0.13
Between sires within types within seasons	7	599.04	9.17	0.57	0.50	7	0.43	0.01	85.58	0.08
Within sires within types within seasons	46	3377.47	53.92	6.29	0.37*	45	5.43	0.12	73.42	0.14

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 4.--ANALYSIS OF COVARIANCE OF T.D.N. PER # GAIN (Y) ON WITHER HEIGHT (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	2103.21	56.50	9.99	0.39*	55	8.47			
Between seasons	1	796.42	42.84	2.30	-1.00	1	0.93	0.93*	796.42**	2.30**
Within seasons	55	1306.79	13.66	7.68	0.14	54	7.54	0.14	23.76	0.14
Between types within seasons	2	586.68	-8.57	0.82	-0.39	2	1.36	0.68*	293.34**	0.41
Within types within seasons	53	720.12	22.23	6.86	0.32*	52	6.18	0.12	13.59	0.13
Between sires within types within seasons	7	128.36	0.37	0.57	0.04	7	0.69	0.10	18.34	0.08
Within sires within types within seasons	46	591.76	21.86	6.29	0.36*	45	5.48	0.12	12.86	0.14

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares.

ms: Mean square

Table 5.--ANALYSIS OF COVARIANCE OF T.D.N. PER # GAIN (Y) ON LENGTH OF BODY (X)

Variability due to:	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	3234.51	88.16	9.99	** 0.49	55	7.58			
Between seasons	1	1134.81	51.14	2.30	-1.00	1	0.55	* 0.55	** 1134.81	** 2.30
Within seasons	55	2099.70	37.02	7.68	* 0.29	54	7.03	0.13	38.18	0.14
Between types within seasons	2	529.52	-7.81	0.82	-0.39	2	1.45	** 0.72	** 264.76	0.41
Within types within seasons	53	1570.18	44.84	6.86	** 0.43	52	5.58	0.11	29.63	0.13
Between sires within types within seasons	7	242.69	3.74	0.57	0.32	7	0.56	0.08	34.67	0.08
Within sires within types within seasons	46	1327.49	41.10	6.29	** 0.45	45	5.02	0.11	28.86	0.14

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 6.--ANALYSIS OF COVARIANCE OF T.D.N. PER # GAIN (Y) ON WIDTH OF CHEST (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	310.67	34.20	9.99	0.61**	55	6.22			
Between seasons	1	4.66	3.28	2.30	-1.00	1	1.66	1.66**	4.66	2.30**
Within seasons	55	306.00	30.92	7.68	0.64**	54	4.56	0.08	5.56	0.14
Between types within seasons	2	29.29	0.10	0.82	0.02	2	1.13	0.56**	14.64	0.41
Within types within seasons	53	276.71	30.82	6.86	0.71**	52	3.43	0.07	5.22	0.13
Between sires within types within seasons	7	68.64	3.46	0.57	0.55	7	0.74	0.11	9.81	0.08
Within sires within types within seasons	46	208.07	27.37	6.29	0.76**	45	2.69	0.06	4.52	0.14

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 7.--ANALYSIS OF COVARIANCE OF RATE OF GAIN (Y) ON CIRCUMFERENCE OF MUZZLE (X)

		Squares and products				Errors of estimate			Analysis of variance	
Variability due to	D/F	x^2	xy	y^2	r	D/F	ss	ms	ms(X)	ms(Y)
Totals	56	186.25	0.66	3.82	0.02	55	3.82			
Between seasons	1	13.04	-1.13	0.10	-1.00	1	0.11	0.11	13.04	0.10
Within seasons	55	173.21	1.79	3.72	0.07	54	3.71	0.07	3.15	0.07
Between types within seasons	2	12.45	-0.80	1.77	-0.17	2	1.79	0.80**	6.23	0.89**
Within types within seasons	53	160.76	2.59	1.95	0.15	52	1.91	0.04	3.03	0.04
Between sires within types within seasons	7	34.58	1.30	0.71	0.26	7	0.68	0.10**	4.94	0.10**
Within sires within types within seasons	46	126.18	1.29	1.25	0.10	45	1.23	0.03	2.74	0.03

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares.

ms: Mean square

Table 8.--ANALYSIS OF COVARIANCE OF RATE OF GAIN (Y) ON CIRCUMFERENCE OF CANNON BONE (X)

		Squares and products				Errors of estimate			Analysis of variance	
Variability due to	D/F	x^2	xy	y^2	r	D/F	ss	ms	ms(X)	ms(Y)
Totals	56	51.38	4.80	3.82	** 0.34	55	3.37			
Between seasons	1	12.63	1.11	0.10	-1.00	1	0.00	0.00	** 12.63	0.10
Within seasons	55	38.76	3.69	3.72	* 0.31	54	3.37	0.06	0.70	0.07
Between types within seasons	2	6.87	1.97	1.77	0.56	2	1.51	** 0.76	** 3.44	** 0.89
Within types within seasons	53	31.89	1.73	1.95	0.22	52	1.86	0.04	0.60	0.04
Between sires within types within seasons	7	5.95	1.16	0.71	0.57	7	0.63	** 0.09	0.85	** 0.10
Within sires within types within seasons	46	25.94	0.56	1.25	0.10	45	1.23	0.03	0.56	0.03

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 9.--ANALYSIS OF COVARIANCE OF RATE OF GAIN (Y) ON CIRCUMFERENCE OF PAUNCH (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	4434.69	13.25	3.82	0.10	55	3.78			
Between seasons	1	22.97	1.50	0.10	-1.00	1	0.09	0.09	22.97	0.10
Within seasons	55	4411.72	11.75	3.72	0.09	54	3.69	0.07	80.21	0.07
Between types within seasons	2	435.21	-0.59	1.77	-0.02	2	1.78	0.89**	217.60	0.89**
Within types within seasons	53	3976.51	12.34	1.95	0.14	52	1.92	0.04	75.03	0.04
Between sires within types within seasons	7	599.04	5.05	0.71	0.24	7	0.68	0.10**	85.58	0.10**
Within sires within types within seasons	46	3377.47	7.29	1.25	0.11	45	1.23	0.03	73.42	0.03

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 10.--ANALYSIS OF COVARIANCE OF RATE OF GAIN (Y) ON WITHER HEIGHT (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	2103.22	50.71	3.82	0.57**	55	2.60			
Between seasons	1	796.42	8.84	0.10	1.00	1	0.22	0.22*	796.42**	0.10
Within seasons	55	1306.79	41.87	3.72	0.60**	54	2.38	0.04	23.76	0.07
Between types within seasons	2	586.68	30.05	1.77	0.93	2	0.62	0.31**	293.34**	0.88**
Within types within seasons	53	720.12	11.82	1.95	0.32*	52	1.76	0.03	13.59	0.04
Between sires within types within seasons	7	128.36	6.57	0.71	0.68	7	0.56	0.08*	18.34	0.10**
Within sires within types within seasons	46	591.76	5.25	1.25	0.19	45	1.20	0.03	12.86	0.03

** Significant at .01 level. ss: Sum of squares

* Significant at .05 level. ms: Mean square

Table 11.--ANALYSIS OF COVARIANCE OF RATE OF GAIN (Y) ON LENGTH OF BODY (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	3234.51	49.82	3.82	0.45**	55	3.06			
Between seasons	1	1134.81	10.55	0.10	1.00	1	0.06	0.06	1134.81	0.10
Within seasons	55	2099.70	39.26	3.72	0.44**	54	2.99	0.06	38.18	0.07
Between types within seasons	2	529.52	28.35	1.77	0.93	2	1.11	0.56**	264.76	0.89**
Within types within seasons	53	1570.18	10.91	1.95	0.20	52	1.88	0.04	29.63	0.04
Between sires within types within seasons	7	242.69	6.91	0.70	0.54	7	0.64	0.09**	34.67	0.10**
Within sires within types within seasons	46	1327.49	4.00	1.25	0.10	45	1.23	0.03	28.86	0.03

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 12.--ANALYSIS OF COVARIANCE OF RATE OF GAIN (Y) ON WIDTH OF CHEST (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	310.67	4.69	3.82	0.14	55	3.75			
Between seasons	1	4.66	0.68	0.10	1.00	1	0.08	0.08	4.66	0.10
Within seasons	55	306.00	4.01	3.72	0.12	54	3.67	0.07	5.56	0.07
Between types within seasons	2	29.29	5.06	1.77	0.70	2	1.72	0.86**	14.64	0.89**
Within types within seasons	53	276.71	-1.05	1.95	-0.04	52	1.95	0.04	5.22	0.04
Between sires within types within seasons	7	68.64	1.80	0.71	0.26	7	0.74	0.11**	9.81	0.10**
Within sires, within types within seasons	46	208.07	-2.85	1.25	-0.18	45	1.21	0.03	4.52	0.03

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 13.--ANALYSIS OF COVARIANCE OF T.D.N. PER # GAIN (Y) ON $\frac{\text{WEIGHT}}{\text{WITHER HEIGHT}}$ (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	17.44	8.04	9.99	0.61**	55	6.28			
Between seasons	1	1.63	1.94	2.30	1.00	1	0.95	0.95**	1.63*	2.30**
Within seasons	55	15.81	6.10	7.68	0.55**	54	5.33	0.10	0.29	0.14
Between types within seasons	2	1.11	0.24	0.82	0.26	2	0.80	0.40*	0.55	0.41
Within types within seasons	53	14.71	5.85	6.86	0.58**	52	4.53	0.09	0.28	0.13
Between sires within types within seasons	7	3.40	0.95	0.57	0.68	7	0.37	0.05	0.49	0.08
Within sires within types within seasons	46	11.31	4.90	6.29	0.58**	45	4.17	0.09	0.25	0.14

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 14.--ANALYSIS OF COVARIANCE OF T.D.N. PER # GAIN (Y) ON $\frac{\text{WIDTH OF HEAD}}{\text{LENGTH OF HEAD}}$ (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x	xy	y		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	0.01	0.06	9.99	0.18	55	9.65			
Between seasons	1	0.00+	0.00+	2.30	-1.00	1	2.34	2.34**	0.00+	2.30**
Within seasons	55	0.01	0.06	7.68	0.22	54	7.30	0.14	0.00+	0.14
Between types within seasons	2	0.00+	0.03	0.82	0.75	2	0.55	0.27	0.00+	0.41
Within types within seasons	53	0.01	0.03	6.86	0.12	52	6.76	0.13	0.00+	0.13
Between sires within types within seasons	7	0.00+	-0.00+	0.57	-0.08	7	0.58	0.08	0.00+	0.08
Within sires within types within seasons	46	0.01	0.03	6.29	0.14	45	6.17	0.14	0.00+	0.14

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 15.--ANALYSIS OF COVARIANCE OF T.D.N. PER # GAIN (Y) ON $\frac{\text{WIDTH OF CHEST}}{\text{WITHER HEIGHT}}$ (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	0.03	0.06	9.99	0.10	55	9.88			
Between seasons	1	0.01	-0.13	2.30	-1.00	1	3.64	3.64**	0.01**	2.30**
Within seasons	55	0.02	0.18	7.68	0.43**	54	6.24	0.12	0.00+	0.14
Between types within seasons	2	0.00	0.04	0.82	0.81	2	0.38	0.19	0.00+*	0.41
Within types within seasons	53	0.02	0.14	6.86	0.38**	52	5.86	0.11	0.00+	0.13
Between sires within types within seasons	7	0.00+	0.03	0.57	0.67	7	0.33	0.05	0.00+	0.08
Within sires within types within seasons	46	0.02	0.11	6.29	0.35*	45	5.53	0.12	0.00+	0.14

Table 16.--ANALYSIS OF COVARIANCE OF T.D.N. PER # GAIN (Y) ON $\frac{\text{DEPTH OF CHEST}}{\text{LENGTH OF CANNON BONE}}$(X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	1.67	2.14	9.99	0.52**	55	7.25			
Between seasons	1	0.23	0.73	2.30	1.00	1	0.95	0.95**	0.23**	2.30**
Within seasons	55	1.44	1.41	7.68	0.42**	54	6.30	0.12	0.03	0.14
Between types within seasons	2	0.66	0.62	0.82	0.84	2	0.24	0.12	0.33**	0.41
Within types within seasons	53	0.78	0.79	6.86	0.34*	52	6.06	0.12	0.01	0.13
Between sires within types within seasons	7	0.15	0.01	0.57	0.03	7	0.74	0.11	0.02	0.08
Within sires within types within seasons	46	0.63	0.78	6.29	0.39**	45	5.31	0.12	0.01	0.14

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 17.--ANALYSIS OF COVARIANCE OF RATE OF GAIN (Y) ON $\frac{\text{WEIGHT}}{\text{WITHER HEIGHT}}$ (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x	xy	y		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	17.44	1.06	3.82	0.13	55	3.75			
Between seasons	1	1.63	0.40	0.10	1.00	1	0.06	0.06	1.63*	0.10
Within seasons	55	15.81	0.66	3.72	0.09	54	3.69	0.07	0.29	0.07
Between types within seasons	2	1.11	0.72	1.77	0.51	2	1.74	0.87**	0.55	0.89**
Within types within seasons	53	14.71	-0.06	1.95	-0.01	52	1.95	0.04	0.28	0.04
Between sires within types within seasons	7	3.40	0.14	0.71	0.09	7	0.71	0.10**	0.49	0.10**
Within sires within types within seasons	46	11.31	-0.19	1.25	-0.05	45	1.24	0.03	0.25	0.03

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 18.--ANALYSIS OF COVARIANCE OF RATE OF GAIN (Y) ON $\frac{\text{WIDTH OF HEAD}}{\text{LENGTH OF HEAD}}$ (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	0.01	-0.08	3.82	-0.38**	55	3.28			
Between seasons	1	0.00+	-0.00+	0.10	-1.00	1	0.09	0.09	0.00+	0.10
Within seasons	55	0.01	-0.08	3.72	-0.38**	54	3.19	0.06	0.00+	0.07
Between types within seasons	2	0.00+	-0.07	1.77	-1.00*	1	1.24	0.62**	0.00+	0.89**
Within types within seasons	53	0.01	-0.01	1.95	-0.07	52	1.94	0.04	0.00+	0.04
Between sires within types within seasons	7	0.00+	-0.00+	0.71	-0.34	7	0.70	0.10**	0.00+	0.10**
Within sires within types within seasons	46	0.01	-0.00+	1.25	-0.03	45	1.25	0.03	0.00+	0.03

** Significant at .01 level.

* Significant at..05 level.

ss: Sum of squares

ms: Mean square

Table 19.--ANALYSIS OF COVARIANCE OF RATE OF GAIN (Y) ON $\frac{\text{WIDTH OF CHEST}}{\text{WITHER HEIGHT}}$ (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x	xy	y		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	0.03	-0.15	3.82	-0.44**	55	3.07			
Between seasons	1	0.01	-0.03	0.10	-1.00	1	0.01	0.01	0.01**	0.10
Within seasons	55	0.02	-0.13	3.72	-0.42**	54	3.05	0.06	0.00+	0.07
Between types within seasons	2	0.00+	-0.07	1.77	-0.98	2	1.23	0.62**	0.00+*	0.89**
Within types within seasons	53	0.02	-0.05	1.95	-0.26*	52	1.82	0.04	0.00+	0.04
Between sires within types within seasons	7	0.00+	+0.00+	0.71	+0.01	7	0.74	0.11**	0.00+	0.10**
Within sires within types within seasons	46	0.02	-0.05	1.25	-0.37*	45	1.08	0.02	0.00+	0.03

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 20.--ANALYSIS OF COVARIANCE OF RATE OF GAIN (Y) ON $\frac{\text{DEPTH OF CHEST}}{\text{LENGTH OF CANNON BONE}}$ (X)

		Squares and products				Errors of estimate			Analysis of variance	
Variability due to	D/F	x^2	xy	y^2	r	D/F	ss	ms	ms(X)	ms(Y)
Totals	56	1.67	-1.06	3.82	-0.42**	55	3.15			
Between seasons	1	0.23	0.15	0.10	+1.00	1	0.44	0.44**	0.23	0.10
Within seasons	55	1.44	-1.21	3.72	-0.52**	54	2.71	0.05	0.03	0.07
Between types within seasons	2	0.66	-1.06	1.77	-0.98	2	0.79	0.39**	0.33	0.89**
Within types within seasons	53	0.78	-0.15	1.95	-0.12	52	1.92	0.04	0.01	0.04
Between sires within types within seasons	7	0.15	0.03	0.71	+0.10	7	0.73	0.10**	0.02	0.10**
Within sires within types within seasons	46	0.63	-0.19	1.25	-0.21	45	1.19	0.03	0.01	0.03

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 21.--ANALYSIS OF COVARIANCE OF LENGTH FROM FIRST RIB TO PELVIC BONE (Y) ON LENGTH OF BODY (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	3125.02	2243.01	2068.49	0.88**	55	458.55			
Between seasons	1	419.22	308.62	227.20	1.00	1	0.16	0.16	419.22**	227.20*
Within seasons	55	2705.79	1934.38	1841.28	0.87**	54	458.39	8.49	49.20	33.48
Between types within seasons	2	1734.18	1438.58	1205.37	1.00	2	75.48	37.74**	867.09**	602.68**
Within types within seasons	53	971.61	495.80	635.91	0.63**	52	382.91	7.36	18.33	12.00
Between sires within types within seasons	7	148.10	29.38	116.46	0.22	7	127.62	18.23**	21.16	16.64
Within sires within types within seasons	46	823.51	466.42	519.45	0.71**	45	255.28	5.67	17.90	11.29

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

Table 22.--ANALYSIS OF COVARIANCE OF AREA OF RIB EYE MUSCLE (Y) ON WIDTH OF LOIN (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	145.42	191.56	2323.92	0.33*	55	2071.56			
Between seasons	1	1.42	12.28	105.90	1.00	1	76.76	76.76	1.42	105.90
Within seasons	55	143.99	179.28	2218.02	0.32*	54	1994.80	36.94	2.62	40.33
Between types within seasons	2	26.32	101.58	509.65	0.88	2	337.74	168.87**	13.16**	254.83**
Within types within seasons	53	117.67	77.70	1708.37	0.17	52	1657.06	31.87	2.22	32.23
Between sires within types within seasons	7	11.74	12.36	442.33	0.17	7	431.33	61.62*	1.68	63.19*
Within sires within types within seasons	46	105.94	65.34	1266.04	0.18	45	1225.73	27.24	2.30	27.52

** Significant at .01 level.
* Significant at .05 level.

ss: Sum of squares
ms: Mean square

Table 23.---ANALYSIS OF COVARIANCE OF AREA OF RIB EYE MUSCLE (Y) ON PATELLA TO PATELLA (X)

Variability due to	DF	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		DF	ss	ms	ms(X)	ms(Y)
Totals	56	985.56	812.33	2323.92	0.54**	55	1654.38			
Between seasons	1	6.59	26.42	105.90	1.00	1	67.27	67.27	6.59	105.90
Within seasons	55	978.97	785.90	2218.02	0.53**	54	1587.11	29.39	17.80	40.33
Between types within seasons	2	439.92	438.63	509.65	0.93	2	102.46	51.23	219.96**	254.83**
Within types within seasons	53	539.05	347.27	1708.37	0.36**	52	1484.65	28.55	10.17	32.23
Between sires within types within seasons	7	104.14	26.52	442.33	0.12	7	455.17	65.02*	14.88	63.19*
Within sires within types within seasons	46	434.90	320.75	1266.04	0.43**	45	1029.48	22.88	9.45	27.52

** Significant at .01 level.
* Significant at .05 level.

ss: Sum of squares
ms: Mean square

Table 24.--ANALYSIS OF COVARIANCE OF AREA OF RIB EYE MUSCLE (Y) ON SLAUGHTER GRADE OF LOIN (X)

Variability due to	DF	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		DF	ss	ms	ms(X)	ms(Y)
Totals	56	5.01	-32.01	2323.92	-0.30*	55	2119.65			
Between seasons	1	0.64	- 8.22	105.90	-1.00	1	30.89	30.89	0.64**	105.90
Within seasons	55	4.38	-23.79	2218.02	-0.24	54	2088.75	38.68	0.08	40.33
Between types within seasons	2	0.53	- 6.20	509.65	-0.38	2	460.68	230.34**	0.26*	254.83**
Within types within seasons	53	3.85	-17.58	1708.37	-0.22	52	1628.08	31.31	0.07	32.23
Between sires within types within seasons	7	0.51	-8.89	442.33	-0.59	7	384.64	54.95	0.07	63.19*
Within sires within types within seasons	46	3.34	- 8.69	1266.04	-0.13	45	1243.43	27.63	0.07	27.52

** Significat at .01 level.
* Significant at .05 level.

ss: Sum of squares
ms: Mean square

Table 25.--ANALYSIS OF COVARIANCE OF AREA OF RIB EYE MUSCLE (Y) ON SLAUGHTER GRADE OF ROUND (X)

Variability due to	D/F	Squares and products			r	D/F	Errors of estimate		Analysis of variance	
		x^2	xy	y^2			ss	ms	ms(X)	ms(Y)
Totals	56	9.79	-34.31	2323.92	-0.23	55	2203.71			
Between seasons	1	0.90	- 9.78	105.90	-1.00	1	53.38	53.38	0.90*	105.90
Within seasons	55	8.89	-24.53	2218.02	-0.18	54	2150.32	39.82	0.16	40.33
Between types within seasons	2	4.03	-21.17	509.65	-0.47	2	444.27	222.14**	2.01**	254.83**
Within types within seasons	53	4.86	- 3.36	1708.37	-0.04	52	1706.05	32.81	0.09	32.23
Between sires within types within seasons	7	0.36	- 5.38	442.33	-0.42	7	440.92	62.99*	0.05	63.19*
Within sires within types within seasons	46	4.50	+ 2.02	1266.04	+0.03	45	1265.13	28.11	0.10	27.52

**Significant at .01 level.
* Significant at .05 level.

ss: Sum of squares
ms: Mean square

Table 26.—ANALYSIS OF COVARIANCE OF ACTUAL MEASURED FAT OVER RIB (Y) ON SLAUGHTER GRADE OF THICKNESS OF FAT (X)

Variability due to	D/F	Squares and products			r	Errors of estimate			Analysis of variance	
		x^2	xy	y^2		D/F	ss	ms	ms(X)	ms(Y)
Totals	56	3.26	2.38	6.06	0.54**	55	4.33			
Between seasons	1	0.01	0.00+	0.00+	1.00	1	0.00+	0.00+	0.01	0.00+
Within seasons	55	3.26	2.38	6.06	0.54**	54	4.33	0.08	0.06	0.11
Between types within seasons	2	0.22	0.10	0.05	0.92	2	0.03	0.01	0.11	0.03
Within types within seasons	53	3.04	2.28	6.01	0.53**	52	4.30	0.08	0.06	0.11
Between sires within types within seasons	7	0.49	0.69	1.56	0.79*	7	0.84	0.12	0.07	0.22*
Within sires within types within seasons	46	2.55	1.59	4.46	0.47**	45	3.46	0.08	0.06	0.10

** Significant at .01 level.

* Significant at .05 level.

ss: Sum of squares

ms: Mean square

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