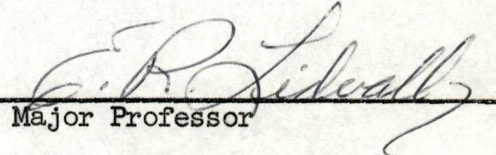


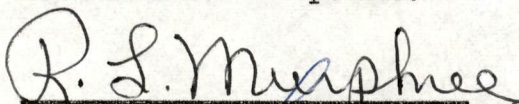
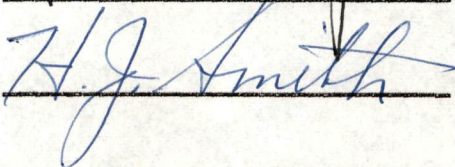
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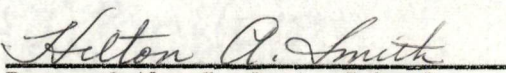
I am submitting herewith a thesis written by Harold Glen Fogleman entitled "The Relationship of Selected Live Animal Measurements to Carcass Length in Swine." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.


Major Professor

We have read this thesis and
recommend its acceptance:

Accepted for the Council:


Dean of the Graduate School

THE RELATIONSHIP OF SELECTED LIVE ANIMAL MEASUREMENTS
TO CARCASS LENGTH IN SWINE

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Harold Glen Fogleman
August 1966

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CHAPTER I

INTRODUCTION

Surveys have indicated that consumers prefer high quality lean cuts of pork in preference to those cuts which are excessively fat. A decreased demand for lard, consumer resistance to fatty foods, more specialization in meat marketing and selection for improved production traits have increased the need for improved evaluation techniques in swine breeding and selection.

The advent of swine certification programs created a need and desire for simplified methods of measuring certain conformation and/or carcass traits on the live animal. Such methods would allow extensive information to be obtained without sacrificing potentially superior breeding animals.

Backfat thickness, carcass length and area of the longissimus dorsi muscle have been used extensively as measures of carcass desirability in swine certification programs. Research studies indicate that backfat thickness and loin eye area may be determined with a high degree of accuracy on the live hog. Probing hogs for backfat thickness has proven to be a practical and useful tool to select those hogs which have less backfat. Ultrasonic evaluation techniques have been introduced in recent years and serve as a tool to measure depth of backfat and area of loin eye.

The relationship between live animal measurements and carcass length has not been studied extensively in swine. There is general agreement in swine carcass studies that a low correlation exists between carcass length and carcass cut-out value. On the other hand, there is limited research evidence that added length in swine is associated with greater sow productivity.

This study was undertaken in an effort to develop a method of predicting carcass length in swine from certain live animal measurements. The relationship between carcass length and certain carcass traits also was studied.

CHAPTER II

REVIEW OF LITERATURE

Only a limited amount of literature has been published relating live hog measurements to carcass length. There is considerable published data concerning the value and importance of other carcass traits such as backfat thickness (BF), loin eye area (LEA) and lean cut percentage.

Ferrin (1939) reported that hogs measuring from 46 to 48 inches in body length (ear to tail) and from 29 to 31 inches in carcass length produced a higher proportion of desirable carcasses when slaughtered at 225 pounds live weight than hogs above 48 inches in body length or above 31 inches in carcass length.

Live hog length measurements were studied by Phillips and Dawson (1936) utilizing the following methods:

Method A - this method involved restraining the hog by placing a wire loop around the mandible and measuring from the base of the ear to the root of the tail with both a steel tape and calipers.

Method B - a livestock scaling device was used which obtained a ratio of one portion of the hog's body to another.

Method C - photographs were made and the images were enlarged to life size.

Phillips and Dawson recommended Method A as the most satisfactory, especially from the economic and time saving points of view.

Length measurements were taken on 141 hogs by Hetzer et al. (1950) as described by Phillips and Dawson (1936). These workers stated that since a hog's position changes so frequently, body measurements such as those studied might not be reliable. As a first step to determine the relative accuracy, the correlation or repeatability of single measurements on the same hog was calculated for each measurement. The repeatability between single measurements of body length was 72.4 per cent. Each measurement was taken twice on the same hog by each of two men; the average correlation of the four measurements being 0.913.

Bratzler and Margerum (1935) had three experienced livestock men score 434 live hogs for body length. The hogs were divided into three weight groups: 181-200 pounds, 201-220 pounds and 221-240 pounds. The three judges had the following correlation coefficients for the respective weight groups: Judge "A"--0.66, 0.39 and 0.18; Judge "B"--0.57, 0.42 and 0.15; and Judge "C"--0.60, 0.29 and 0.13.

Hetzer, Zeller and Hankins (1956) stated that neither visual estimates nor individual body measurements were sufficiently accurate to warrant their general use in swine improvement programs.

Measurements of backfat thickness, scores for market grade and various body measurements were obtained on 107 crossbred hogs by King, Hetzer and Zeller (1962). Among the live hog measurements taken was the length of body from ear to tail. To facilitate measuring, each

hog was restrained with the loop of a wire hog catcher placed around the maxilla. The body measurements were taken to the nearest 0.1 centimeter in accordance with the method described by Phillips and Dawson (1936).

The carcass traits studied were: (1) combined yield of lean cuts--hams, loins, picnic shoulders and shoulder butts; (2) yield of fat cuts--fat back, leaf fat, plate and fat trimmings; (3) LEA at the last rib; and (4) yield of lean meat in the right ham, calculated as a percentage of the weight of the right ham.

At 225 pounds, a significant simple correlation of 0.31 was obtained between yield of lean cuts and length from ear to tail in gilts. In barrows, there was a significant correlation of 0.29 between length from ear to tail and yield of lean meat in the right ham.

Tuma, Merkel and Mackintosh (1958) reported that 39 barrows were appraised by five experienced livestock men to determine the accuracy with which individuals can estimate carcass length by observing the live animal. The correlation coefficients for the estimated compared to the actual carcass length varied from 0.36 to 0.73.

Bowman, Whatley and Walters (1962) and Zobriský et al. (1959) showed that carcass length was of little value in predicting per cent separable lean or yield of fat. Doornenbal, Wellington and Stouffer (1962) reported that carcass length was of little value as an index of carcass composition, showing a negative relationship ($r = -.14$) with per cent protein and a positive relationship ($r = 0.30$) with

per cent fat. Bogart, Weaver and Comfort (1940) reported a correlation of 0.52 between body length and carcass length in a study of 69 Poland China hogs.

King (1957) examined the relationship between various carcass traits. Although all measurements were made on the carcass, some were more or less analogous to live measurements, i.e., width and depth of body and length of leg. None of these were highly related to carcass length.

Using 81 barrows and 118 barrows and gilts, Heidenreich et al. (1961) reported that body length score, submitted by three judges, was less accurate in estimating actual carcass length than was body length measurement. Correlations of 0.53 and 0.56 were noted between body length measurement and carcass length, for the barrows and the barrows and gilts, respectively. This was compared to correlations of 0.44 and 0.57 for body length score and carcass length, for the barrows and the barrows and gilts, respectively.

The relation of carcass length to other carcass traits has been investigated. In a detailed eight-year study, Hiner and Thornton (1962) slaughtered hogs at a standard weight of 225 lb. Carcass lengths ranged from 26 to 35 inches. Results indicated that an increase in carcass length was associated with a decrease in fat cuts, BF and bacon weight and an increase in ham and loin weights in the Yorkshire and Duroc breeds. In the Duroc breed the combined lean cuts and LEA increased up to 31 inches, then started to decline. However, these fluctuated in the Yorkshire breed.

Correlations of carcass length and carcass cut-out were low, the highest being 0.38 (Pearson et al., 1956). Yield of fat was influenced very little by carcass length (Zobrisky et al., 1959). The correlation of carcass length with separable lean, separable fat, or lean cut yield was generally not high (Graham et al., 1963). Kline and Goll (1964) reported a non-significant correlation between carcass length and per cent ham and loin. Breidenstein (1963) obtained correlations of carcass length with ham and loin as a per cent of carcass weight ($r = 0.21$), dollar value per hundred pounds of carcass ($r = 0.15$) and dollar value per hundred pounds of live weight ($r = 0.12$).

CHAPTER III

EXPERIMENTAL PROCEDURE

Data were obtained from 74 market hogs which were measured alive and then slaughtered at the University of Tennessee Meat Laboratory during the winter of 1966. Forty-two of the hogs were from the University of Tennessee Swine Testing Station and consisted of 18 barrows and 24 gilts, representing the Yorkshire, Duroc and Hampshire breeds. The remaining 32 hogs were Duroc gilts from the registered Duroc herd at the University of Tennessee Agricultural Experiment Station, Knoxville.

I. EXPERIMENT I

The initial experiment involved 42 hogs from the Tennessee Swine Testing Station. These hogs were removed from the testing station pens as they reached approximately 205 pounds body weight. They were then trucked 7 miles to the U.T. Meat Laboratory, where they were allowed a 24-hour shrinkage period without feed but had free access to water. During this period, external body measurements were obtained and carcass length estimated by three experienced livestock judges. The estimates by the three judges were made independently to the nearest 0.1 inch before the hogs were measured.

In previous studies, difficulty was encountered in developing techniques for restraining the hogs while obtaining live body measurements. The restraining crate used in this study is, as far as is known,

the first time such a device has been used to restrain hogs for length measurements (Figure 1). The restraining crate was originally designed for use in somascope studies at the University of Tennessee. This device was similar to a swine breeding crate in size and shape. The ends of a 16-inch canvas were attached to rods which could be rolled by handles located at the entrance of the crate. A two-by-four inch board extending the length of the crate was attached to the middle of the canvas as it rested in the bottom of the crate. The purpose of the board was to support the head and to provide more rigid support of the entire animal. The hog was driven into the crate and suspended by cranking the handles, which in turn rolled the canvas onto the rods. A strap was then fastened over the neck, which aided in keeping the hog confined.

Once in position, the ventral surface of the hog was resting on the board. The canvas "saddle" was in contact with approximately one-third of the hog's lateral surface before it flared to the sides of the crate, thus holding the hog in an upright position. All four legs were hanging straight down, and the entire body appeared to be in a relaxed state. Each hog was positioned as straight from nose to tail as possible.

Measurements were obtained between prominent points of the hog's external anatomy. These points were established by both observing and palpating the hogs after they were restrained. The anatomical points established were:

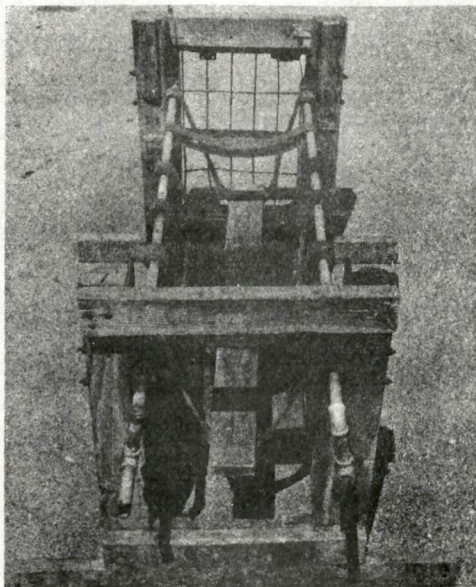
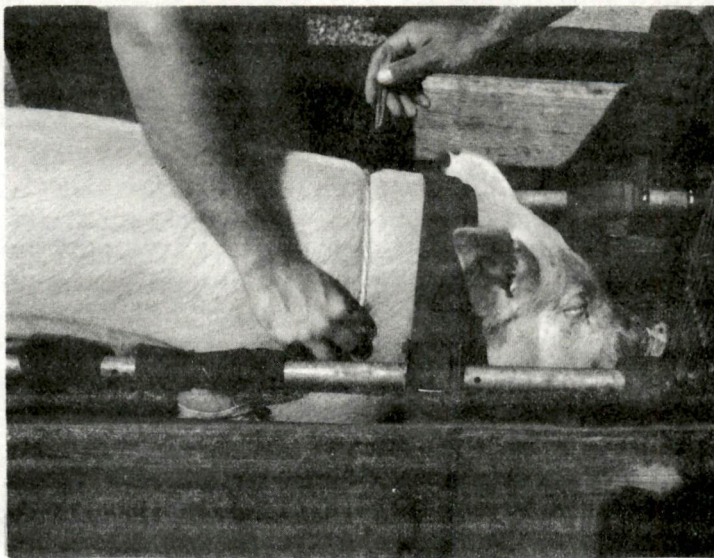


Figure 1. Swine restraining crate.

1. Poll - located at the base of the skull.
2. Tuber spinae - located on the lateral surface of the scapula
(point of the shoulder).
3. Last rib.
4. Tuber coxae - the most lateral portion of the anterior
surface of the ilium (hip).
5. Root of tail.

A point on the dorsal midline corresponding to the anatomical points on the lateral surfaces was determined (Figure 2). This was accomplished by firmly holding the end of a 16-inch rubber tube to an established point and stretching it over the dorsal surface to the identical point on the opposite side. The location of the rubber tubing as it passed over the spinous processes was observed for accuracy and identified by penetrating the hog's skin with a small, sharp-pointed probing knife. This method of identifying a specific location was used for the tuber spinae, the tuber coxae and the last rib. This method enabled measurements of the distance between any two of the previously mentioned points by simply restraining the hog, locating and identifying the points and recording the readings from a steel measuring tape which was extended from the poll to the root of the tail along the dorsal midline. These measurements were taken in duplicate to the nearest millimeter.

Another set of measurements was taken along the animal's lateral surface from the central and most lateral portion of the



(a) Method of identifying tuber spinae location.



(b) Method of identifying tuber coxae location.

Figure 2. Methods of determining anatomical points on live hog.

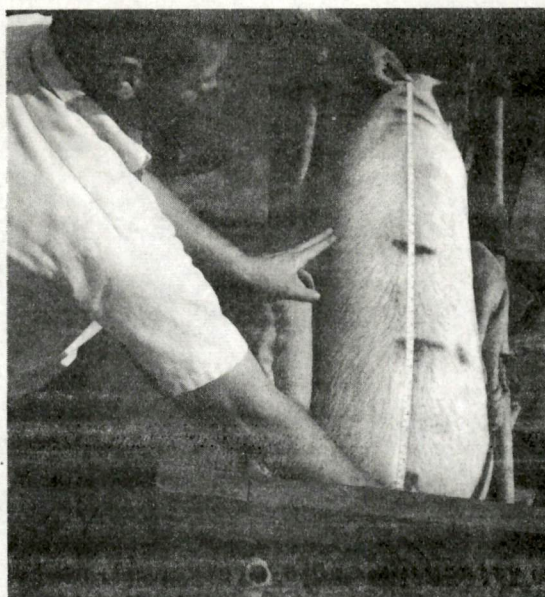
tuber spinae to the central and most lateral portion of the tuber coxae (Figure 3). Both left and right lateral surfaces were measured to the nearest millimeter with a steel tape.

After slaughter, the warm carcasses were hung in a thermostatically controlled 38° F. cooler for 48 hours before cutting. After chilling, carcass length was measured to the nearest millimeter from the anterior edge of the aitch bone to the anterior edge of the first rib at the dorsal attachment. Backfat measurements, including skin thickness, were taken to the nearest millimeter at the first rib, last rib and last lumbar vertebra and averaged. A tracing of the cross-section of the l. dorsi muscle was taken between the tenth and eleventh ribs. LEA was measured to the nearest 0.01 square inch with a compensating polar planimeter. The right side of each carcass was cut according to Reciprocal Meat Conference (1952) procedures. Each cut was weighed to the nearest 0.1 pound. These values, along with BF thickness and LEA, were utilized in computations of correlation coefficients with carcass length. The live animal measurements were utilized in an attempt to derive equations for predicting carcass length from selected live measurements.

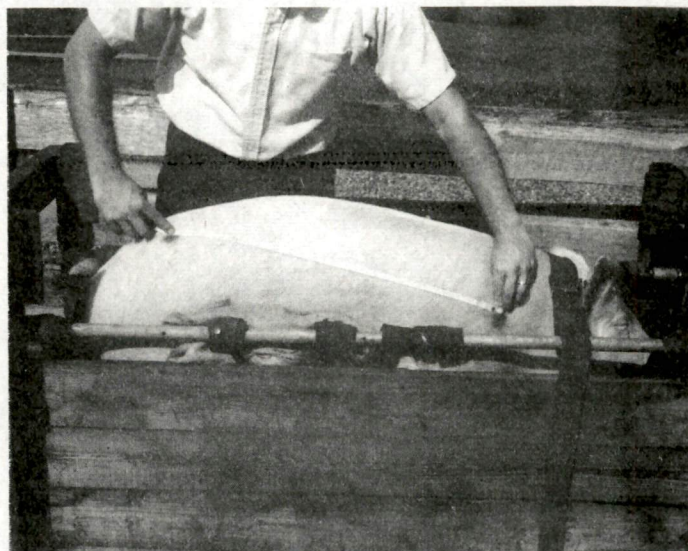
II. EXPERIMENT II

Experiment II of this study involved 32 Duroc gilts ranging in weight from 181 to 231 pounds. All data were collected on the same day. All hogs received identical treatment throughout the data collection period.

Procedures for obtaining live hog measurements and carcass length were the same as in Experiment I. The measurements which



(a) Method of obtaining measurements along dorsal surface of live hogs.



(b) Method of obtaining measurements along lateral surface of live hogs.

Figure 3. Methods of obtaining measurements from live hog.

yielded higher correlations with carcass length in Experiment I again were made. The anatomical points established in order to obtain these measurements were:

1. Poll
2. Tuber spinae
3. Last cervical vertebra
4. Tuber coxae
5. Root of tail

The last cervical vertebra was located by palpating the neck. There is a distinct indentation as pressure is applied with the finger tips along the spinous processes moving anteriorly from the top of the shoulders. The point of indentation is between the larger last cervical vertebra and the much smaller next to last cervical vertebra. This indentation was especially prominent in leaner hogs. This location was marked by making a small cut with a probing knife.

The last rib was omitted as a point of measurement because of difficulty in consistently locating the desired point. Also, there was no attempt to estimate carcass length in the live hogs by visual appraisal. The lateral measurements between the tuber spinae and the tuber coxae were again obtained utilizing the steel measuring tape as described in Experiment I. Also, a simple set of calipers was designed and utilized to obtain these same lateral measurements. Since all correlation coefficients between carcass traits and length were either low or negative in Experiment I, they were not calculated in Experiment II.

III. EXPERIMENT III

A prediction equation, constructed from data obtained in Experiments I and II, was utilized to predict the carcass length of all 74 hogs in the experiment.

IV. STATISTICAL PROCEDURES

The data were analyzed by simple correlation and multiple regression procedures to determine the relationship between selected live animal measurements and actual carcass length as described by Snedecor (1956).

Coefficients of determination (R^2) were obtained. This is the estimated variation in the dependent variable explained by the independent variable in question.

$$r_{12} = \frac{\sum x_1 x_2}{\sqrt{(\sum x_1^2)(\sum x_2^2)}}$$

where:

r_{12} is the estimate of the correlation of X_1 and X_2 .

$\sum x_1^2$ is the pooled sum of squares of deviation from the means of X_1 .

$\sum x_2^2$ is the pooled sum of squares of deviation from the means of X_2 .

$\sum x_1 x_2$ is the pooled sum of products of deviations from the means of X_1 and X_2 .

The prediction equations were based on the following formula:

$$\hat{Y} = \bar{y} + (b_1 X_1 - b_1 \bar{x}_1) + (b_2 X_2 - b_2 \bar{x}_2) + \\ \dots (b_n X_n - b_n \bar{x}_n)$$

where:

$\hat{Y}$ is the carcass length.

$\bar{y}$ is the overall mean of the dependent variable.

b is the partial regression coefficient of the independent variable.

X is the independent variable of the individual hog.

$\bar{x}$ is the overall mean of the independent variable.

CHAPTER IV

RESULTS AND DISCUSSION

I. EXPERIMENT I

The distribution of the 42 hogs by breed and sex was:

<u>Breed</u>	<u>Barrows</u>	<u>Gilts</u>	<u>Total</u>
Hampshire	7	4	11
Duroc	4	15	19
Yorkshire	7	5	12
Total	18	24	42

The means and standard errors of the traits studied are shown in Table I. These hogs were much meatier than the average market hog in Tennessee. Average backfat thickness was 3.02 cm. with a range from 2.31 to 4.16 cm. Average carcass length was 75.7 cm. with a range from 70.1 to 80.8 cm. The square inches of loin eye at the tenth rib ranged from 3.3 to 6.5 with a mean of 4.60. The per cent of lean cuts on a carcass basis averaged 56.1 and all hogs were graded U.S. 1.

Among the measurements taken, the one from the poll to the tuber spinae had the smallest standard error. The measurement from the poll to the root of the tail had the largest standard error. This indicates that the longer measurements generally had higher standard errors than the shorter ones.

TABLE I
MEANS AND STANDARD ERRORS FOR TRAITS STUDIED--
EXPERIMENT I

Trait	Mean	Standard error
Poll to tuber spinae, cm.	23.0	0.25
Poll to last rib, cm.	67.9	0.50
Poll to tuber coxae, cm.	85.8	0.44
Poll to root of tail (1st measurement), cm.	108.9	0.57
Poll to root of tail (2nd measurement), cm.	109.0	0.57
Tuber spinae to last rib, cm.	44.7	0.42
Tuber spinae to tuber coxae (dorsal), cm.	62.6	0.36
Tuber spinae to root of tail, cm.	85.8	0.47
Last rib to tuber coxae, cm.	17.9	0.38
Last rib to root of tail, cm.	41.1	0.40
Tuber coxae to root of tail, cm.	23.1	0.34
Tuber spinae to tuber coxae (right side-tape), cm.	64.0	0.32
Tuber spinae to tuber coxae (left side-tape), cm.	64.0	0.32
Judge "A" length estimates, cm.	75.3	0.24
Judge "B" length estimates, cm.	75.3	0.32
Judge "C" length estimates, cm.	75.4	0.23
Carcass length, cm.	75.6	0.32
Off test weight, lb.	206.8	1.03
Kill weight, lb.	197.2	0.96
Average fat thickness, cm.	3.02	0.07
Average fat thickness (adj. 200 lbs.), cm.	2.84	0.09
Carcass weight, lb.	143.0	0.83
Loin eye area, sq. in.	4.60	0.10
Ham weight, lb.	15.9	0.14
Loin weight, lb.	11.7	0.14
Shoulder weight, lb.	12.7	0.14
Ham per cent	22.1	0.17
Loin per cent	16.3	0.22
Shoulder per cent	17.6	0.17
Ham + loin per cent	38.4	0.34
Ham + loin + shoulder per cent	56.1	0.42

Judges' estimates of carcass length. The three judges were better estimators of carcass length than most of the linear measurements. Both Judge "A" and Judge "B" had average estimates of 75.3 cm., while Judge "C" had an average of 75.4 cm. Judges "A" and "C" had standard errors of 0.24 and 0.23, respectively, while Judge "B" had a standard error of 0.32. This indicates that Judges "A" and "C" tended to have a narrower range of length estimates than did Judge "B". Table II gives simple correlation coefficients between carcass length and the live hog measurements. All three judges' estimates were significantly related ($P < .01$) to carcass length. Correlation coefficients with carcass length were 0.61, 0.74 and 0.70 for estimates of judges "A", "B" and "C", respectively.

Tuber spinae to tuber coxae. The highest single correlation with carcass length was obtained with the measured distance between the tuber spinae and the tuber coxae on the lateral surface of the hog. The correlation coefficient between this measurement and carcass length was 0.78 on the left side and 0.74 on the right side. Carcass length was measured only on the left side. This may account for the slightly higher correlation obtained from the left side measurement.

Both of these measurements were superior to the three judges in predicting carcass length in swine. There is no available literature concerning this measurement, and as far as is known, this was the first time it has been used in an effort to predict carcass length in swine.

TABLE II

SIMPLE CORRELATION COEFFICIENTS BETWEEN CARCASS LENGTH
AND SELECTED LIVE MEASUREMENTS--
EXPERIMENT I

Variable ^a	R ²
Poll to tuber spinae	0.39*
Poll to last rib	0.35*
Poll to tuber coxae	0.58**
Poll to root of tail	0.70**
Poll to root of tail	0.69**
Tuber spinae to last rib	0.20
Tuber spinae to tuber coxae	0.42**
Tuber spinae to root of tail	0.64**
Last rib to tuber coxae	0.18
Last rib to root of tail	0.54**
Tuber coxae to root of tail	0.43**
Tuber spinae to tuber coxae (right side)	0.74**
Tuber spinae to tuber coxae (left side)	0.78**
Estimated carcass length	
Judge "A"	0.61**
Judge "B"	0.74**
Judge "C"	0.70**

*P<.05.

**P<.01.

While the left and right side lateral measurements from the tuber spinae to the tuber coxae explained 61.2 and 54.8 per cent of the variation in carcass length, respectively, the same measurement along the dorsal surface accounted for only 17.8 per cent. This probably was due to the error encountered in locating the two points on the dorsal surface of the hog.

Poll to root of tail. A correlation coefficient of 0.99 was obtained between the two measurements from the poll to the root of the tail over the dorsal surface of the hog. This repeatability was much higher than reported by Hetzer et al. (1950) and may be due to using the restraining crate. Approximately one-third of the hogs were released after the first measurement, then restrained and measured a second time. About two-thirds of the hogs were measured both times without releasing them from the crate.

A correlation of 0.69 was obtained between carcass length and the measurement from the poll to the root of the tail. This again was higher than any correlation found in the literature concerning this measurement. Heidenreich et al. (1961) obtained correlation coefficients of 0.44 and 0.57 for barrows and for barrows and gilts, respectively, using methods as described by Phillips and Dawson (1936).

Tuber spinae to root of tail. A correlation of 0.64 was obtained between carcass length and the measurement from the tuber spinae to the root of the tail taken on the dorsal surface of the hog. This measurement explained 41.1 per cent of the variation in carcass

length, compared to 48.4 per cent explained by the poll to the root of the tail measurement. This difference can perhaps be explained by the fact that the location of the tuber spinae could not be identified as accurately as could such points as the poll and the root of the tail.

Poll to tuber coxae. The measurement from the poll to the tuber coxae over the dorsal surface of the live hog had a correlation coefficient of 0.57 with carcass length. This was lower than the correlation obtained with carcass length for the poll to the root of the tail ($r = 0.69$) and the tuber spinae to the root of the tail ($r = 0.64$) measurements. This again could be explained by the error encountered in locating points on the dorsal surface of the hog. A note was made while collecting data that, on some of the fatter hogs, the tuber coxae was somewhat difficult to locate. These results support this note.

Comparisons of the correlation coefficients obtained from the last two measurements indicate that less variation existed in length of neck than in length of ham. The judges commented that certain hogs were "short hammed"; however, notes were insufficient to make a detailed study of this observation.

Poll to tuber spinae and tuber coxae to root of tail. The poll to the tuber spinae and the tuber coxae to the root of the tail measurements over the dorsal surface had almost identical means; 23.08 and 23.17, respectively. However, the tuber coxae to the root of the tail measurement accounted for 18.7 per cent of the variation in carcass length, compared to 15.5 per cent accounted for by the poll to the

tuber spinae measurement. Although neither are significantly correlated with carcass length, these results indicate that length of rump (length of ham) is slightly more highly correlated with carcass length than is length of neck.

Other live measurements. The last rib appeared to be the most difficult structure to locate on the live hog. This was indicated by the fact that the three lowest correlations obtained between live measurements and carcass length were associated with measurements involving the last rib. The poll to the last rib, the tuber spinae to the last rib and the last rib to the tuber coxae explained only 12.2, 4.0 and 3.2 per cent, respectively, of the variation in carcass length. None of these measurements were significantly correlated with carcass length. However, the distance from the last rib to the root of the tail was associated with 29.2 per cent ($P < .01$) of the variation in carcass length.

Carcass traits. Carcass length was significantly correlated (Table III) with off-feed weight ($r = 0.39$), slaughter weight ($r = 0.40$) and carcass weight ($r = 0.40$). Thus, there was a tendency for the longer hogs to be heavier. However, only about 16 per cent of the variation in carcass length was associated with these factors. These findings are in agreement with Mullins et al. (1960), Kline and Goll (1964) and Hiner and Thornton (1962).

All indicators of cut-out were not significantly correlated with carcass length. Some of the associations were negative. These results

TABLE III
SIMPLE CORRELATION COEFFICIENTS BETWEEN CARCASS
LENGTH AND SELECTED CARCASS TRAITS--
EXPERIMENT I

Variables	r
Off test weight, lb.	0.39*
Kill weight, lb.	0.40**
Total carcass weight, lb.	0.40**
Avg. fat thickness, cm.	-.02
Avg. fat thickness (adj. 200 lbs.), cm.	-.09
Loin eye area, sq. in.	-.03
Ham weight, lb.	0.18
Loin weight, lb.	0.04
Shoulder weight, lb.	0.22
Ham per cent	-.10
Shoulder per cent	-.16
Ham + loin per cent	0.02
Ham + loin + shoulder per cent	-.16

*P<.05.

**P<.01.

are in agreement with Bowman, Whatley and Walter (1962), Zobrisky et al. (1959) and Doornenbal, Wellington and Stouffer (1962).

Multiple correlation coefficients. Various combinations of independent variables are given in Table IV. The addition of breed significantly increased the R^2 values when applied in the mathematical models. When the lateral measurement from the tuber spinae to the tuber coxae on the left side of the live hog was used, 61 per cent of the variation in carcass length was explained. However, when breed was included with this measurement, 65 per cent of the variation in carcass length was explained. One combination which included the measurements from the poll to the tuber spinae, the poll to the root of the tail and the tuber coxae to the root of the tail explained 48 per cent of the carcass length variation; the addition of breed increased the percentage to 62. Notes made while collecting these data indicated that the tuber spinae appeared to be located slightly more anteriorly in the Yorkshire breed than in the Duroc and Hampshire breeds. The results here indicate that this could be true.

Prediction equations. Table V lists some of the prediction equations constructed from data obtained in Experiment I. The second equation was used to predict carcass length in the 32 hogs in Experiment II.

TABLE IV
PROPORTION OF VARIATION IN CARCASS LENGTH EXPLAINED BY
VARIOUS COMBINATIONS OF INDEPENDENT VARIABLES--
EXPERIMENT I

Variable ^a	R ²
X ₁	0.61
X ₁ , a ₁	0.65
X ₂ , X ₃ , X ₄ , X ₅	0.54
X ₂ , X ₃ , X ₄ , X ₅ , a ₁	0.64
X ₂ , X ₃ , X ₄	0.34
X ₂ , X ₃ , X ₄ , a ₁	0.54
X ₂ , X ₆ , X ₅	0.48
X ₂ , X ₆ , X ₅ , a ₁	0.62
X ₂ , X ₇	0.34
X ₂ , X ₇ , a ₁	0.54
X ₈ , X ₅	0.41
X ₈ , X ₅ , a ₁	0.56
X ₂ , X ₉ , X ₄	0.33
X ₂ , X ₉ , X ₄ , a ₁	0.54

^a
X₁ = Tuber spinae to tuber
coxae (left side-tape).
X₂ = Poll to tuber spinae.
X₃ = Tuber spinae to last rib.
X₄ = Last rib to tuber coxae.
X₅ = Tuber coxae to root of
tail.

X₆ = Poll to root of tail.
X₇ = Poll to tuber coxae.
X₈ = Tuber spinae to root of
tail.
X₉ = Poll to last rib.
a₁ = Breed.

TABLE V
EQUATIONS FOR PREDICTING CARCASS LENGTH FROM
SELECTED LIVE MEASUREMENTS--
EXPERIMENT I

Variable	Equation
X_1 = Tuber spinae to tuber coxae	$\hat{Y} = 25.8 + (0.778)(X_1)$
X_1 = Tuber spinae to tuber coxae	$\hat{Y} = 35.4 + (0.628)(X_1) + a_1$
a_1 = Breed ^a	$a_1 = -.361$ $a_2 = -.385$ $a_3 = +.746$
X_2 = Poll to tuber spinae X_3 = Tuber spinae to last rib X_4 = Last rib to tuber coxae X_5 = Tuber coxae to root of tail	$\hat{Y} = 31.3 + (0.368)(X_2) + (0.335)(X_3)$ $+ (0.552)(X_4) + (0.475)(X_5)$
X_2 = Poll to tuber spinae X_3 = Tuber spinae to last rib X_4 = Last rib to tuber coxae X_5 = Tuber coxae to root of tail a_1 = Breed	$\hat{Y} = 41.7 + (0.330)(X_2) + (0.246)(X_3)$ $+ (0.388)(X_4) + (0.361)(X_5) + a_1$ $a_1 = -.653$ $a_2 = -.473$ $a_3 = +1.126$
X_2 = Poll to tuber spinae X_3 = Tuber spinae to last rib X_4 = Last rib to tuber coxae a_1 = Breed	$\hat{Y} = 51.6 + (0.404)(X_2) + (0.233)(X_3)$ $+ (0.236)(X_4) + a_1$ $a_1 = -.834$ $a_2 = -.647$ $a_3 = +1.481$
X_6 = Poll to root of tail X_2 = Poll to tuber spinae X_5 = Tuber coxae to root of tail	$\hat{Y} = 30.57 + (0.405)(X_2) - (0.020)(X_6)$ $- (.020)(X_5)$

^a a_1 = Hampshire, a_2 = Duroc and a_3 = Yorkshire.

II. EXPERIMENT II

The off-feed weight for the 32 Duroc gilts in Experiment II ranged from 181 to 231 pounds and averaged 206.1 pounds. The means and standard errors of the measurements studied are shown in Table VI. These results indicate, as did those in Experiment I, that as the magnitude of the measurement increased, the standard error also increased. All measurements except from the poll to the last cervical vertebra, and the tuber coxae to the root of the tail over the dorsal surface of the hog were significantly correlated ($P < .01$) with carcass length.

A prediction equation, formulated from the tuber spinae to the tuber coxae lateral measurement plus the breed variable in Experiment I, was utilized to predict carcass length in the 32 live hogs. In Experiment I, this equation explained 65 per cent of the variation in carcass length. The prediction equation for carcass length was:

$$\hat{Y} = 35.4 + (0.628)(X_{12}) + a_1$$

where:

$\hat{Y}$ = carcass length, cm.

X_{12} = lateral measurement from the tuber spinae to tuber coxae, cm.

a_1 = breed (Duroc = -.555)

Carcass length estimates by this equation and deviations from actual carcass length appear in Table VII. The simple correlation coefficient between estimated and actual carcass length was 0.73. Twenty of the 32 lengths were estimated within 1.0 cm. while 6 deviated from the actual by more than 2.0 cm.

TABLE VI
MEANS AND STANDARD ERRORS FOR TRAITS STUDIED--
EXPERIMENT II

Trait	Mean	Standard error
Poll to last cervical vertebra, cm.	13.6	0.25
Poll to tuber coxae, cm.	85.6	0.62
Poll to root of tail, cm.	107.2	0.70
Last cervical vertebra to tuber coxae, cm.	72.1	0.58
Last cervical vertebra to root of tail, cm.	93.6	0.71
Tuber coxae to root of tail, cm.	21.5	0.47
Tuber spinae to tuber coxae, (right side-tape), cm.	64.7	0.29
Tuber spinae to tuber coxae (left side-tape), cm.	64.6	0.26
Tuber spinae to tuber coxae (right side-calipers), cm.	62.6	0.31
Tuber spinae to tuber coxae (left side-calipers), cm.	63.0	0.33
Carcass length, cm.	74.7	0.36
Off feed weight, lb.	206.1	2.72
Length predicted by equation developed in Experiment I, cm.	75.6	0.16

TABLE VII
 PREDICTED CARCASS LENGTH WITH DEVIATIONS
 FROM ACTUAL LENGTH--
 EXPERIMENT II

Predicted carcass length, cm.	Deviation from carcass length, cm.
75.2	+0.5
77.4	-0.7
75.8	-0.8
76.5	-0.2
74.7	+1.1
77.2	-0.1
75.7	+0.7
75.8	+1.1
76.1	+0.6
75.2	-0.8
75.2	-0.3
75.6	+1.2
75.2	+1.0
77.0	+0.3
76.8	+0.8
74.7	+1.7
77.0	+0.7
75.8	-0.1
75.9	-0.5
74.0	+0.5
75.2	+0.9
75.0	-2.5
75.5	+1.8
74.7	+1.9
77.0	+0.3
75.4	+0.6
76.5	+0.6
75.8	+2.0
74.0	+2.5
75.6	+5.6
73.9	+3.9
75.0	+3.0

Last cervical vertebra to tuber coxae. Table XIII gives simple correlation coefficients of selected live measurements with actual carcass length. The highest single correlation coefficient with carcass length found in this study was the measurement obtained from the last cervical vertebra to the tuber coxae over the dorsal surface ($r = 0.82$). This measurement was not obtained in Experiment I. It was noted during the data collection period that the location of the last cervical vertebra was somewhat difficult to establish in some hogs. The high correlation coefficient obtained, however, indicates that this measurement warrants more study.

Poll to tuber coxae. The measurement obtained from the poll to the tuber coxae along the topline of the hog had a correlation coefficient of 0.80 with carcass length. The same relationships in Experiment I was lower ($r = 0.58$). Greater experience in measuring may have increased the accuracy of this measurement.

Although the difference in correlations between carcass length and the poll to the tuber coxae ($r = 0.82$) measurement and the last cervical vertebra to the tuber coxae ($r = 0.80$) was small, these results indicate that eliminating the variation in length of the neck may increase the accuracy of external measurements.

Last cervical vertebra to root of tail. The correlation coefficient for the last cervical vertebra to the root of the tail measurement taken over the dorsal surface with carcass length was 0.62. This measurement explained 26 per cent less of the variation in carcass

TABLE VIII
SIMPLE CORRELATION COEFFICIENTS BETWEEN CARCASS LENGTH
AND SELECTED LIVE MEASUREMENTS--
EXPERIMENT II

Variables	r
Poll to last cervical vertebra, cm.	-.02
Poll to tuber coxae, cm.	0.80**
Poll to root of tail, cm.	0.62**
Last cervical vertebra to tuber coxae, cm.	0.82**
Last cervical vertebra to root of tail, cm.	0.62**
Tuber coxae to root of tail, cm.	-.08
Tuber spinae to tuber coxae (right side-tape), cm.	0.58**
Tuber spinae to tuber coxae (left side-tape), cm.	0.72**
Tuber spinae to tuber coxae (right side-calipers), cm.	0.62**
Tuber spinae to tuber coxae (left side-calipers), cm.	0.66**
Off feed weight, lb.	0.71**
Length predicted by equation developed in Experiment I, cm.	0.73**

**P<.01.

length than did the measurement from the poll to the tuber coxae. These results seem to indicate that there is considerable variation in length of ham or length of rump, which is not associated with carcass length.

Tuber spinae to tuber coxae. The correlation coefficients obtained between carcass length and the tuber spinae to the tuber coxae measurement on the lateral surfaces were 0.72 on the left side and 0.58 on the right side. It should be noted again that the measurement for carcass length was obtained by measuring only the left side of the carcass. Although the correlation coefficients in Experiment II are slightly lower than those found in Experiment I, the left side again was more highly correlated with carcass length than was the right side.

In Experiment I the measurement from the tuber spinae to the tuber coxae on the lateral surface of the live hog had the highest single correlation with carcass length ($r = 0.78$). It was postulated that the use of calipers to obtain this measurement could increase the accuracy of this figure. The caliper measurements obtained were correlated 0.66 and 0.62 with carcass length, left and right sides, respectively. The caliper measurement correlations were not as high as the same measurements with the steel measuring tape. However, the left side measurement again was more highly correlated with carcass length than was the right side measurement.

Off-feed weight. A highly significant correlation was found between off-feed weight and carcass length ($r = 0.71$). This was compared to a correlation coefficient of 0.39 obtained between off-feed weight and carcass length in Experiment I. The higher correlation in Experiment II was undoubtedly due to the wider range in off-feed weights of the hogs used in Experiment II.

Other measurements. A negative correlation coefficient was obtained between carcass length and the measurement from the poll to the last cervical vertebra ($r = -.02$). Also, the measurement from the tuber coxae to the root of the tail over the dorsal surface of the hog and carcass length were negatively correlated ($r = -.08$). These are considerably lower than those obtained in Experiment I, indicating that the relationship between carcass length and the lengths of the neck and the ham is not consistent. It may be concluded that correlation coefficients between these measurements and carcass length are not high.

Multiple correlation coefficient of independent variables.

Various combinations of selected independent variables and their R^2 values are given in Table IX. Off-feed weight and the lateral measurement from the tuber spinae to the tuber coxae obtained with a steel measuring tape were combined. The measurement from the tuber spinae to the tuber coxae explained 52.0 per cent of the variation in carcass length. The addition of off-feed weight to this measurement increased the R^2 value to 61 per cent. The same model with weight squared increased the R^2 value to 72 per cent, and the addition of weight cubed raised the per cent to 73.

TABLE IX

PROPORTION OF VARIATION IN CARCASS LENGTH EXPLAINED BY VARIOUS
COMBINATIONS OF SELECTED INDEPENDENT VARIABLES--
EXPERIMENT II

Variables ^a	R ²
X ₁	0.52
X ₁ , X ₂	0.61
X ₁ , X ₂ , X ₂ ²	0.72
X ₁ , X ₂ , X ₂ ² , X ₂ ³	0.73
X ₁ , X ₂ ² , X ₂ ³	0.72
X ₁ , X ₂ ²	0.60
X ₁ , X ₂ ³	0.60
X ₁ , X ₁ ² , X ₁ ³	0.53
X ₁ , X ₁ ²	0.53
X ₁ , X ₁ ³	0.53
X ₂ , X ₃	0.70

^aX₁ = Tuber spinae to tuber coxae (left side-tape).X₂ = Off-test weight.X₃ = Last cervical vertebra to tuber coxae.

The measurement from the last cervical vertebra to the tuber coxae, taken over the topline, explained 67 per cent of the variation in carcass length. When off-feed weight was added to this measurement the R^2 value increased to 70 per cent.

Prediction equations. The selected variables utilized and the prediction equations constructed are found in Table X. The variables include the tuber spinae to the tuber coxae lateral measurement taken from the hogs' left side with a steel measuring tape. Also, off-feed weight and the measurement from the last cervical vertebra to the tuber coxae over the dorsal surface of the hog are included.

III. EXPERIMENT III

Table XI gives the combined means and standard errors for the selected measurements studied from the 42 hogs in Experiment I and 32 hogs in Experiment II.

Simple correlation coefficients between carcass length and selected live hog measurements from Experiment I and II combined are presented in Table XII.

A simple correlation of 0.69 was obtained between carcass length and the measurement taken from the tuber spinae to the tuber coxae on the hogs' left side with a steel measuring tape. Carcass length and the poll to the root of the tail measurement over the dorsal surface of the hog were highly correlated ($r = 0.68$). The poll to the tuber coxae measurement, taken over the topline, had a correlation coefficient of 0.67 with carcass length. Off-feed

TABLE X
EQUATIONS FOR PREDICTING CARCASS LENGTH FROM
SELECTED LIVE HOG MEASUREMENTS--
EXPERIMENT II

Variables ^a	Equations
X_1	$\hat{Y} = 10.35 + (0.996)(X_1)$
X_1, X_2	$\hat{Y} = 76.2 + (0.620)(X_1) + (0.537)(X_2)$
X_1, X_2, X_2^2	$\hat{Y} = -128.47 + (0.736)(X_1) +$ $(14.6)(X_2) - (0.344)(X_2^2)$
X_2, X_3	$\hat{Y} = 25.3 + (0.348)(X_2^2) + (0.392)(X_3)$

- ^a
 X_1 = Tuber spinae to tuber coxae (left side-tape).
 X_2 = Off-test weight.
 X_3 = Last cervical vertebra to tuber coxae.

TABLE XI
MEANS AND STANDARD ERRORS FOR TRAITS STUDIED--
EXPERIMENT III

Measurement	Mean	Standard error
Poll to tuber coxae, cm.	85.7	0.36
Poll to root of tail, cm.	108.2	0.45
Tuber coxae to root of tail, cm.	22.4	0.29
Tuber spinae to tuber coxae (right side-tape), cm.	64.3	0.22
Tuber spinae to tuber coxae (left side-tape), cm.	64.3	0.22
Carcass length, cm.	75.2	0.24
Off feed weight, lb.	206.6	1.31

TABLE XII
SIMPLE CORRELATION COEFFICIENTS BETWEEN CARCASS
LENGTH AND SELECTED LIVE MEASUREMENTS--
EXPERIMENT III

Variables	Carcass length
Poll to tuber coxae, cm.	0.67**
Poll to root of tail, cm.	0.68**
Tuber spinae to tuber coxae (left side-tape), cm.	0.69**
Tuber coxae to root of tail, cm.	0.24
Tuber spinae to tuber coxae (right side-tape), cm.	0.61**
Off feed weight, lb.	0.54**

**P<.01.

weight, as expected, was highly correlated ($P < .01$) with carcass length ($r = 0.54$).

The multiple correlation coefficient for the lateral tape measurement from the tuber spinae to the tuber coxae, off-feed weight, off-feed weight squared and the breed variable was $R^2 = 0.69$. This model appears to be superior to all others formulated during this study, especially from a practical standpoint.

This prediction equation for carcass length is:

$$\hat{Y} = -93.82 + (0.545)(X_1) + (1.27)(X_2) - (0.003)(X_2^2) + a_i$$

where:

$\hat{Y}$ = Carcass length, cm.

X_1 = Measurement from the tuber spinae to the tuber coxae
(left side-tape), cm.

X_2 = Off-feed weight, lb.

X_2^2 = Off-feed weight squared

a_i = a_1 - Hampshire (-.343)
 a_2 - Duroc (-.555)
 a_3 - Yorkshire (+.898)

Carcass length estimates from this prediction equation and deviations from actual carcass length are reported in Table XIII.

TABLE XIII
 PREDICTED CARCASS LENGTH WITH DEVIATIONS
 FROM ACTUAL CARCASS LENGTH--
 EXPERIMENT III

Predicted carcass length, cm.	Deviation from actual carcass length, cm.	Predicted carcass length, cm.	Deviation from actual carcass length, cm.
72.9	+0.6	74.8	- .6
74.1	- .2	71.6	+0.1
74.8	+0.9	71.2	0.0
76.1	-1.6	75.1	+1.1
76.4	+1.1	73.9	+1.7
77.7	-1.1	74.6	- .1
75.8	-1.0	76.3	-1.8
74.6	- .3	75.0	-1.6
75.5	- .3	75.7	-1.0
76.2	+0.7	74.1	+1.5
75.3	- .8	75.9	-1.4
74.5	-1.8	74.3	- .7
72.7	-4.1	75.0	+0.3
73.9	-2.0	74.6	- .9
78.2	+1.1	74.9	-1.1
78.3	-1.3	74.8	- .7
76.2	-1.0	74.4	0.0
74.7	- .4	74.1	- .1
73.4	-2.4	76.3	- .3
73.6	-1.9	75.2	- .8
73.4	+1.3	74.3	+1.3
75.4	+0.7	75.6	- .7
74.7	- .3	75.3	- .4
77.9	+0.7	75.5	- .9
78.6	-2.3	76.6	- .9
75.4	+0.5	73.2	-1.1
74.9	- .2	73.9	+1.4
75.2	+1.1	74.2	-3.1
75.6	+2.0	72.6	- .2
77.9	+0.9	76.4	- .3

TABLE XIII (continued)

Predicted carcass length, cm.	Deviation from actual carcass length, cm.	Predicted carcass length, cm.	Deviation from actual carcass length, cm.
77.2	+1.0	75.3	+0.5
76.7	- .3	75.9	0.0
77.2	- .2	74.9	+1.1
76.9	+1.8	71.0	- .5
75.1	-1.4	72.4	+2.4
73.8	+0.3	71.9	+1.9
74.5	-1.5	72.2	+0.2

CHAPTER V

SUMMARY AND CONCLUSIONS

A study involving 42 Hampshire, Duroc and Yorkshire market hogs and 32 Duroc gilts was conducted in an effort to derive an equation to predict carcass length from certain live measurements. These hogs were raised under similar environmental conditions and were slaughtered at the University of Tennessee Meat Laboratory during the winter of 1966. This study was conducted in three separate experiments. The 42 market hogs were involved in Experiment I, the 32 Duroc gilts utilized in Experiment II and these two groups were combined to obtain results in Experiment III.

In Experiment I, a high correlation coefficient of 0.78 was obtained between carcass length and the tuber spinae to the tuber coxae lateral measurement, taken on the left side with a steel measuring tape. Highly significant correlation coefficients were obtained between carcass length and most live measurements. A multiple correlation coefficient, including the lateral measurement from the tuber spinae to the tuber coxae and the breed variable, accounted for 65 per cent of the variation in carcass length. The only carcass trait highly correlated with carcass length was carcass weight.

In Experiment II, a simple correlation of 0.74 was obtained between carcass length and the lateral measurement from the tuber spinae to the tuber coxae on the hogs' left side, with a steel

measuring tape. Off-feed weight also was found to be highly correlated with carcass length ($r = 0.71$). A combination of these two variables accounted for 61 per cent of the variation in carcass length. This same model with the addition of off-feed weight squared accounted for 72 per cent of the variation in carcass length.

A measurement obtained from the last cervical vertebra to the tuber coxae along the dorsal surface was highly correlated with carcass length ($r = 0.82$). When this measurement was combined with off-feed weight, 70 per cent of the variation in carcass length was explained.

The simple correlation coefficients obtained in Experiment III indicated that the lateral measurement obtained from the tuber spinae to the tuber coxae on the hog's left side with a steel measuring tape was more highly correlated with carcass length than any other single measurement taken.

The prediction equation that contained off-feed weight, off-feed weight squared, the breed variable and the lateral measurement from the tuber spinae to the tuber coxae on the hog's left side with a steel measuring tape was the most accurate and one of the simplest used. This combination of variables accounted for 69 per cent of the variation in carcass length in the 74 hogs studied.

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LITERATURE CITED

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