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Growth development, carcass composition, and pork quality of Duroc boars, barrows, and gilts slaughtered at various weights

Gordon Ferrell Jones

To the Graduate Council:

I am submitting herewith a dissertation written by Gordon Ferrell Jones entitled "Growth development, carcass composition, and pork quality of Duroc boars, barrows, and gilts slaughtered at various weights." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

R.R. Shrode, Major Professor

We have read this dissertation and recommend its acceptance:

C.S. Hobbs, Wm. R. Backus, S.A. Griffin, L.M. Josephson, D.O. Richardson

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

December 21, 1970

To the Graduate Council:

I am submitting herewith a dissertation written by Gordon Ferrell Jones entitled "Growth, Development, Carcass Composition, and Pork Quality of Duroc Boars, Barrows, and Gilts Slaughtered at Various Weights." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

Robert R. Shrode
Major Professor

We have read this dissertation and recommend its acceptance:

Sumner A. Griffin

Don O. Richardson

L. M. Josephson

E. R. Lidvall

Charles S. Hobbs

Wm. R. Backus

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for
Graduate Studies and Research

GROWTH, DEVELOPMENT, CARCASS COMPOSITION, AND PORK QUALITY OF DUROC BOARS, BARROWS, AND GILTS SLAUGHTERED AT VARIOUS WEIGHTS

A Dissertation

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

by

Gordon Ferrell Jones

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ABSTRACT

A study involving 36 experimental and 8 observation pigs was conducted to acquire basic knowledge concerning body composition and development patterns of the growing meat-type pig. Linear measurements of muscle, fat, and bone were obtained on two boars, two barrows, and two gilts from each of six litters at three-week intervals up to a weight of 175 pounds and at two-week intervals up to 225 pounds when half of the pigs were slaughtered. Measurements were continued at two-week intervals on the remaining pigs to their slaughter weight of 300 pounds. A boar, gilt, and barrow from each litter were slaughtered at 225 pounds, and the remaining littermates were slaughtered at 300 pounds. Specific gravity, routine carcass data, pork quality determinations, and chemical composition data were obtained on each carcass. In addition, chemical composition data were collected on three pigs comparable to the experimental pigs at each of the observation weights of 75 and 150 pounds.

Boars had a higher accumulative average daily gain than barrows and gilts up to 225 pounds, and barrows gained faster than gilts. The advantage of boars over barrows and gilts became more evident at weights beyond 225 pounds. Boars converted feed more efficiently than barrows. The feed efficiency advantage for boars over barrows and gilts was much greater at 300 than at 225 pounds as boars were only slightly less efficient between 225 and 300 pounds than from 75 to 225 pounds.

Both skeleton and muscle had attained a greater percentage of their final 225- or 300-pound measurement at 75 pounds than had fat.

The rate of increase of skeletal size was slower than muscular growth, and both skeleton and muscle developed at a slower rate than fat from 75 to 300 pounds.

The rate of increase in fat depth became more rapid at weights beyond 150 pounds, and, also, differences among individuals and sexes became more apparent. The rapid growth and increase in variation among individuals was largely due to the rapid rate of increase in depth of the second and third fat layers. About 75 to 80 percent of the third fat layer depth at 300 pounds was deposited between 225 and 300 pounds.

Ultrasonic estimates and carcass measures of fatness at the tenth- and last-rib areas were highly correlated with percent lean cuts, percent ether extract, and percent protein in the carcass. Measurements obtained over the l. dorsi on both the live animal and carcass were more highly correlated with carcass composition than were midline measurements of live-animal and carcass fatness. At 225 pounds, correlations involving depth of the first two fat layers were higher than those that included all three fat layers. However, at 300 pounds correlations including layers 1, 2, and 3 were as high or higher than those with only layers 1 and 2 included.

The percentages of total body length constituted by each body section (poll to scapula, scapula to last rib, last rib to illium, and illium to root of tail) were similar at all weights.

Correlations between carcass length and measures of fatness and muscling were of much greater magnitude at 300 than at 225 pounds. This indicates that the pigs which continued to grow skeleton from 225 to 300 pounds remained lean and continued to grow muscle; whereas, pigs that had a slower increase in skeletal growth tended to become fat and also had a slower rate of muscular growth than the longer pigs.

These data indicate that individual differences become more evident at heavier weights and that these differences are more observable by practical methods of live-animal evaluation at the heavier weights. Therefore, for most effective results, selection of prospective breeding animals, especially boars, should be conducted at weights beyond 200 pounds.

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INTRODUCTION

Swine producers are currently evaluating prospective breeding animals (boars and gilts) for muscle-fat composition at weights ranging from 150 to 250 pounds by visual appraisal, backfat probe, ultrasonic evaluation, full or half-sib carcass data, or some combination of these. Generally speaking, live-animal fat and muscle estimates and carcass measurements are adjusted to a standard 200-pound live weight basis for boars, barrows, and gilts.

Two methods of adjusting backfat and loin-eye area estimates, as well as days required to reach a 200-pound live weight, are in use by swine testing stations, researchers, and breeders of commercial and purebred swine. One method involves the use of a constant adjustment factor for a given weight deviation from 200 pounds live weight. The second method utilizes the ratio between the estimate at a given body weight and a standard weight of 200 pounds. Both methods of adjustment are based upon the assumption that muscle-fat relationship and growth are relatively constant from about 160 to 260 pounds live weight.

Differences in carcass figures among boars, barrows, and gilts have been noted at conventional slaughter weights. Likewise, composition studies of pigs suggest a definite variation in growth and development of bone, muscle, and fat among sexes, *viz*., boars, barrows, and gilts as well as among pigs of the same sex.

Certain practical and economic factors suggest that hogs may be marketed at heavier weights in the future. In fact, swine certification programs have recently been altered so that pigs may be slaughtered at weights ranging up to 240 pounds. However, carcass backfat, loin-eye area, carcass length measurement, and days to 200 pounds (or 220 pounds) are being adjusted by assuming a constant growth pattern for each trait for both barrows and gilts. Sonoray loin-eye area estimates and backfat probes of boars and gilts are often adjusted to standard 200-pound live weights using constant adjustment factors for widely differing pig weights.

A more thorough knowledge is needed concerning the actual pattern of skeletal and muscle growth and the rate at which the subcutaneous fat layers are deposited in each of the sexes of meat-type pigs. The relationship of performance to growth of muscle, fat, and bone beyond conventional market weights and the factors affecting pork quality are of major concern to the swine industry.

The objectives of this experiment were to study muscle, fat, and skeletal growth in excellent meat-type Duroc boars, barrows, and gilts from 70 pounds to 300 pounds live weight and to study also the correlations involving conventional carcass cutout variables, carcass chemical composition, pork quality characteristics, and various performance traits.

CHAPTER II

REVIEW OF LITERATURE

I. GROWTH AND DEVELOPMENT

Growth and development patterns of muscle, fat, and bone in swine have been subjected to much discussion and conjecture. Specific knowledge of these patterns based on objective experimental data is necessary to make most effective a selection program directed toward improving various economic swine traits.

McMeekan (1940) concluded that the growth of the body as a whole is the result of differential growth of the constituent parts of the body. He proposed that body growth in swine conforms to the law of developmental direction, exhibiting a well-defined anterior-posterior gradient from earlier to later developing regions. The head and limbs appear as relatively early developing parts with the fore limbs being slightly earlier developing than the hind limbs. The major body tissues exhibit a marked differential growth pattern, skeleton, muscle, and fat developing in that order. The earlier developing skeleton makes a greater proportion of its growth earlier in life than does muscle, while muscle makes a greater proportion of its growth earlier than does the later developing fat. The skeletal units of the head and trunk exhibit an anterior-posterior pattern of growth while the bones of the limb show a centripetal pattern, the upper extremities being later developing than the lower extremities. Differential growth in bone form as well as in weight occurs, growth in thickness occurring later than growth in length.

McMeekan (1940) described the pig at birth as being largely head, neck, and legs with a short shallow body and poorly developed hindquarters. The most marked change in growth of the pig after birth is an increase in proportional length to four and eight weeks of age, followed by an increasing tendency toward deepening and thickening of the body. The head, neck, and legs become proportionally smaller with this increased length and depth of body. By 24 and 28 weeks of age, the hindquarters have deepened and thickened so that they exceed the size of the head and neck both proportionally and in weight. The weight of muscle exceeds that of all other tissues from birth to 24 weeks when it is overtaken by fat. At birth the amount of skeleton exceeds the amount of fat; but this position is quickly reversed, and the weight of bone is less than that of both muscle and fat after four weeks of age. Also, skin weight exceeds that of fat at birth, but it is the tissue present in smallest amount at all other ages. By 28 weeks the skeleton has increased over the amount present at birth by 30.4 times, while muscle has increased 81.6 times and fat 676.7 times. Skin tissue has increased 32.5 times and follows closely the growth curve of the skeleton.

McMeekan (1940) found that bone had the slowest rate of increase with only a small increase to 20 and 24 weeks and a decrease thereafter. Muscle has the greatest rate of growth to about 16 weeks when it is overtaken by fat, the growth rate of which has been increasing rapidly. This more rapid growth of fat is maintained so that at 24 and 28 weeks, about 50 percent more fat than muscle is being laid down in the body. There is an approximately constant rate of growth of muscle from 4 to 16 weeks and from 16 to 28 weeks and of fat from 16 weeks onward.

Histological studies by McMeekan (1940) led to the conclusion that the increase in size of muscle fiber is sufficient to account for the increase in mass of muscle tissue. He found no evidence of any increase in the number of muscle fibers during post-natal life. Studies by Joubert (1956) and Staun (1963) confirm these results.

Brooks et al. (1964) reported a rapid increase in fat soon after birth and continuing to about four weeks of age. A similar increase in fat was reported by Jezkova (1966) up to 26 days of age in Large White piglets. Thus, it appears that this early development of fat is necessary because of the role fat plays in temperature regulation, and this rapid rate of development decreases until about 16 weeks of age.

Callow (1948) reported that in general the ratio of weight of muscular tissue to that of bone increases during fattening but that individual carcasses may show wide variations. Callow (1949) concluded also that there is a high correlation between the percent of fatty tissue and the percentage of muscular tissue. The use of a linear regression equation using fat percentage to predict percent of muscle tissue resulted in a simple correlation of -.98 between actual and predicted percent of muscle tissue. Therefore, the major changes in anatomy of carcasses and in the chemical composition of their tissues largely depend on the degree of fatness of the carcass. The findings of Cuthbertson and Pomeroy (1962) indicate that the proportion of muscle in the carcass exceeded that of the other tissues in carcasses weighing from 50 to 92 kg. However, while the rates of growth of muscle and bone were similar during this period, the growth rate of fat was markedly greater.

Zobrisky et al. (1958) studied various carcass traits during growth and fattening of a group of 72 crossbred (Landrace x Poland) pigs slaughtered at weights of 50, 100, 150, 200, 250, and 300 pounds. Relative to initial weight, the lean, fat, and bone in the carcass increased by powers of the increase in weight of ham, the approximate powers being 0.85, 1.52, and 0.68, respectively. The analyses indicated that relative to live weight, the increases of carcass fat and total ham fat, of carcass subcutaneous fat and ham subcutaneous fat, and of carcass lean and ham lean were similar. Male castrates were more highly finished than gilts at each of the six slaughter weights. In a similar study, Allen et al. (1961) slaughtered 56 pigs at weights ranging from 50 to 200 pounds to determine carcass composition. Lean meat increased at a decreasing rate as slaughter weight increased. From 150 to 200 pounds the following carcass increases occurred: longissimus dorsi muscle, 0.7 sq. in. in area and 267 gm. in weight; separable lean, 15.0 pounds and total edible protein, 4.2 pounds. The changes in backfat thickness, trim fat, and total separated fat from hogs slaughtered at 150 to 200 pounds were 1.00 to 1.27 inches, 8.3 to 15.9 pounds, and 27.2 to 45.5 pounds, respectively. Percent lean cuts increased up to 150 pounds live weight and then decreased to 200 pounds, while percent primal cuts continued to increase up to 200 pounds live weight.

Robison (1962) studied the backfat deposition on a group of 162 Yorkshire and Duroc barrows and gilts. The shoulder probes at 95, 141, and 184 pounds were 0.69, 1.10, and 1.48 inches and the loin probes were 0.60, 0.85, and 1.10 inches. There were no apparent differences in the growth pattern of fat among the breed-sex subgroups. Buck (1963) found that there were no differences in the ranking of boars with respect to estimates of carcass traits when the boars were measured at 150, 200, and 260 pounds. He found, however, that the carcass becomes less lean as the slaughter weight increases and that the difference is more observable between 200 and 260 pounds than between 150 and 200 pounds. At these weights, there is at least as much lean as fat produced in the shoulder and ham but more fat than lean is produced in the back and in the streak. Results obtained by Rittler et al. (1964), however, show that future gains in fat depth up to 100 kg. finish weight could not be estimated in a reliable way from measurements taken at lighter weights. They concluded that there were individual differences among pigs in development and gain in depth of fat at the various fattening stages. Similar differences were found in the muscle development pattern. Urban and Hazel (1965) studied fat deposition ultrasonically at four-week intervals from eight weeks of age to a minimum weight of 90 kg. They found that correlations between ultrasonic measurements at different times were positive but small. The regression of total fat depth and layer depth on body weight was essentially linear during the period studied. Schmidt and Schumann (1965) found that during fattening from 100 to 120 kg. live weight, carcass length increased 5 cm.; backfat thickness, 0.5 cm.; side fat thickness, 0.6 cm.; and back muscle surface, 3.7 sq. cm.

Type differences. Zebrowski (1962) found no difference in body composition between Large White and Pulawska pigs at two months of age; but differences were present at four months of age, and the magnitude of these differences continued to increase with age. He concluded that within the Pulawska breed the end of the "lean period" and the beginning of the "fat period" occurred at about the five-month age and at a live weight of 52 kg.; whereas, within the Large White breed, this transition occurred between ages six and nine months. The fat percentage increased continuously for both breeds, and the percentage of bone declined rather rapidly. The percent of muscle in the Large White breed continued to increase up to four months of age while remaining about constant in the Pulawska breed from two to four months of age. In a study involving 56 White Improved pigs slaughtered at weights from 30 to 80 kg., Gabris (1965) found that lard formation began to prevail over muscle formation at weights of 50 to 60 kg. He concluded that by raising the intensity of growth in pigs up to the 50-kg. weight and by adjusting feed of pigs weighing more than 50 kg., better meat utility could be achieved.

McMeekan (1939) concluded that the variability of a character appears to be affected by the rate of development of the character and that the later developing characters tend to be more variable than earlier developing characters. Hammond (1922) found that the proportion of bone varied among breeds and that the proportion of bone tended to decrease with age. Buck (1963) found that a good percentage of lean is associated with increased bone. Culbertson et al. (1928) found differences among litters ranging from 5.50 to 6.13 inches in circumference of the front shin measured at the finished weight.

McMeekan (1937) found that shortness of loin was the most serious fault of the bacon pig in New Zealand and that the fault became more apparent in heavier weights. Overfatness also was associated with a deficiency in length. Hiner and Thornton (1962) found that an increase in carcass length was associated with a decrease in fat cuts, backfat thickness, and bacon weight, and with an increase in ham and loin weights. Data on 473 Yorkshire and Duroc pigs revealed that carcass length varied from 26 to 35 inches at a slaughter weight of 225 pounds. As carcass length increased, the combined lean weights and eye muscle area increased in the Duroc breed up to a length of 31 inches, then started to decline but fluctuated in the Yorkshire breed. Wiley et al. (1951) found that pork carcasses of the same weight varied as much as ten inches in body length and eight inches in length of rear leg and that carcass length and leg length were related. There was a slight tendency also for percentage of lean cuts to increase with an increase in either leg or body length.

Other studies have indicated that the correlation of carcass length with other economically important traits is almost zero. Bowland (1964) found that measures on the live hog such as length, heart girth, and shoulder height were of limited value as predictors of carcass characteristics. Price et al. (1957) found that carcass length showed no significant correlation with cut-out, chemical composition, or exterior fat thickness. Fredeen et al. (1964) found that variation in carcass length accounted for 9 percent of the total variation in percent of trimmed lean cuts.

Oslage et al. (1966) investigated the nitrogen deposition in modern meat-type German Improved Landrace pigs with the use of a respiration apparatus. They found that daily nitrogen deposition was about 16 to 17 g. at beginning weights of 20 to 40 kg. and that this level of deposition continued at nearly the same rate up to a weight of 130 kg. A decrease in the rate of deposition could be recognized at weights greater than 130 kg. They concluded that the pattern of nitrogen retention in the growing-fattening period of the modern meat-type pig is different from that of the obsolete lard-type pig. The nitrogen deposition seems to be linear with weight for a much longer period of time in the modern meat-type pig than in the fatter type pig. Otto (1966) studied the growth characteristics of 190 pigs and found that protein deposition or muscle growth continued to a weight of 130 kg. and afterwards decreased. Great differences were present among the sexes in their ability to develop and store protein.

Sex differences. Results reported by Burgess (1965) and by Moore (1966) clearly indicate that both boars and gilts produce longer carcasses than littermate barrows. Burgess (1965) found both boar and gilt carcasses to be one inch longer than barrow carcasses, but the differences reported by Moore (1966) were only 0.8 and 0.5 inches, respectively. Results reported by Bruner et al. (1958), Kropf (1959), Charette (1961), Kropf et al. (1962), and Emerson et al. (1964) are in general agreement with these findings.

Buck et al. (1962) investigated carcass data from 250 test station pigs and found that gilts had a higher percentage of lean meat, larger eye muscle dimensions and smaller measurements of backfat thickness than barrows. The findings of Bruner et al. (1958), Zobrisky et al. (1961), Burgess (1965), and Moore (1966) are in agreement with these results. Boars were included in the work of Burgess and Moore, but no significant differences between boars and gilts were found for average backfat thickness, loin-eye area, or percentage of lean cuts.

Burgess (1965) found no significant differences among sexes in fat thickness at the first rib, but boars had significantly less fat at the last rib and last lumbar vertebra than barrows and less fat at the last rib than gilts. Gilts did not differ significantly from barrows at the last rib but were significantly leaner at the last lumbar vertebra. Charette (1961) reported also that boars had less fat over the loin than gilts, and boars and gilts had less fat over the shoulder and back than did barrows.

Hetzer et al. (1956) studied live-animal measurements on 45 boars, 30 barrows, and 65 gilts at 150, 175, 200, and 225 pounds. Thickness of backfat of barrows was intermediate between that of boars and gilts at a weight of 150 pounds, but barrows laid on fat significantly faster until at a weight of 250 pounds, they exceeded both boars and gilts. Gilts exceeded boars in backfat thickness at all four weights. Buck (1963) observed that in both barrows and gilts, the percentage of lean meat added in the weight range 200 to 260 pounds live weight is less than that in the range 150 to 200 pounds live weight. This difference is greater in barrows, especially in the back cut. The sex difference (in favor of the lean gilt) becomes more pronounced in the heavier weight range.

Staun (1963) conducted histological studies on carcasses of gilts, boars, and castrates of the same race and found no significant differences in the number and diameter of the muscle fibers when the animals were slaughtered at a live weight of 90 kg.

Chemical composition. The relative proportions of water, fat, and protein vary among pigs of different weights and body type. Loeffel et al. (1943) found that carcasses from 150-pound pigs contained 32 percent fat and 51 percent lean, while those from 400-pound pigs contained 55 percent fat and 34 percent lean. Allen et al. (1961) reported that ether extract in the carcass increased from 31.0 to 54.7 pounds from 150 to 200 pounds slaughter weight. Hix et al. (1967) performed chemical analyses on 24 market hogs and found the average composition to be 52.00 percent moisture, 30.37 percent ether extract, 15.21 percent protein, and 2.5 percent ash. Henry et al. (1963) studied 79 carcasses from hogs weighing 200 pounds. The proximate percent protein, fat, and moisture of the untrimmed (boneless) wholesale cuts was 13.2, 43.1, and 41.0. Hornicke (1961) indicated that in all species of animals thus far investigated, water content of fat-free body substance progressively decreases with growth.

Callow (1938) showed that the water content of muscle tissue from pigs fed similarly but killed at different ages fell from 81 percent at birth to about 76 percent at 28 weeks. Varying the growth rate of the pigs produced wide differences in the amount of fat in the l. dorsi muscle (0.53 percent to 0.15 percent). Loeffel et al. (1943) reported that the flesh from the loin increased in fatness with advancing weight; and as the percentage of fat increased, the percentage of water, protein, and ash declined. Callow (1947) concluded that as growth and fattening proceeds, the extra chemical fat which is laid down is partitioned unequally among the tissues. An increasing proportion of the fat goes into the fatty tissues, and a decreasing proportion goes into the muscular tissues. In the fatty tissues themselves, a larger proportion of the extra fat goes into the subcutaneous fatty tissue, and a smaller proportion into the intermuscular fatty tissue. Kielanowski et al. (1954) reported the fat content of the l. dorsi to be 2.19 percent in barrows and 1.88 percent in gilts, but the difference was not significant. Callow (1948) found that there was considerable individual variation among carcasses in the percentage of what he called "chemical fat" (presumably ether extract) in the muscle which shows that factors other than the general level of fatness play a considerable part in determining fat content of the muscular tissue.

Zebrowski (1962) compared the composition of Pulawska and Large White pigs at two, four, six, and nine months of age. There was no difference in percentage of lean and fat in the primal cuts at two months of age, but at each of the other ages, the Large Whites had a higher percentage of lean and a lower percentage of fat in the primal cuts. At four months of age there was a difference of 3.66 percent in the content of lean in the primal cuts and 5.21 percent in the content of fat. At six months the differences were 4.39 and 6.67 percent, and at nine months the differences were 7.76 and 9.48 percent.

Houston and Reed (1966) derived an expression using percentage of water (W) and percentage of fat (F) in an attempt to obtain a rough estimate of true growth to be used in meat science. The expression is

$$A = \frac{W}{100 - (W + F)} \text{ X } 100$$

$$= \frac{W}{R} \text{ X } 100 \text{ where R is the dry, fat-free residue.}$$

They reasoned that the dry, fat-free residue of meat is a rough measure of all the materials involved in essential growth; and since water is a further requisite for such growth, they suggested that the ratio might provide a rough indication of growth.

Specific gravity. The ratio of the weight of a carcass under water compared to the weight of the carcass in air is referred to as specific gravity. Brown et al. (1951), Whiteman et al. (1953), Pearson et al. (1956), Price et al. (1957), and Doornenbal et al. (1962) showed that specific gravity is more highly correlated with percent chemical fat and protein in the carcass than is average backfat thickness of the carcass. Brown et al. (1951) found the average specific gravity for 66 carcasses to be 1.027. Intragroup correlations of specific gravity with area of loin eye, percentage primal cuts, percentage lean cuts, and carcass length were positive and highly significant. Doornenbal et al. (1962) reported the correlation of specific gravity with chemically determined protein and with chemically determined fat to be 0.91 and -.94, respectively. The average backfat thickness showed a correlation of 0.69 with the percentage of carcass fat. Alexandrawicz et al. (1964) and Joblin (1966) concluded that sex has no effect upon the specific gravity measurement; however, Kropf (1959) found that gilt carcasses had higher specific gravity than barrow carcasses. Adam and Smith (1964) concluded that the muscle/fat ratio exerted a markedly greater influence on specific gravity than did the muscle/bone ratio.

II. PERFORMANCE CHARACTERISTICS

Average daily gain. Marked differences in rate of growth have been noted among boars, barrows, and gilts at various weights. In a study involving 550 baconers, Murray (1934) observed that males averaged 2.99 pounds at birth while females averaged only 2.78 pounds. The relative difference in weight became less up to about 13 weeks, but after four months the barrows became heavier than the gilts. The maximum variability in weight appeared to be around five months of age.

Craig et al. (1956) found progressive weight differences, ranging from 0.134 pound at birth to 4.5 pounds at 180 days of age in favor of boars over gilts. Boars were significantly heavier than gilts by about 5 percent at birth and by about 3 percent at 21, 56, 154, and 180 days of age.

Wagner et al. (1963) studied 108 crossbred barrows and gilts and found that barrows gained significantly faster than gilts. This work is in general agreement with the results of Lacy (1932), Bruner et al. (1958), Mulholland et al. (1960), Omtvedt et al. (1962), Cox (1963), Magee (1964), and Moore (1966), but it is in disagreement with results obtained by Charette (1961) and Burgess (1965). Omtvedt et al. (1962) observed that barrows gained 1.54 pounds per day while contemporary gilts gained 1.41 pounds per day. Cox (1963) reported that gilts weighed 5.4 percent less than barrows at 154 days of age. Magee (1964) found that the difference in weight between non-inbred barrows and gilts at 154 days of age was 17.1 pounds in favor of the barrows.

Bratzler et al. (1954) found no effect of delayed castration or non-castration on average daily gain. Moore (1966) made similar observations on a group of boars and barrows fed from 80 to 200 pounds live weight. Boars had an average daily gain of 1.64 while barrows gained 1.69 pounds per day. Conflicting results were reported by Burgess (1965) who found that from 80 to 200 pounds live weight boars had significantly higher average daily gain than did barrows (1.92 pounds vs. 1.82 pounds). Wagner et al. (1963), however, found no significant difference in rate of gain between boars and gilts.

Buck (1963) obtained results from singly-penned pigs to indicate that rate of gain up to 150 pounds live weight is not indicative of rate of gain to 200 pounds. Thus, it appears that selection for rate of gain in boars and gilts should be conducted at a weight comparable to the final weight desired for market swine.

Scott (1930) concluded that within the range of body length in lard-type hogs, length is positively correlated with rate of gain. Murray (1934) obtained results indicating that length cannot be significantly influenced by rate of gain since length nears its maximum earlier in the pig's life. Later maturing aspects such as body depth and thickness of backfat can be influenced significantly.

Feed efficiency. The amount of feed consumed divided by gain has been the conventional measure of feed efficiency in swine. Thus, the smaller the value, the more desirable the feed efficiency. Burgess (1965) found that boars were significantly more efficient users of feed than either barrows or gilts and that gilts were more efficient than barrows. Charette (1961) and Moore (1966) found also that boars were more efficient than either barrows or gilts but reported no significant difference between barrows and gilts. Bratzler *et al*. (1954) found that delayed castration or non-castration has no effect on feed efficiency. Wagner *et al*. (1963) found that boars were more efficient users of feed than were gilts. Bruner *et al*. (1958) reported that gilts required ten pounds less feed per hundred pounds gain than did barrows.

Allen *et al*. (1961) found that the feed use per pound of pig by pigs slaughtered at 50, 100, 150, and 200 pounds was 3.58, 3.05, 3.19, and 3.44, respectively. The conversion of feed protein to meat was 19.6

percent up to 150 pounds live weight, but only 16.7 percent from 150 to 200 pounds live weight. The conversion of feed energy to muscle and fat energy was 25.3 percent up to 150 pounds live weight and 30.8 percent from 150 to 200 pounds live weight. Results reported by Urban and Hazel (1965) show that feed efficiency over the period from eight weeks of age to the time of attainment of 90 kg. live weight did not appear to be correlated with live-animal ultrasonic measurements or mechanical probe at time of slaughter. The correlations involving feed efficiency and ultrasonic fat measures for four-week periods were small and negative.

Results reported by Buck (1963) from singly-penned pigs show that feed consumption up to 150 pounds live weight is not indicative of feed consumption between 150 and 200 pounds live weight. He found that an average of 3.9 pounds of feed was required for each pound of gain between 150 and 200 pounds live weight and that 4.3 pounds of feed was required for each pound of gain between 200 and 260 pounds live weight, but the feed required per pound of gain up to 150 pounds live weight was not an accurate indicator of feed consumed per pound of gain at heavier weights.

III. LIVE-ANIMAL EVALUATION TECHNIQUES

Backfat probe. The technique of using a simple metal ruler to measure the backfat depth in live swine was first proposed by Hazel and Kline (1952). The correlation between the average of four backfat measurements taken on live hogs and the average of four similar measurements taken on the carcasses was 0.81. Measurements made on 96 live hogs were slightly more accurate as indicators of leanness and percentage of primal cuts than were carcass measurements of backfat thickness. Similar results were reported by DePape and Whatley (1956), Hetzer et al. (1956), and Holland and Hazel (1958). Hazel and Kline (1952) concluded that the most accurate locations for probing were just behind the shoulder and at the middle of the loin about 1.5 inches off the midline of the body. Hetzer et al. (1956), Robison et al. (1960), and Meyer et al. (1966) found that the backfat probe taken at the middle of the loin gave the highest correlation with percentage of lean cuts of all the live-animal and carcass backfat measures that were taken. Bowland (1964) reported that the use of a metal ruler to measure backfat at three points on the live market-weight pig was an excellent indicator of carcass backfat.

Ultrasonic techniques. The use of high frequency sound waves to detect differences in animal tissue density and thus measure depth of particular tissue layers has been utilized during the past decade to estimate muscle-fat relationships in farm animals. Hazel and Kline (1959) used an ultrasonic scanning device to estimate fat thickness on 56 market hogs. Measurements were read two inches off the midline of the back behind the shoulder, at the middle of the back, and at the rear of the loin at a frequency of 2.5 mc./s. After removing differences due to sex and carcass weight, the correlation between ultrasonic fat depth and percent lean cuts was -.90. The corresponding correlation with ruler probe was -.89. Price et al. (1960) showed that live probe, carcass backfat, and ultrasonic measurements of fat were equal in value for predicting lean and primal cut-out. Results reported by Hazel and Kline (1959), Rittler et al. (1964), and Meyer et al. (1966) indicated that the fat depth measured at the middle of the loin from the tenth- to the last-rib location was the most accurate single indicator of total carcass leanness.

Burgess (1965) ultrasonically measured fat deposition of boars, barrows, and gilts at four weights (69, 107, 148, and 230 pounds). He found that the first fat layer was deposited at about the same rate in boars, barrows, and gilts from 69 to 230 pounds. Neither was there any difference among the sexes in rate of deposition of the second fay layer up to a weight of 148 pounds, but from 148 to 230 pounds the fat deposition in the second layer of barrows occurred more rapidly than in the boars and gilts, which deposited fat in the second layer at about the same rate. Considerable variation in depth of third fat layer was found among individual pigs. Fat deposition occurred more rapidly in this layer in barrows than in boars and gilts from 107 to 230 pounds, and the data suggested that fat layer deposition in the third layer was somewhat faster in gilts than in boars. There was, however, appreciable variation among operators in their ability to detect and measure the third fat layer.

Price et al. (1960) reported that ultrasonic estimates of loin-eye muscle depth taken over the center of the back in live hogs was significantly correlated with depth and area determinations taken from a tracing. The measurements of lean, however, did not show sufficiently high relationships with lean cut-out to be practically useful for prediction. Price et al. (1960) obtained a correlation of 0.74 between actual eye muscle area estimated on live animals utilizing ultrasonic reflection measurements coupled with angles of incidence at a selected series of sites over the last rib. These workers concluded that this method of determining eye muscle size in live swine was too time consuming and tedious for practical use. Schoen (1964) studied ultrasonic measurements on 100 live pigs and found that correlations between the ultrasonic measures and the portion of the cuts rich in meat and fat showed significant correlations with all characters except muscle thickness. He concluded that backfat thickness was obviously suited for estimating not only the portion of cuts rich in fat but also the portion of the cuts rich in meat. Burgess (1965) and Moore (1966) obtained small, positive but non-significant correlations between ultrasonically estimated l. dorsi area and percent lean cuts.

Lauprecht et al. (1965) obtained ultrasonic estimates on 132 live pigs and found that the backfat thickness measured laterally about six cm. from the vertebral column was more highly correlated with lean and fat cuts of the carcass than was backfat thickness on the vertebral column or thickness of muscle. Multiple correlations including backfat thickness on the vertebral column and thickness of muscle showed only a small gain in accuracy over the lateral backfat measurement alone. Joblin (1965) found among 42 fully dissected carcasses and 64 chemically analyzed carcasses from pigs that were measured by ultrasonic means before slaughter that five ultrasonic measurements were significantly correlated ($r = 0.58$ to 0.84) with carcass composition. Midline carcass measurements were poorer indicators of carcass composition than measurements taken over the eye muscle.

Meyer et al. (1966) studied the relationship of ultrasonic with other objective measures of carcass cutability and found that ultrasonic measurements of l. dorsi muscle area, live-animal backfat ruler probe measurements, and ultrasonic and carcass backfat measurements of swine were all significantly associated with yield of lean cuts and yield of trim fat. The second fat layer in the thoracic-lumbar region was more closely associated with fat yield and yield of four lean cuts than were the first and third fat layers. Ultrasonic and carcass depth measurements of the first and second fat layers did not differ significantly. A comparison of the depth measurements of the third layer of fat illustrated considerable variation between these two methods. The inability of technicians to consistently distinguish between the third layer of fat and the dorsal edge of the l. dorsi muscle and the distortion of this fat layer during chilling and processing contributed to this variation.

Ramsey (unpublished data) studied loin-eye tracings from 100 pork carcasses and found a correlation of 0.9 between depth and area of the l. dorsi muscle at the tenth-rib location. The numerical value of the depth of the loin-eye muscle measured in centimeters was an accurate indicator of the area expressed in square inches. For example, a depth measurement of 4.8 cm. converts to an estimated area of 4.8 square inches. He thus proposed a system to estimate loin-eye area by measuring the depth of the l. dorsi at a single location 2.5 inches lateral to the spinous processes with the sonoray. Correlations ranging from 0.5 to 0.9 between estimated and actual loin-eye area have been obtained using this system.

Isler and Swiger (1963) obtained coefficients of correlation ranging from -.45 to -.63 between each of five ultrasonic fat measurements taken five cm. off the midline of the back and percent lean cuts. A multiple regression equation utilizing the six backfat measurements, a ham fat measurement and live weight to predict percent lean cuts gave a multiple correlation of 0.82. The addition of actual loin-eye area to the equation was of little value for increasing accuracy. Jones et al. (1970) obtained a multiple correlation coefficient of 0.83 in a multiple regression system to predict percent lean cuts in the carcass by utilizing live weight and second fat layer depth at the tenth- and last-rib location as independent variables in the prediction equation. The addition of carcass loin-eye area gave no significant improvement in the prediction. Measurements to the bottom of the third fat layer were more difficult to obtain than were measurements to the bottom of the second fat layer, and correlations involving third fat layer depth were sporadic and somewhat lower than those involving depth to the bottom of the second fat layer.

Length and other live-animal measures. Phillips and Dawson (1936) studied methods of measuring body length of live hogs. They concluded that the best method among those studied was one that 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. Hetzer et al. (1950) utilized this method to obtain measurements of length of 141 live hogs. They concluded that since a hog's body position changes so frequently, body measurements for length may not be reliable. The repeatability of single measurements on the same hog was 0.72. Heidenreich et al. (1961) obtained correlations of 0.53 and 0.56 between live-animal length and carcass length in barrows and gilts, respectively.

Fewson and LeRoy (1959) concluded that the usefulness of body length measured on living animals appears to be very questionable since averages of five repeated measurements at a time were still unsatisfactory. Bowland (1964) likewise found that measures on the live pig such as length, heart girth, and shoulder height were of limited value as predictors of carcass characteristics.

Fogleman (1966), however, reported a highly significant correlation of 0.78 between carcass length and length from the tuber spina to the tuber coxa taken on the live hog's left side with a steel tape. These measurements were taken with the pig in a relaxed, suspended position in a restraining crate. By restraining pigs in a similar manner, Spears (1967) obtained a simple correlation of 0.87 between carcass length and length measured from the poll to the root of the tail of the live hog.

Ramsey (unpublished data) studied live-animal body length measurements on a group of 210-pound Duroc, Hampshire, and Yorkshire barrows and gilts and found that total body length varied among breed-sex subgroups. However, the percentages of total body length constituted by each of four body sections (poll to scapula, scapula to last rib, last rib to illium, and illium to root of tail) were essentially the same for each breed-sex subgroup.

Halda (1965) studied the relationship of selected live-animal measures and the percentage made up of predominantly meaty parts of the carcass half. In gilts the correlations of length of body and of circumference of the hind leg above the tarsal joint with this percentage were 0.215 and 0.338, respectively. In barrows the corresponding correlations were 0.237 and 0.275, respectively.

Gerasch (1965) proposed the use of the L/U Index (length of trunk x 100/circumference of chest) as a measure of body composition in the growing pig. Correlations of -.56 and -.69 were obtained between L/U Index and average backfat thickness in barrows and gilts, respectively.

IV. PORK QUALITY CHARACTERISTICS

Marbling. Murray (1934) reported that barrows have better marbling than gilts. These results are in agreement with those of Judge *et al.* (1959), Wagner *et al.* (1963), and Burgess (1965), but in disagreement with the results reported by Moore (1966). Moore (1966) found that the marbling scores of barrows and gilts were not significantly different but that both gilts and barrows had significantly more marbling than boars. Burgess (1965) observed that the marbling score of boars was not significantly different from that of either barrows or gilts, but Wagner *et al.* (1963) found that gilts had slightly more intramuscular fat than boars.

Cooking results. Loeffel *et al.* (1943) reported that the evaporation loss of roasts during the cooking process did not seem to be correlated with weight or fatness of the roasts. Weight loss of the roasts through drippings increased with fatness. Relatively little difference in palatability was noted between the roasts from pigs of different weights. It appeared that the roasts from heavier hogs were coarser in texture and the drippings became richer in flavor with added finish and weight.

Henry *et al.* (1963) reported that taste-panel tenderness score was correlated with marbling ($r = 0.37$) and juiciness ($r = 0.63$). Warner-Bratzler shear score was significantly correlated with taste-panel tenderness score ($r = -.73$) and with marbling ($r = 0.25$). Marbling was significantly correlated with flavor ($r = 0.23$) but not with juiciness. Burgess (1965) found that roasts from both barrows and gilts received significantly higher taste-panel scores for flavor than did those from boars. Moore (1966) found, however, that flavor scores for boar and gilt roasts were not significantly different. Burgess (1965) observed that taste-panel scores for tenderness were higher for barrow roasts than gilt roasts but that boar roasts were not significantly different from either barrow roasts or gilt roasts. Moore (1966) found both boar and barrow roasts to be more tender than gilt roasts, but there was no significant difference between taste-panel scores of boar and barrow roasts. Burgess (1965) found that Warner-Bratzler shear values were less for barrow roasts than either boar or gilt roasts and that boar and gilt roasts were not significantly different. Emerson et al. (1964) noted also that gilt roasts were less tender than those from barrows, requiring an average of 1.0 pound more shear force. Moore (1966) indicated that there was no significant difference among boar, barrow, and gilt meat as measured by the Warner-Bratzler Shear. Boar meat required approximately 1.0 pound less shear force than that of barrows or gilts. Bratzler et al. (1954) observed that meat from boars was soft, dark-colored, and lacked marbling as compared to that of barrows and concluded that it was definitely inferior from a palatability standpoint.

V. PRESENT STATUS OF KNOWLEDGE IN THIS PROBLEM AREA

Authors in general agree that the growth of the body as a whole is the result of differential growth of the constituent parts of the body. Skeleton is an earlier developing component of the body than muscle in the growing pig, and muscle develops earlier than fat, which, as the animal matures, becomes the largest component of gain.

There are drastic differences, however, among types of pigs in their developmental pattern. The age and/or weight at which rates of growth of the body components change may vary greatly among types. There is general agreement among researchers in England, Denmark, Germany, and the United States that the modern meat-type pig develops muscle and/or deposits protein at the maximum rate of development for a much longer period and to a heavier weight than the shorter fat-type pig.

Differences in fatness and muscling among pigs become more pronounced at heavier weights, thus making the measurement and evaluation of economically important traits simpler and more accurate at heavier weights. There is sufficient evidence to suggest that rate of gain and feed efficiency up to a weight of 150 pounds cannot be utilized to predict accurately performance beyond 150 pounds.

Boars gain faster and convert feed more efficiently than either gilts or barrows, and gilts are somewhat more efficient than barrows. Both boars and gilts produce leaner, heavier muscled carcasses than barrows. Barrow carcasses, however, produce pork which tends to be somewhat more acceptable in eating quality than either boars or gilts. Pork from boar carcasses usually has a characteristic "boar" odor, especially at heavier weights, which may be unacceptable to the consumer.

Chemical composition studies show that the percent fat in the total carcass increases as subcutaneous fat depth increases. The increase in intramuscular fat, however, occurs at a much slower rate than the subcutaneous fat. There is an inverse relationship between percent protein and percent fat in pork carcasses. Data comparing the chemical composition of carcasses from boars, barrows, and gilts are not available.

Specific gravity has proven to be a more accurate predictor of percent lean cuts, percent fat, and percent protein in the pork carcass than has average carcass backfat thickness.

Measurements of backfat thickness with a ruler probe have been equally valuable or more valuable than actual carcass backfat measures as indicators of conventional carcass cutability and chemical composition. The sonoray has proven to be comparable to the backfat probe for measuring backfat thickness. Measurements of fatness taken from 1.5 to 2.5 inches off the midline of the back at locations from the tenth to the last rib have been more highly correlated with carcass cutability when measured with either the backfat probe or the sonoray than have measurements taken at other locations.

Data on thickness of the three subcutaneous fat layers at various weights are not yet numerous enough to characterize reliably the developmental pattern for the three distinct layers. First and second layer depths can be accurately measured with the sonoray, but the third layer is quite variable in depth and is difficult to measure. Measures of third-fat layer depth thus appear to be of little or no value in equations for predicting carcass cutability in data currently available for study.

Body length measurements of pigs taken in the standing position have proven to be worthless. However, measurements of body length taken on pigs in a relaxed, restrained position have been found to be excellent predictors of carcass length.

Scientific studies involving detailed periodic measurement of skeletal, bone, muscle, and fat development have not been undertaken.

Therefore, clear cut patterns of growth and development of skeleton, muscle, and fat have not been established with experimental data in the growing pig.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. SOURCE OF DATA

Data were collected on pigs selected from the purebred Duroc herd of the Tennessee Agricultural Experiment Station, Knoxville, Tennessee. This study included 36 experimental and 8 observation pigs from the 1968 March farrowing season.

II. ASSIGNMENT TO TREATMENTS

Twenty-four boars and 12 gilts were selected from six litters sired by Shiloh, a superior certified meat sire. The dams were sired by two boars, three by King Formula CMS and three by Master Lad B (Figure 1).

Actual selections for the experiment were made after the pigs were weaned at approximately 80 days of age and a weight of about 75 pounds each (Table I). All sows and pigs had received similar treatment during gestation, farrowing, and during the nursing period. The four boar pigs most similar in weight and phenotypic appearance were chosen from each litter and two of these (randomly taken) were castrated. The two littermate gilts which most closely matched the four boar pigs in weight and general appearance were then selected from each litter.

Six pigs from each litter were than assigned to treatment such that one boar, one barrow, and one gilt would be slaughtered at 225 pounds, and one of each sex would be slaughtered at about 300 pounds.

Pen Number											
1	2	3	4	5	6	7	8	9	10	11	12
B2a	b2a	G2a	B2b	b2b	G2b	B1a	b1a	G1a	B1b	b1b	G1b

B = Boar 1 = Slaughtered at 225 pounds

b = Barrow 2 = Slaughtered at 300 pounds

G = Gilt a = Dam sired by King Formula CMS

b = Dam sired by Master Lad B

Figure 1. Design of experiment.

TABLE I

NUMBER OF ANIMALS AND MEANS FOR SELECTED TRAITS

	B2a	b2a	G2a	B2b	b2b	G2b	B1a	b1a	G1a	B1b	b1b	G1b
Number of animals	3	3	3	3	3	3	3	3	3	3	3	3
Initial lotting age, days	85.3	85.3	85.3	82.3	82.3	82.3	85.3	85.3	85.3	82.3	82.3	82.3
Initial lotting weight, lb.	80.7	82.0	75.7	70.3	68.0	67.3	78.3	76.3	69.7	74.7	73.0	75.3
Off-feed age, days	187.4	222.0	206.4	184.6	201.0	216.6	153.0	153.3	158.4	154.0	159.3	168.3
Off-feed weight, lb.	299.3	294.3	295.0	297.3	298.3	293.7	226.3	222.3	225.3	211.0	228.0	224.0
Shrunk slaughter weight, lb.	295.0	290.0	291.0	294.3	296.0	287.7	223.3	220.3	217.7	209.7	222.7	220.7

Three pigs of the same sex were allotted to each pen. Pigs from dams sired by the same boar were penned together (Figure 1). Thus, the experiment included 36 animals, 18 to be slaughtered at conventional market weights and 18 to be fed to a heavier weight.

The experiment was designed to study growth, development, and composition of the meat-type pig with particular emphasis on live weights of 75, 150, 225, and 300 pounds. Eight additional observation pigs sired by Shiloh and from dams comparable to those of the experimental pigs were selected to be used in carcass composition and chemical analysis studies at weights of 75 and 150 pounds. Two boars (one castrated) and a gilt were fed to weights of about 150 pounds at which time they were slaughtered for detailed study of carcass composition. Similar studies were conducted with a barrow slaughtered at each of the final weights of 225 and 300 pounds.

III. RATION AND FEEDING METHODS

All pigs were self-fed a complete mixed ration in 5 x 20 feet concrete confinement pens equipped with standard swine self-feeders and automatic waterers. A 16-percent protein meal ration was fed throughout the experiment. The composition of the ration is shown in Table II.

IV. GROWTH STUDY PROCEDURES

Linear measurements of skeletal and muscular growth and fat deposition were taken on the live animals at the beginning of the experiment and at three-week intervals until the experimental pigs reached an approximate average pen weight of 175 pounds. Measurements were then

TABLE II

COMPOSITION OF RATION

Ingredient	Pounds
No. 2 Yellow corn, ground	751
Soybean oil meal (44%)	150
Meat scraps (50%)	50
Dehydrated alfalfa meal (17%)	30
Dicalcium phosphate	10
Salt	5
Vitamin premix[a]	2
Antibiotic[b]	1
Trace mineral premix[c]	1
	1,000

[a]Provided an addition to the ration of 2 gm. riboflavin, 4 gm. pantothenic acid, 9 gm. niacin, 10 gm. choline, 10 mg. B_{12}, 400,000 I.U. Vit. A, 250,000 I.U. Vit. D.

[b]Contained 10 gm. chlorotetracycline per pound.

[c]Provided an addition to the ration of 100 ppm. of Mn, 3 ppm. I, 1 ppm. Co, 100 ppm. Fe, 10 ppm. Cu, and 100 ppm. Zn.

taken at two-week intervals until slaughter and at time of slaughter. Pigs were weighed, and rate of gain and feed efficiency data were calculated on an accumulative basis and for each growth period.

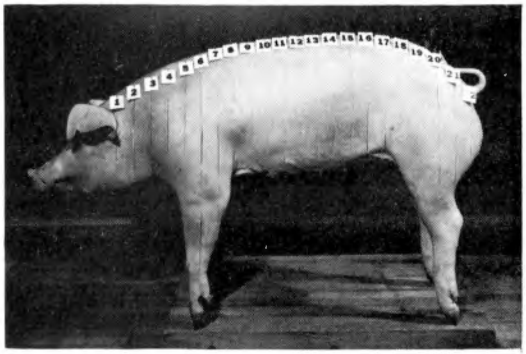
The observation pigs were measured only prior to slaughter at the respective slaughter weights of 75, 150, 255, and 300 pounds. These pigs were slaughtered and frozen in as nearly normal standing position as possible (Figure 2). The pigs were later cut into cross and longitudinal sections so that bone, muscle, and fat topography could be studied. Color photographs were taken of each section and made into 2 x 2 slides (Figures 3, 4, and 5).

V. LINEAR MEASUREMENT PROCEDURES

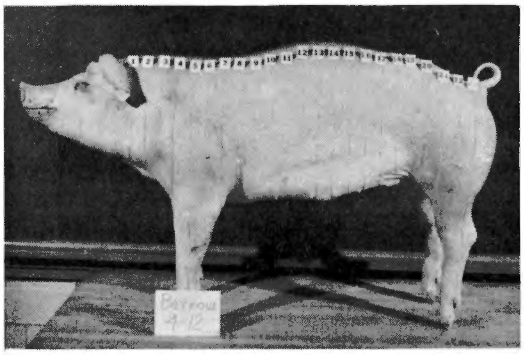
All linear measurements were taken while the pigs were in a restraining crate with the legs of the pig completely off the ground in a relaxed position. A small restraining cradle was used for the first two measurements while the pigs were small enough to be lifted by hand (Figure 6a), but a "sonoray crate" with a removable side panel was used for the remaining measurements (Figure 6b).

Chest circumference or heart girth was measured posterior to the front legs with a cloth tape similar to a weight-predicting tape used on cattle. The tape was placed in the crate or cradle before the pig was placed into the restrained position and the measurement was then read to the nearest tenth of an inch.

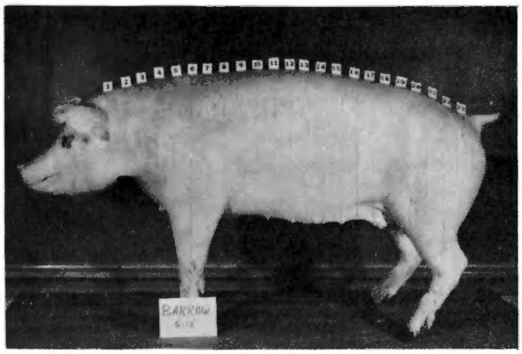
Body length measurements were obtained between prominent points of the pig's external anatomy. These points were located after clipping the hair from the back of the pig, both by observing and palpating the pigs after they were restrained. The anatomical points located were:



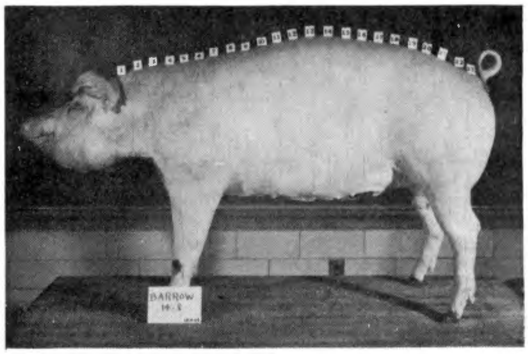
(a) 75 pound



(b) 150 pound

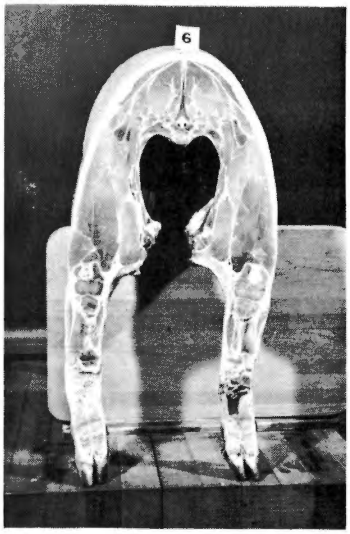


(c) 225 pound

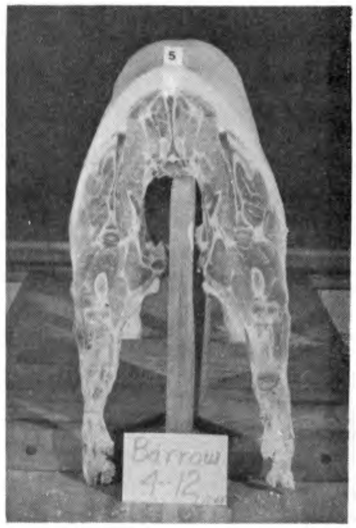


(d) 300 pound

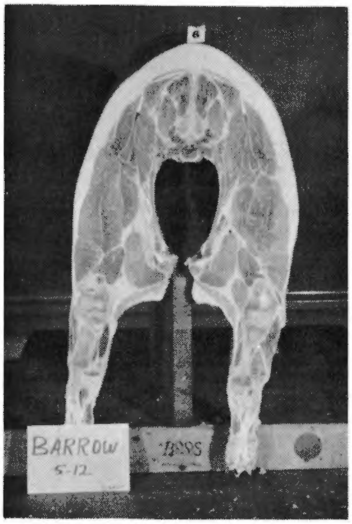
Figure 2. Side view of four observation pigs.



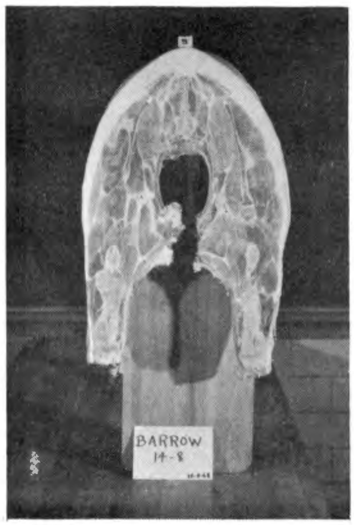
(a) 75 pound



(b) 150 pound

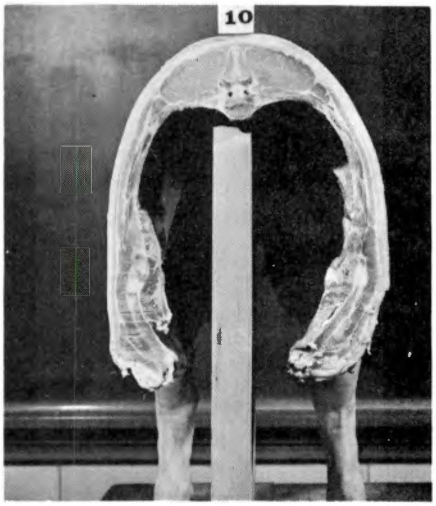


(c) 225 pound

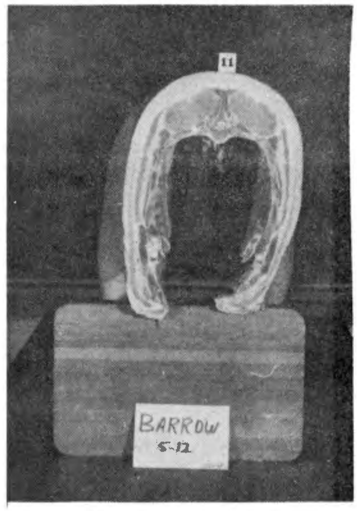


(d) 300 pound

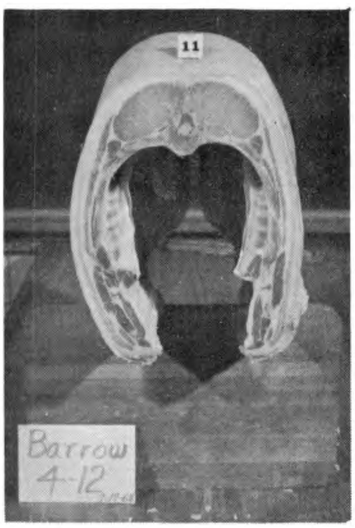
Figure 3. First-rib cross-sectional view of four observation pigs.



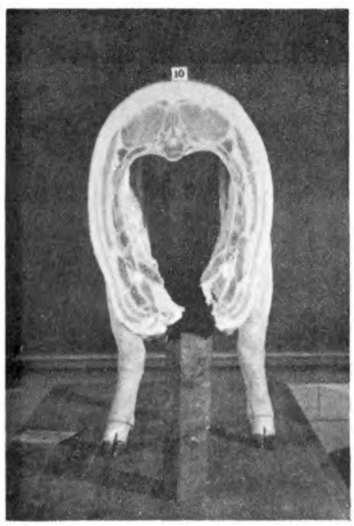
(a) 75 pound



(b) 150 pound



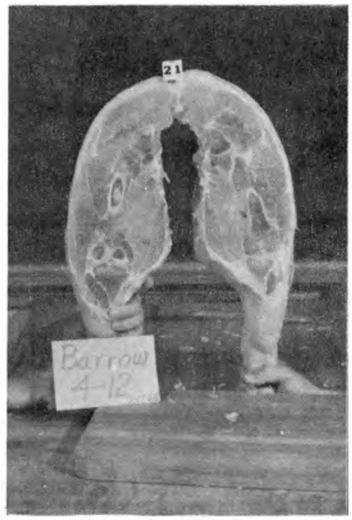
(c) 225 pound



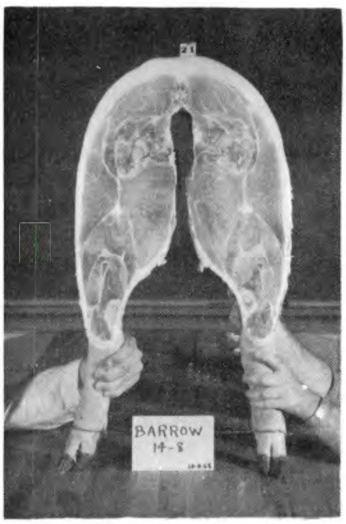
(d) 330 pound

Figure 4. Tenth-rib cross-sectional view of four observation pigs.

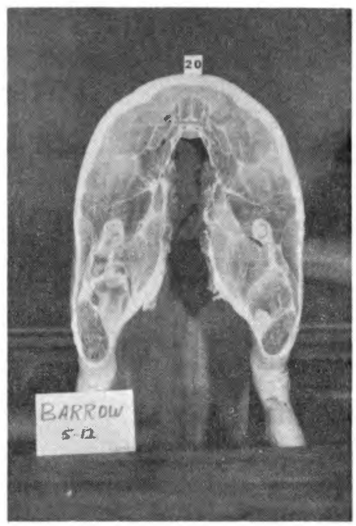
(a) 75 pound



(b) 150 pound

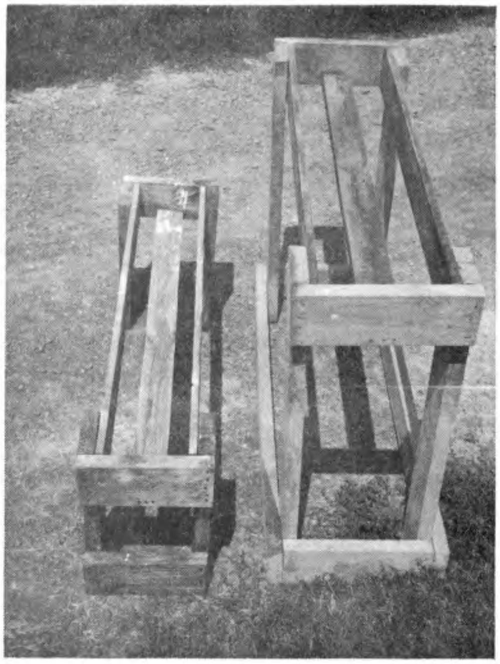


(c) 225 pound

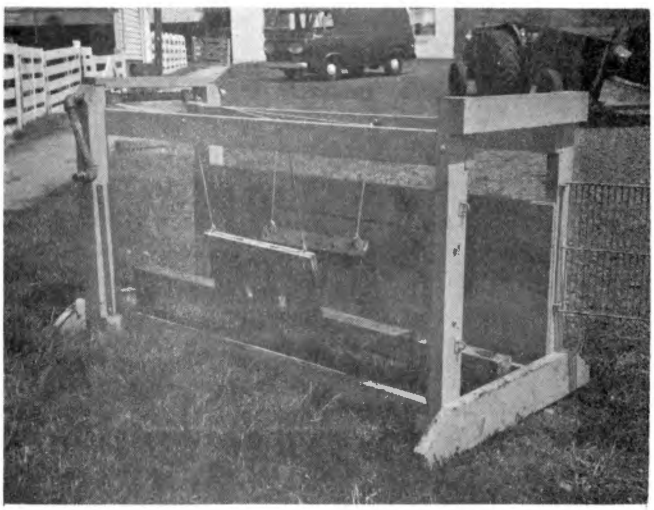


(d) 300 pound

Figure 5. Middle of ham cross-sectional view of four observation pigs.



(a) Cradle to restrain pigs for first two measurements.



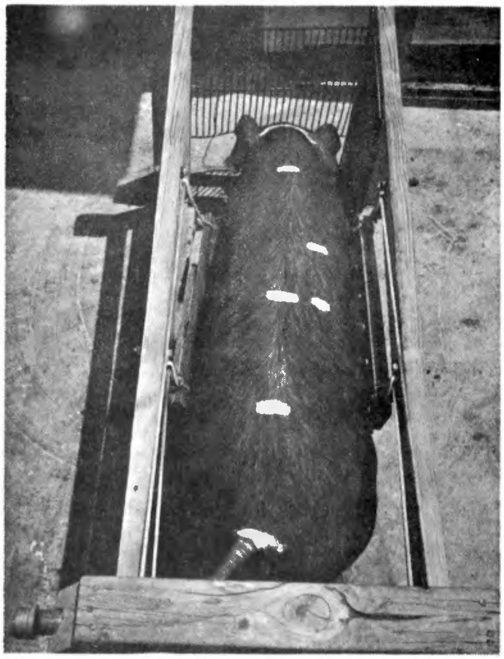
(b) Crate to restrain pigs for remaining measurements.

Figure 6. Restraining equipment.

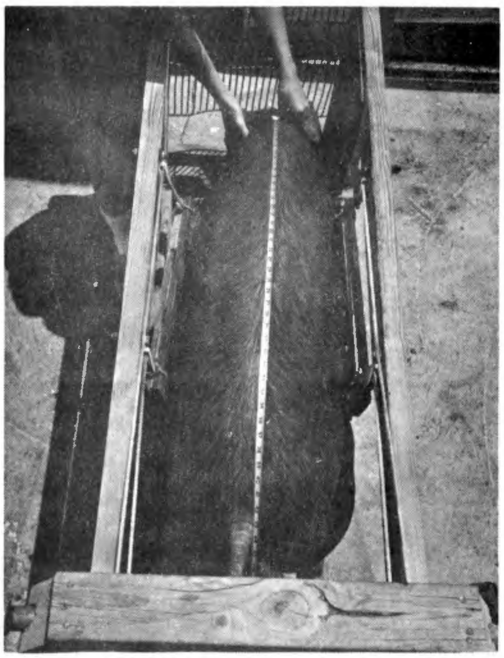
1. Poll--located at the base of the skull (nuchal crest).
2. Point of shoulder--located on the lateral surface of the scapula (tuber spina).
3. Last rib.
4. Point of hip--the most lateral portion of the anterior surface of the hip (tuber coxa).
5. Root of tail--base of coccygeal vertebra.

Points on the dorsal midline corresponding to the anatomical points on the lateral surfaces were located (Figure 7a). This was accomplished by firmly holding the end of a small string at the established point on one side of the pig's body and stretching it over the dorsal surface to the identical point on the opposite side. The location of the string as it passed over the spinous processes was observed for accuracy and identified by placing a black mark with a magic marker directly above the spinous process. This method of identifying a specific location was used for the point of the shoulder, the last rib, and the point of hip. The poll was located by palpation and the root of the tail was determined from the first anterior wrinkle of the tail by holding the tail at a 90-degree angle to the posterior part of the body. A measurement was taken from the center of the posterior edge of the nuchal crest to the base of the coccygeal vertebra (root of tail) with a steel tape (Figure 7b). Measurements were recorded from the poll to each of the other four points located along the dorsal surface of the pig's back. Lengths of the four body sections were then determined by subtraction.

Length measurements were taken of the right front leg, the right rear leg, and the tail with a steel tape. The front leg was measured



(a) Sites for midline measurements of length and backfat and sites for fat and muscle depth measurements over the l. dorsi.



(b) Measuring body length with a steel tape.

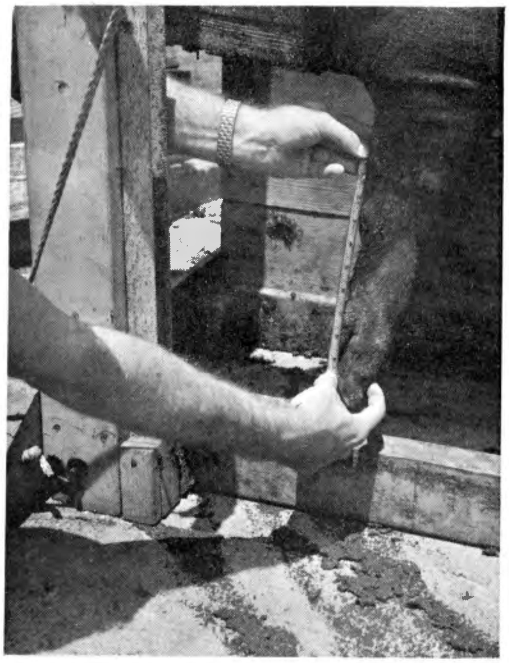
Figure 7. Live-animal measurement sites.

from the olecranon (elbow joint) to the bottom of the foot. The rear leg was measured from the tuber calcis (hock joint) to the bottom of the foot (Figure 8a). The tail was measured from the second coccygeal vertebra to the tip.

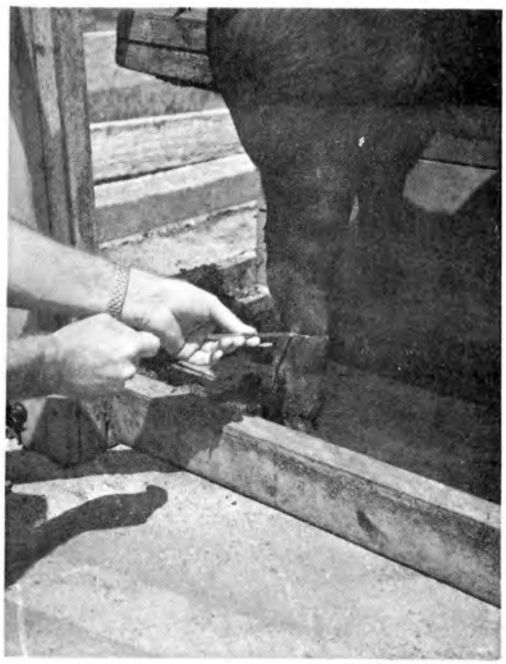
Bone circumference measurements also were taken on the right front leg, right rear leg, and the tail. A string in a small plastic tube was placed around the bone and the distance that the string extended from the end of the tube was measured (Figure 8b). This distance was subtracted from the distance that the entire string extended from the tube to give the bone circumference. The point of smallest circumference of the front leg (metacarpus) was measured and the circumference at a point half the distance from the largest point of the hock joint to the bottom of the foot was measured on the rear leg. The measurement on the tail was taken between the first and second coccygeal vertebra.

Subcutaneous fat layer depth and muscle depth were measured by the use of a Branson Model 12 sonoray equipped with a 2.0 megacycle, 1.27 cm. zth transducer. The machine was calibrated with the second echo at 4.35 so that muscle depth was read at a ratio of 1:2 and fat depth was measured at a ratio of 1:1.71. Depths of the first and second fat layers measured at the point-of-shoulder, last-rib, and point-of-hip locations over the dorsal midline were recorded (Figure 7a). These locations correspond to the first-rib, last-rib, and last-lumbar measurements that are obtained on pork carcasses to obtain average backfat thickness.

The last rib was located by palpation, and at this point the most prominent area of the <u>longissimus dorsi</u> (LD) was located. Sonoray readings were taken normal to the surface of the pig's body over the center of the



(a) Measuring length of right rear leg.



(b) Measuring circumference of right rear leg.

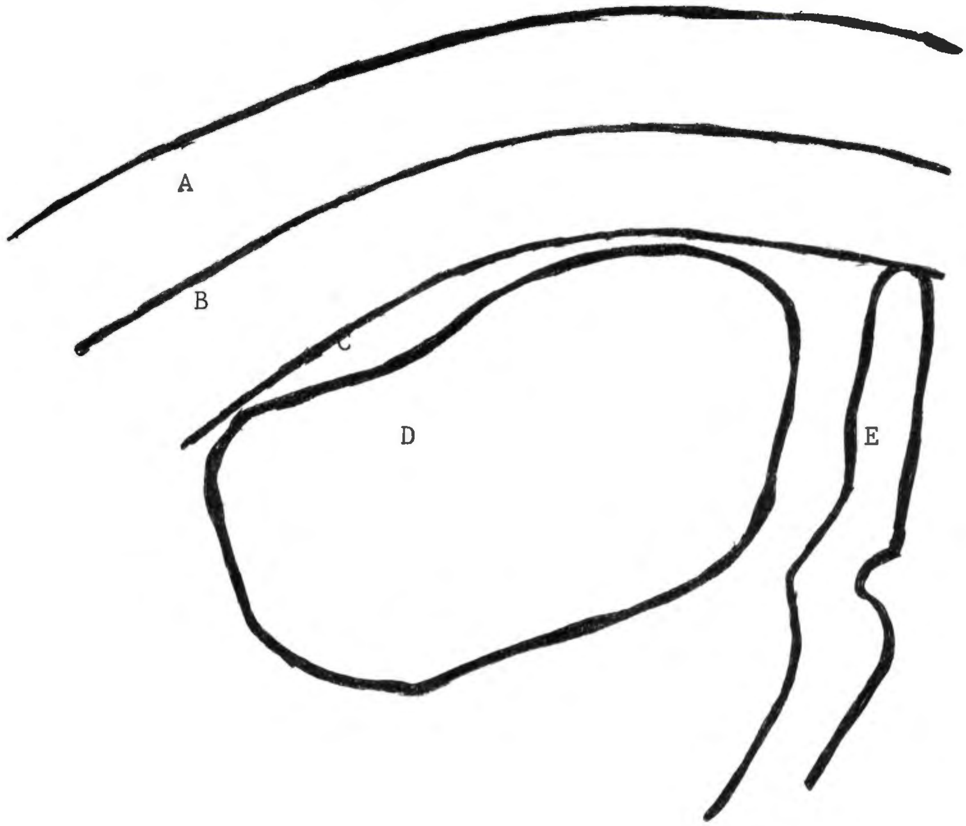
Figure 8. Technique for measuring bone length and bone circumference.

LD (Figure 7a, page 41). Measurements of depth to the bottom of the first, second, and third fat layers and to the bottom of the LD were recorded (Figure 9). The tenth rib was located by counting four ribs forward from the last rib location (Figure 7a). The tenth rib was accurately located on those pigs that had 14 ribs, but the location was somewhat to the rear of the tenth rib on those pigs that had more than 14 ribs. Measurements similar to those taken at the last rib were taken at the tenth-rib location.

Final live-animal measurements were taken one day prior to slaughtering, and the location of certain live-animal measurement sites were identified so that measurements on the carcass could be obtained at the same points. A scalpel was used to mark the first-rib, last-rib, and last-lumbar locations over the dorsal midline and the center of the LD at the tenth- and last-rib locations.

VI. SLAUGHTERING PROCEDURES

Pigs were weighed at weekly intervals as they approached slaughter weights of 225 or 300 pounds. As the pigs reached the desired off-feed weights of 225 to 235 and 295 to 305 pounds, they were allowed a 24-hour shrinkage period without feed but with free access to water. Pigs were placed in individual pens for the shrinkage period, and careful attention was given to insure that boars were not allowed near other boars. After the shrinkage period, the pigs were penned separately on a truck and hauled eight miles from Blount Farm to The University of Tennessee Meats Laboratory for slaughter.



(a) Fat layer 1
(b) Fat layer 2
(c) Fat layer 3
(d) Longissimus dorsi (loin-eye muscle)
(e) Backbone (spinous process)

Figure 9. Schematic cross-sectional diagram of fat layers and the longissimus dorsi muscle at the tenth-rib location.

The pigs were slaughtered immediately after arrival at the Meats Laboratory. Weights of non-carcass components were recorded, and hot carcass weights were obtained. The warm carcasses were sawed down the center of the back and allowed to hang in a cooler thermostatically controlled to maintain a temperature of 34 to 36° F. for 48 hours before cutting.

A 24-hour post-slaughter weight was obtained in air and in water at cooler temperature so that specific gravity of the carcasses could be calculated. The weight in water was taken with the carcasses completely submerged in a large specific-gravity tank filled with water. Specific gravity was determined as the ratio of carcass weight in air to carcass weight in water.

After the 48-hour chilling period, carcass length was measured from the anterior edge of the first rib at the dorsal attachment to the anterior edge of the aitch bone. The subcutaneous fat was measured with a ruler to the bottom of the first layer, including skin thickness, and to the bottom of the second layer over the vertebral column at the three locations where measurements were taken on the live pig. Fat measurements were taken to the bottom of the first layer, including skin, bottom of the second layer, and bottom of the third layer at the scan sites over the tenth- and last-rib locations.

A tracing was made of the cross section of the l. dorsi at the tenth- and last-rib scan sites. The tracings were measured to the nearest 0.01 sq. in. with a compensating polar planimeter. Depth measurements of the tracings were taken at approximately the same angle that the measurements were taken on the live animals with the sonoray.

The right side of each carcass was cut according to procedures outlined at the 1952 Reciprocal Meat Conference. Each cut was weighed to the nearest tenth of a pound. The weights of the cuts from the right side of each carcass were doubled and expressed as a percentage of the total chilled carcass weight.

VII. QUALITY DETERMINATIONS

The loin and ham from the right side of each carcass were given subjective scores for marbling and pork quality. Marbling was scored numerically from one to ten, one representing "devoid" and ten representing "abundant." The Wisconsin System (1963) of pork quality standards was used for scoring hams and loins. Numerical scores ranging from one to five are based upon visual appraisal for color, firmness, texture, and water binding capacity.

Penetrometer readings were taken on the _l. dorsi_ and the fat tissues from a one-inch cross section of the untrimmed loin taken posterior to the tenth rib. Six muscle and six fat readings were obtained uniformly across the surfaces of the tissue, and the averages of the muscle readings and of the fat readings were recorded.

A four-rib section of the trimmed loin taken anterior to the tenth rib was obtained for cooking studies. The roasts were packaged in air-tight waxed paper and stored at 0° F. until cooked for sensory panel analysis. The roasts were then removed from the freezer and allowed to thaw at room temperature before cooking. The roasts were cooked to an internal temperature of 169° F. in an oven at 350° F. The percentage loss due to evaporation and to dripping during cooking was determined.

A one-inch diameter core was taken from the medial and lateral portion of the cooked l. dorsi, and each core was sheared four times with a Warner-Bratzler shear. The average of these eight values was used for calculations.

Sensory scores for flavor, juiciness, and tenderness were determined on each roast by a four-member trained panel. A hedonic scoring system ranging from one to ten was used by each panel member for evaluating sensory factors.

VIII. CHEMICAL ANALYSES

The left side of each carcass was boned and skinned after the feet had been conventionally removed and weighed. Weights of the bones and skin were recorded. The boned-out, skinned portion was cut into small pieces and thoroughly mixed. These were then ground through a 1/2-inch plate with a Hobart electric grinder. The ground meat was thoroughly mixed and reground using a 1/4-inch plate. The meat was again thoroughly mixed and ten 1/2-pound samples were randomly taken to be used as a representative sample of the carcass. The approximately five-pound sample was again mixed and ground with a small Hobart sample grinder using a 1/8-inch plate. This sample was mixed and ground with a 1/16-inch plate on the smaller grinder. The sample was mixed in a small container, and samples were randomly taken to fill two four-ounce sample bottles. These bottled samples were sealed and frozen at 0° F. until chemical analyses were performed.

A four-rib section of the l. dorsi and the semitendinosis were removed from the carcass before the dissection procedure began. The external covering of each muscle was removed to insure against the presence of any subcutaneous or intermuscular fat. These muscle samples were ground on a small sample grinder and sampled in the same manner as the samples from the total carcass.

Moisture, ether extract, and protein analyses were conducted according to procedures outlined by the Association of Official Agricultural Chemists. Duplicate analyses were conducted for each muscle and whole-carcass sample. The average of the two determinations for each sample was used for calculations.

Whole carcasses from the eight observation pigs were boned out and skinned, and the boneless, skinless portion of each carcass was sampled and analyzed by the same procedure used for the experimental pigs.

IX. STATISTICAL PROCEDURE

The data were analyzed using conventional statistical procedures as described in standard textbooks on statistical methods. All variables of interest were subjected to analysis of variance to test the effects of treatment, grandsire, and sex. Simple correlations among all variables were calculated.

CHAPTER IV

RESULTS AND DISCUSSION

I. GROWTH AND DEVELOPMENT

The results of this experiment are in general agreement with the conclusions of McMeekan (1940) concerning the differential growth pattern of the body tissues. Skeletal and skin growth occurred earlier than muscular growth, and muscular growth occurred earlier than fat growth.

The means for the various skeletal measurements at approximate weights of 75, 150, 225, and 300 pounds and the changes in measurements that occurred with each 75-pound increment of weight are shown in Table III. The percentages of the final skeletal measurements at 225 and 300 pounds that were attained at approximate weights of 75, 150, and 225 pounds are shown in Table IV. Total body length, bone length, and bone circumference measured at 75 pounds represented a high percentage of the final measurements. Skeletal development progressed at a decreasing rate from 75 to 300 pounds which is in agreement with the conclusions of McMeekan (1940). The proportion of skeletal growth in each subsequent period beyond 75 pounds decreased.

Likewise, the percentage of bone and skin from carcasses of pigs slaughtered at approximate weights of 75, 150, 225, and 300 pounds decreased rapidly up to a weight of 225 pounds as shown in Table V. These data further support the conclusions of McMeekan (1940).

These data are in disagreement with the conclusion of McMeekan (1940) that the fore limbs are earlier developing than the hind limbs.

TABLE III

MEANS FOR SKELETAL MEASUREMENTS AT 75, 150, 225, AND 300 POUNDS WITH THE INCREASES IN MEASUREMENTS FOR EACH 75-POUND INCREMENT

Measurement	75	Increase	150	Increase	225	Increase	300
Length of body (cm.)							
Poll to scapula	15.2	(5.3)	21.5	(2.4)	23.9	(2.3)	26.2
Poll to last rib	47.1	(12.70	59.8	(7.1)	66.9	(6.6)	73.5
Poll to illium	61.9	(18.2)	80.1	(11.2)	91.3	(8.7)	100.0
Poll to root of tail	75.3	(22.2)	97.5	(13.4)	110.9	(10.4)	121.3
Scapula to last rib	31.8	(6.5)	38.3	(4.8)	43.1	(4.2)	47.3
Last rib to illium	14.9	(5.4)	20.3	(4.1)	24.4	(2.1)	26.5
Illium to root of tail	13.3	(4.0)	17.3	(2.3)	19.6	(1.7)	21.3
Bone circumference (cm.)							
Right front leg	11.8	(2.2)	14.0	(1.1)	15.1	(2.1)	17.2
Right rear leg	12.4	(2.1)	14.5	(1.1)	15.6	(2.1)	17.7
Tail	6.0	(.5)	6.5	(.5)	7.0	(1.8)	8.8
Bone length (cm.)							
Right front leg	21.6	(4.8)	26.4	(4.0)	30.4	(2.3)	32.7
Right rear leg	16.2	(2.7)	18.9	(2.7)	21.6	(1.8)	23.4
Tail	20.1	(4.2)	24.3	(4.1)	28.4	(3.2)	31.6
Body circumference (cm.)	71.3	(15.8)	87.1	(16.7)	103.8	(11.1)	114.9

TABLE IV

AVERAGE PERCENTAGE OF FINAL SKELETAL MEASUREMENTS AT 225 AND 300 POUNDS ATTAINED AT 75, 150, AND 225 POUNDS

	Pounds				
	75		150		225
Measurement	% of 225	% of 300	% of 225	% of 300	% of 300
Body length					
Poll to root of tail	68.1	62.1	87.9	80.4	91.4
Bone circumference					
Right front leg	78.1	68.6	92.7	81.4	87.8
Right rear leg	79.5	70.0	92.9	81.9	88.1
Tail	85.7	68.2	92.8	73.9	79.5
Bone length					
Right front leg	71.0	66.0	86.8	80.7	93.9
Right rear leg	75.0	69.2	87.5	80.8	92.3
Tail	70.8	63.6	85.6	76.9	89.9
Body circumference	68.7	61.2	84.0	75.8	90.3

TABLE V

BONE AND SKIN COMPOSITION OF CARCASSES FROM OBSERVATION AND EXPERIMENTAL GROUPS

Component	Observation 1 75 pounds 3 pigs	Observation 2 150 pounds 3 pigs	Experimental 1 225 pounds 18 pigs	Experimental 2 300 pounds 18 pigs
Bone weight (lb.)	5.07	12.70	16.70	19.54
Bone (%)	17.98	14.84	10.96	9.62
Skin weight (lb.)	1.90	4.20	6.12	8.76
Skin (%)	6.74	4.91	4.02	4.31

Table IV shows that the percentages of final bone circumference and bone length that were attained at lighter weights were approximately the same for the front and rear limbs. During no period was a higher percentage of hind limb growth than front limb growth observed. The circumference measurements in this experiment included the skin and some subcutaneous tissue surrounding the bone; however, the amount present on the front and rear limbs appeared to be similar.

Bone circumference had attained a higher percentage of its final measurement than had bone length at weights of 75 and 150 pounds. This is somewhat contradictory to the conclusion of McMeekan (1940) that growth in thickness of bone occurs later than growth in length of bone. At 225 pounds, however, bone length had attained a higher percentage of its final 300-pound measurement than had bone circumference.

The average percentages of total body length (poll to root of tail) represented by each body section at approximate weights of 75, 150, 225, and 300 pounds are shown in Table VI. The percentages of total body length constituted by each section (poll to scapula, scapula to last rib, last rib to illium, and illium to root of tail) were similar at all weights. These results agree with those of Ramsey (unpublished data) and show that within the weight range of this experiment, each section of the body grew as a relative percentage of the total body length. These results are, however, in general disagreement with the conclusions of McMeekan (1940) concerning the anterior-posterior gradient of development of body regions. These data do not, however, include the period from birth to 75 pounds and, thus, some additional research in this area would be valuable.

TABLE VI

AVERAGE PERCENTAGE OF TOTAL BODY LENGTH (POLL TO ROOT OF TAIL) IN EACH BODY SECTION AT 75, 150, 225, AND 300 POUNDS

	Pounds			
Body Section	75	150	225	300
Poll to scapula	20.18	22.05	21.55	21.59
Poll to last rib	62.54	61.33	60.32	60.59
Poll to illium	82.20	82.15	82.32	82.44
Scapula to last rib	42.23	39.28	38.86	38.99
Last rib to illium	19.78	20.82	22.00	21.84
Illium to root of tail	17.66	17.74	17.67	17.55

The means for the ultrasonic estimates of fat and muscle at approximate weights of 75, 150, 225, and 300 pounds and the increases that occurred in each measurement with 75-pound increments of weight are shown in Table VII. Fat development increased at an increasing rate which is in accord with the findings of McMeekan (1940). The rate of increase of fat was most rapid in the tenth- and last-rib areas. Live-animal and/or carcass measurements taken near the tenth- or last-rib locations over the _l. dorsi_ have been the most accurate of all live-animal and carcass measurements as indicators of total carcass cutability; therefore, total fatness of the carcass must have increased at an increasing rate which is in harmony with the conclusions of McMeekan (1940) and Allen _et al_. (1961).

The rapid increase in total fat depth at the tenth- and last-rib locations over the center of the _l. dorsi_ was mainly attributable to the increase in depth of the second and third fat layers. The rate of increase of the first fat layer decreased while the rate of increase in second and third layer depth increased. No third fat layer was observed in any of the 36 pigs at the beginning weight of 75 pounds. At 150 pounds, a third fat layer was detected on only 5 pigs at the tenth-rib location and on 16 pigs at the last-rib location.

Muscle growth as measured by the increase in ultrasonic depth of the _l. dorsi_ was somewhat intermediate between that of skeleton and fat. There was, however, some error of measurement of both muscle and fat with the sonoray, but the trends are similar to those exhibited by the carcass measurements.

The average percentages of final ultrasonic measurements at 225 and 300 pounds attained at 75, 150, and 225 pounds are shown in Table VIII. The percentages of fat attained at the lighter weights were lower

TABLE VII

MEANS FOR ULTRASONIC ESTIMATES OF FAT AND MUSCLE AT 75, 150, 225, AND 300 POUNDS WITH THE INCREASES IN ESTIMATES FOR EACH 75-POUND WEIGHT INCREMENT

Location	75	Increase	150	Increase	225	Increase	300
Midline fat (cm.)							
First rib, layer 1	.94	(.48)	1.42	(.26)	1.68	(.29)	1.97
First rib, layer 2	1.26	(.76)	2.02	(.44)	2.48	(.40)	2.88
Last rib, layer 1	.66	(.44)	1.10	(.24)	1.34	(.21)	1.55
Last rib, layer 2	.40	(.34)	.74	(.39)	1.13	(.37)	1.50
Last lumbar, layer 1	.83	(.61)	1.43	(.25)	1.68	(.35)	2.03
Last lumbar, layer 2	.40	(.22)	.62	(.30)	.92	(.15)	1.07
Average total	1.50	(.94)	2.44	(.72)	3.08	(.56)	3.66
Center of *l. dorsi* fat (cm.)							
Tenth rib, layer 1	.69	(.48)	1.17	(.14)	1.31	(.32)	1.63
Tenth rib, layer 2	.32	(.26)	.58	(.37)	.95	(.43)	1.38
Tenth rib, layer 3	.00	(.03)	.03	(.24)	.27	(.73)	1.00
Total	1.01	(.77)	1.78	(.75)	2.53	(1.48)	4.01
Last rib, layer 1	.64	(.36)	1.00	(.18)	1.18	(.17)	1.35
Last rib, layer 2	.25	(.20)	.45	(.22)	.67	(.18)	.85
Last rib, layer 3	.00	(.10)	.10	(.03)	.03	(.69)	.82
Total	.89	(.66)	1.55	(.43)	1.98	(1.04)	3.02
Depth of *l. dorsi* (cm.)							
Tenth rib	3.15	(1.67)	4.82	(.76)	5.58	(.06)	5.64
Last rib	2.92	(1.37)	4.39	(1.19)	5.58	(.32)	5.90

TABLE VIII

AVERAGE PERCENTAGE OF FINAL ULTRASONIC MEASUREMENTS AT 225 AND 300 POUNDS ATTAINED AT 75, 150, AND 225 POUNDS

	Pounds				
	75		150		225
Location	% of 225	% of 300	% of 225	% of 300	% of 300
Midline fat (cm.)					
First rib, layer 1	56	48	85	72	85
First rib, layer 2	51	44	81	70	86
Last rib, layer 1	49	43	82	71	86
Last rib, layer 2	35	27	65	49	75
Last lumbar, layer 1	49	40	85	70	83
Last lumbar, layer 2	43	37	67	58	86
Average total (layers 1 + 2)	49	41	79	67	84
Center of <u>l. dorsi</u> fat (cm.)					
Tenth rib, layer 1	53	42	89	72	80
Tenth rib, layer 2	34	23	61	42	69
Tenth rib, layer 3	0	0	11	3	27
Total (layers 1 + 2 + 3)	40	25	70	44	63
Last rib, layer 1	54	47	85	74	87
Last rib, layer 2	37	29	67	53	79
Last rib, layer 3	0	0	77	12	16
Total (layers 1 + 2 + 3)	45	29	78	51	66
Depth of <u>l. dorsi</u> (cm.)					
Tenth rib	56	56	86	85	99
Last rib	52	49	79	74	95

than those for skeleton and muscle, particularly those at the tenth- and last-rib locations. Only 63 and 66 percent of the 300-pound total fat depth at the tenth- and last-rib location was present at 225 pounds. A major portion of the fat increase from 225 to 300 pounds was in the third layer as only 27 and 16 percent of the 300-pound third fat layer depth at the tenth- and last-rib location was present at 225 pounds. The second fat layer developed later than the first layer, and, thus, the rate of increase of the second fat layer was intermediate between the rates of increase of the first and third fat layers. Up to a weight of 225 pounds, the differences among individuals were mainly attributable to differences in depth of the second fat layer.

The average rate of increase in total subcutaneous fat depth between 75 and 225 pounds was somewhat less than that reported by Allen _et al_. (1961) and Robison (1962). In the study of Allen _et al_. (1961) backfat thickness increased from 1.00 to 1.27 inches from 150 to 200 pounds; whereas, in the present study, backfat increased only from .96 to 1.24 inches from 150 to 225 pounds. For an 89-pound increase in weight, Robison found that shoulder probe increased .79 inches and that loin probe increased .50 inches. The comparable increases in the present study between 75 and 225 pounds were only .76 inches of shoulder fat and .51 inches of fat over the loin. It is likely that there are inherent differences among pigs concerning their fat deposition patterns.

In the present study, _l. dorsi_ depth at the tenth- and last-rib locations increased .76 and 1.19 in. from 150 to 225 pounds. Allen _et al_. (1961) reported an increase of .7 sq. in. in _l. dorsi_ area from 150 to 200 pounds live weight.

Similar to the findings of Burgess (1965), a significant difference ($P < .05$) in second and third fat layer depth was detectable among sexes with the sonoray. There was also a significant ($P < .05$) grandsire effect upon second layer ultrasonic fat depth measured over the center of the l. dorsi. Pigs from dams sired by Master Lad B were leaner than those from King Formula dams.

Measurements of individual fat layer depth in the carcass for the 225- and the 300-pound experimental subgroups are shown in Table IX and Table X. The changes in subcutaneous fat depth in the carcass show deposition trends similar to those of live-animal ultrasonic estimates of fatness. Increases in fatness from 225 to 300 pounds can be largely accounted for by increases in second and third fat layer depth changes. The first fat layer depth is greater at 300 than at 225 pounds; however, the standard deviation of first fat layer depth is about the same at both weights. Means and standard deviations of carcass fat layer depth are shown for the 225- and 300-pound groups in Table XI.

Differences in fatness among individuals became greater as weight increased which is in agreement with the conclusions of Buck (1963). This is particularly important from a selection standpoint since selection of individuals for breeding purposes is often based upon live-animal estimates of fatness. Optimum progress cannot be realized from selection programs if the estimates of performance traits are not accurate. Therefore, estimates of fatness should be taken when practical and when differences among individuals are most pronounced.

Correlations of periodic live-animal skeletal, fat, and muscle measurements for the first five measurement periods are shown in Tables XII, XIII, and XIV. Correlations between successive periods are positive

TABLE IX

CARCASS MEASUREMENTS OF FAT LAYER DEPTH FROM PIGS SLAUGHTERED AT 225 POUNDS

Measurement	Bla	Blb	Gla	Glb	bla	blb
Midline fat (cm.)						
First rib, layer 1	1.63	1.40	1.43	1.63	1.47	1.70
First rib, layer 2	2.37	2.53	2.70	2.40	3.06	2.63
Total layers 1 + 2)	4.00	3.93	4.13	4.03	4.53	4.33
Last rib, layer 1	1.13	1.03	1.30	1.27	1.20	1.23
Last rib, layer 2	1.20	1.00	1.47	1.56	1.40	1.27
Total (layers 1 + 2)	2.33	2.03	2.77	2.83	2.60	2.50
Last lumbar, layer 1	1.60	1.33	1.67	1.87	1.67	1.43
Last lumbar, layer 2	0.90	0.84	0.96	1.00	0.80	1.07
Total (layers 1 + 2)	2.50	2.17	2.63	2.87	2.47	2.50
Average total	2.94	2.69	2.92	3.25	3.20	3.11
Center of <u>l. dorsi</u> fat (cm.)						
Tenth rib, layer 1	1.07	1.00	1.05	1.05	1.08	1.03
Tenth rib, layer 2	1.10	0.78	1.12	0.88	1.29	1.32
Tenth rib, layer 3	0.63	0.40	0.80	0.52	0.95	0.83
Total (layers 1 + 2 + 3)	2.80	2.18	2.97	2.45	3.32	3.18
Last rib, layer 1	1.15	0.87	1.00	1.02	0.97	0.92
Last rib, layer 2	0.67	0.65	0.87	0.71	1.01	0.93
Last rib, layer 3	0.75	0.53	1.01	0.69	0.85	0.72
Total (layers 1 + 2 + 3)	2.57	2.05	2.88	2.42	2.83	2.57

TABLE X

CARCASS MEASUREMENTS OF FAT LAYER DEPTH
FROM PIGS SLAUGHTERED AT 300 POUNDS

Measurement	B2a	B2b	G2a	G2b	b2a	b2b
Midline fat (cm.)						
First rib, layer 1	1.83	1.87	1.77	1.87	1.97	1.93
First rib, layer 2	3.10	2.93	3.56	2.83	3.30	3.64
Total (layers 1 + 2)	4.93	4.80	5.33	4.70	5.27	5.57
Last rib, layer 1	1.60	1.30	1.73	1.43	1.37	1.57
Last rib, layer 2	1.43	1.43	1.74	1.44	2.10	1.93
Total (layers 1 + 2)	3.03	2.73	3.47	2.87	3.47	3.50
Last lumbar, layer 1	2.00	1.77	2.10	1.93	2.10	2.33
Last lumbar, layer 2	0.93	0.96	1.13	1.27	1.27	1.57
Total (layers 1 + 2)	2.93	2.73	3.23	3.20	3.37	3.90
Average total	3.63	3.42	4.01	3.59	4.03	4.32
Center of _l. dorsi_ fat (cm.)						
Tenth rib, layer 1	1.17	1.35	1.58	1.17	1.37	1.30
Tenth rib, layer 2	1.60	1.22	1.45	1.13	2.05	1.83
Tenth rib, layer 3	1.06	0.81	0.89	0.77	1.96	1.10
Total (layers 1 + 2 + 3)	3.83	3.38	3.92	3.07	5.38	4.23
Last rib, layer 1	1.22	1.12	1.32	1.07	1.33	1.30
Last rib, layer 2	1.05	0.81	1.16	0.80	1.25	1.13
Last rib, layer 3	1.36	0.77	0.99	0.70	1.45	0.97
Total (layers 1 + 2 + 3)	3.63	2.70	3.47	2.57	4.03	3.40

TABLE XI

MEANS AND STANDARD DEVIATIONS OF CARCASS FAT LAYER DEPTH MEASUREMENTS AT 225 AND 300 POUNDS

Location	Slaughter Weight, Pounds 225 Mean	SD	300 Mean	SD
Center of *l. dorsi* fat				
Tenth rib, layer 1	1.05	.18	1.32	.23
Tenth rib, layer 2	1.08	.17	1.55	.21
Tenth rib, layer 3	.69	.22	1.10	.44
Last rib, layer 1	.99	.14	1.22	.17
Last rib, layer 2	.81	.13	1.04	.17
Last rib, layer 3	.76	.19	1.04	.36
Midline fat				
First rib, layer 1	1.54	.23	1.87	.16
First rib, layer 2	2.62	.17	3.23	.30
Last rib, layer 1	1.19	.20	1.54	.22
Last rib, layer 2	1.32	.29	1.64	.28
Last lumbar, layer 1	1.59	.28	2.04	.26
Last lumbar, layer 2	2.52	.13	1.19	.18

TABLE XII

CORRELATIONS OF PERIODIC SKELETAL MEASUREMENTS[a]

Traits	3-week Periods	(15)	(14)	(13)	(12)	(11)	(10)	(9)	(8)	(7)	(6)	(5)	(4)	(3)	(2)	(1)
(1) Poll to	1	0.17	0.35	0.04	0.59	0.74	0.13	0.33	0.22	0.46	0.62	0.37	0.69	0.76	0.85	1.00
(2) root of	2	0.16	0.42	0.03	0.59	0.70	0.33	0.44	0.23	0.58	0.62	0.62	0.73	0.84	1.00	
(3) tail	3	0.25	0.50	0.06	0.46	0.59	0.32	0.40	0.34	0.60	0.51	0.64	0.80	1.00		
(4)	4	0.38	0.65	0.04	0.48	0.62	0.39	0.35	0.20	0.40	0.42	0.76	1.00			
(5)	5	0.47	0.63	-.04	0.38	0.48	0.51	0.34	0.02	0.34	0.26	1.00				
(6) Circ. of	1	0.22	0.30	-.13	0.43	0.64	0.42	0.69	0.57	0.70	1.00					
(7) right rear	2	0.18	0.34	-.09	0.54	0.41	0.64	0.78	0.67	1.00						
(8) leg	3	0.12	0.26	0.05	0.03	0.29	0.41	0.58	1.00							
(9)	4	0.30	0.40	0.08	0.43	0.45	0.76	1.00								
(10)	5	0.24	0.50	0.32	0.36	0.32	1.00									
(11) Length of	1	0.38	0.67	0.08	0.65	1.00										
(12) right rear	2	0.39	0.54	0.02	1.00											
(13) leg	3	0.29	0.00	1.00												
(14)	4	0.62	1.00													
(15)	5	1.00														

[a] $r_{.05} = 0.33$, $r_{.01} = 0.42$.

TABLE XIII

CORRELATIONS OF PERIODIC ULTRASONIC FAT DEPTH ESTIMATES[a]

Traits	Period	(15)	(14)	(13)	(12)	(11)	(10)	(9)	(8)	(7)	(6)	(5)	(4)	(3)	(2)	(1)
Midline fat																
(1) Last rib,	1	0.45	0.44	0.59	0.72	0.72	0.35	0.44	0.63	0.62	0.70	0.22	0.47	0.73	0.70	1.00
(2) (layers	2	0.40	0.39	0.52	0.84	0.62	0.23	0.39	0.56	0.78	0.69	0.22	0.52	0.67	1.00	
(3) 1 + 2)	3	0.61	0.61	0.75	0.76	0.51	0.46	0.56	0.75	0.67	0.63	0.34	0.68	1.00		
(4)	4	0.68	0.71	0.50	0.57	0.34	0.57	0.62	0.62	0.62	0.42	0.45	1.00			
(5)	5	0.64	0.48	0.41	0.24	0.08	0.55	0.29	0.32	0.25	0.09	1.00				
Center of <u>l. dorsi</u> fat																
(6) Tenth rib,	1	0.42	0.48	0.66	0.76	0.71	0.39	0.55	-.05	0.71	1.00					
(7) (layers	2	0.54	0.57	0.65	0.75	0.60	0.54	0.63	0.76	1.00						
(8) 1 + 2)	3	0.71	0.77	0.83	0.63	0.60	0.78	0.82	1.00							
(9)	4	0.76	0.83	0.59	0.42	0.42	0.87	1.00								
(10)	5	0.86	0.86	0.59	0.30	0.29	1.00									
(11) Last rib,	1	0.32	0.36	0.57	0.76	1.00										
(12) (layers	2	0.49	0.46	0.64	1.00											
(13) 1 + 2)	3	0.68	0.64	1.00												
(14)	4	0.80	1.00													
(15)	5	1.00														

[a] $r_{.05} = 0.33$, $r_{.01} = 0.42$.

TABLE XII
Correlations of Periodic Skeletal Measurements

TABLE XIV

CORRELATIONS OF PERIODIC ULTRASONIC MUSCLE DEPTH ESTIMATES[a]

Traits	Period	(10)	(9)	(8)	(7)	(6)	(5)	(4)	(3)	(2)	(1)
(1) Loin depth, tenth rib	1	0.42	0.56	0.51	0.64	0.80	0.46	0.49	0.48	0.65	1.00
(2)	2	0.58	0.66	0.58	0.72	0.55	0.61	0.66	0.59	1.00	
(3)	3	0.50	0.62	0.65	0.48	0.40	0.50	0.65	1.00		
(4)	4	0.62	0.92	0.53	0.64	0.35	0.66	1.00			
(5)	5	0.88	0.63	0.48	0.60	0.40	1.00				
(6) Loin depth, last rib	1	0.34	0.46	0.42	0.53	1.00					
(7)	2	0.60	0.61	0.55	1.00						
(8)	3	0.46	0.46	1.00							
(9)	4	0.60	1.00								
(10)	5	1.00									

[a] $r_{.05} = 0.33$, $r_{.01} = 0.42$.

but generally quite small. The highest correlations are generally between measurements taken from adjacent periods. The magnitude of the correlations among periodic ultrasonic estimates are similar to those obtained by Urban and Hazel (1965).

The results support the conclusion of Rittler et al. (1964) that future gains in fat depth cannot be predicted from measurements taken at light weights and that there are individual differences among pigs in the development and gain in fat depth at various stages of growth. Likewise, results of this study indicate that differences exist among individuals in skeletal and muscle development.

Bone weight from half carcasses of pigs slaughtered at 300 pounds was significantly greater ($P < .01$) than from half carcasses of pigs slaughtered at 225 pounds (9.77 vs. 8.35 pounds). There was, however, no significant difference ($P > .10$) in bone weight attributable to grandsire or sex differences. The relative proportion of bone to muscle and fat decreased with an increase in weight which is in support of the conclusion of Hammond (1922).

Skin weight from half carcasses of pigs slaughtered at 300 pounds was significantly greater ($P < .01$) than that from half carcasses of pigs slaughtered at 225 pounds (4.38 vs. 3.06 pounds). There was no significant grandsire effect ($P > .10$) upon skin weight, but boars had significantly greater skin weight ($P < .01$) than either barrows or gilts at 225 and 300 pounds.

The coefficients of variation for carcass length, tenth-rib loin-eye area, and tenth-rib fat depth (layers 1 + 2 + 3) over the l. dorsi were 2 percent, 13 percent, and 21 percent. These findings are in support of the conclusion of McMeekan (1939) that later developing characters tend to be more variable than earlier developing characters. The coefficients of variation for each slaughter weight were similar.

Type differences. Correlations of selected live-animal measurements with carcass length are shown in Table XV. The correlations between bone circumference and carcass length were small but positive and show no definite trends between 225 and 300 pounds. Bone circumference measurements were similar to those reported by Culbertson et al. (1928).

Correlations between bone length and carcass length measurements were small and positive and of about the same magnitude at both 225 and 300 pounds.

The correlations between tenth-rib loin depth and carcass length at 225 and 300 pounds were -.25 and .53. The correlations between depth of fat layers 1 + 2 over the l. dorsi at the tenth-rib location and carcass length were -.03 and -.73 and for the last-rib location -.14 and -.57 at 225 and 300 pounds, respectively. These differences in correlations between carcass length and measures of fat and muscling at 225 and 300 pounds indicate that there is a definite relationship between skeleton or body length and the ending of the "lean period" and the beginning of the "fat period." At 225 pounds, few if any of the pigs had reached the end of the "lean period," and, therefore, the correlations between carcass length and measures of fat and muscling were very low and nonsignificant ($P > .05$). However, at 300 pounds, the shorter pigs had passed from the "lean period" into the "fat period," and the pigs with longer bodies and extra skeletal development had not passed into the "fat period."

TABLE XV

CORRELATIONS BETWEEN SELECTED LIVE-ANIMAL MEASUREMENTS AND CARCASS LENGTH OF PIGS SLAUGHTERED AT 225 AND 300 POUNDS[a]

	Length	
Live-Animal Measurement	225 pounds	300 pounds
Poll to root of tail	0.37	0.63
Bone circumference		
Right front leg	0.41	0.05
Right rear leg	0.13	0.23
Tail	0.33	0.01
Bone length		
Right front leg	0.20	0.27
Right rear leg	0.40	0.21
Tail	0.53	0.50
Loin depth		
Tenth rib	-.25	0.53
Fat over <u>l. dorsi</u>		
Tenth rib (layers 1 + 2)	-.03	-.73
Last rib (layers 1 + 2)	-.14	-.57
Midline fat		
Average total	-.11	-.48
Body circumference	-.10	-.29

[a] $r_{.05} = 0.47$, $r_{.01} = 0.59$.

Therefore, the correlations of measures of fatness and muscling with carcass length were significant ($P < .05$) and much higher at 300 than at 225 pounds. Longer-bodied pigs thus appear to have the ability to continue growing muscle to a heavier weight than do shorter-bodied pigs without depositing excessive fat. These findings support the conclusion of McMeekan (1937) that overfatness is associated with a deficiency in length and that the fault of shortness of loin becomes more apparent at heavier weights.

Pigs from Master Lad B dams were significantly ($P < .01$) longer from the poll to root of tail than pigs from King Formula dams at 300 pounds (122.7 cm. vs. 119.8 cm.), but the difference was not significant ($P > .05$) at 225 pounds. Carcass length was likewise significantly greater ($P < .01$) for pigs from dams by Master Lad B than from King Formula dams at 300 pounds (84.8 cm. vs. 82.6 cm.), but the difference was not significant ($P < .05$) at 225 pounds. Tail length also was significantly longer ($P < .01$) for pigs from Master Lad B dams than for pigs from King Formula dams.

<u>Carcass chemical composition</u>. The average percentages of moisture, ether extract, and protein for whole carcasses and muscle samples from the observation and experimental pigs are shown in Table XVI. The percent of moisture in the whole carcasses decreased with an increase in weight while percent of ether extract increased with increasing weight. The percent of moisture of the whole carcass was significantly greater ($P < .01$) at 225 than at 300 pounds while the percent of ether extract was significantly less ($P < .01$) for the carcasses from the 225-pound group

TABLE XVI

CHEMICAL COMPOSITION OF CARCASSES FROM OBSERVATION AND EXPERIMENTAL GROUPS

Component	Observation 1 75 pounds 3 pigs	Observation 2 150 pounds 3 pigs	Experimental 1 225 pounds 18 pigs	Experimental 2 300 pounds 18 pigs
Moisture (%) whole carcass	62.14	55.38	50.83	47.77
Ether extract (%) whole carcass	18.69	28.90	34.27	38.12
Protein (%) whole carcass	14.83	14.85	14.11	13.15
Moisture (%) muscle sample	76.17	73.17	72.68	72.28
Ether extract (%) muscle sample	1.91	4.13	4.20	4.91
Protein (%) muscle sample	20.56	21.36	21.65	21.63

than for those from the 300-pound group. The percent of protein in the whole carcasses was similar for the two observation groups, but there was a decrease in protein content at each of the off-test experimental weights of 225 and 300 pounds.

The average protein percentage of whole carcasses from the 225-pound group was significantly greater ($P < .01$) than that for the 300-pound group.

The average water content of the fat-free whole carcasses from the 75, 125, 225, and 300-pound groups was 76.42, 77.89, 77.33, and 77.04, respectively. These results are contrary to the statement of Hornicke (1961) that water content of fat-free body substance progressively decreases with growth. In the present study, the skin and bone were not included in the chemical analyses; however, the removal of these components should not change the relative water content of the body substance.

The percent of moisture in the muscle sample from the 75-pound pigs was greater than that from the 150, 225, or 300 pound groups. There was a rapid increase in the ether extract percent of the muscle sample from 75 to 150 pounds, but there was only a slight difference between the 150 and 225 pound groups. There was, however, a significantly higher ($P < .05$) percent of ether extract in the muscle samples from the 300-pound group compared to the 225-pound group.

These results are in agreement with the conclusion of Callow (1947) that as growth and fattening occur, the extra chemical fat which is laid down is partitioned unequally among the tissues. An increasing proportion of the fat goes into the fatty tissues, and a decreasing proportion goes into the muscular tissues. This was particularly true in the present study beyond a weight of 150 pounds.

The average protein content of the muscle samples from the 75-pound group was somewhat lower than that of the samples from the 150, 225, and 300 pound groups. There was no significant difference ($P > .10$) in protein content of the muscle samples from the 225- and 300-pound groups. These findings are in conflict with the findings of Loeffel et al. (1943) that as the fat content of the l. dorsi increased, the protein content decreased.

Ether extract values of the whole carcasses from the 150- and 225-pound groups were similar to those reported by Allen et al. (1961). The percent moisture was somewhat lower (50.83 vs. 52.00), ether extract somewhat higher (34.27 vs. 30.37), and protein somewhat lower (14.11 vs. 15.21) for whole carcasses from the 225-pound group in the present study than the values obtained from a group of 24 market hogs analyzed by Hix et al. (1967). Henry et al. (1963) found the proximate percent protein, fat, and moisture of the untrimmed (boneless) wholesale cuts from 79 carcasses of pigs weighing 200 pounds to be 13.2, 43.1, and 41.0. Comparable values from the 225-pound group in the present study are 14.11, 34.27, and 50.83.

Fat percent in the l. dorsi from the 225-pound group was 4.20 as compared to 2.19 and 1.88, respectively, for barrows and gilts studied by Kielanowski et al. (1954). Callow (1947) reported much lower values ranging from 0.15 to 0.53 percent.

The values of A (the expression of true growth) calculated from the formula proposed by Houston and Reed (1966) for the 75-, 150-, 225-, and 300-pound groups were 3.24, 3.52, 3.41, and 3.39, respectively. The formula was thus of no value as a measure of growth in the present study.

The means for the chemical composition of whole carcasses and muscle samples for the experimental subgroups are given in Table XVII. The moisture content of carcasses of pigs from dams sired by King Formula was significantly less ($P < .05$) than carcasses from offspring of Master Lad B dams (50.4 vs. 51.2 at 225 pounds and 46.4 vs. 49.2 at 300 pounds). Boar carcasses had a significantly higher ($P < .01$) moisture content than gilt or barrow carcasses at each slaughter weight. Gilt carcasses were likewise greater ($P < .01$) in moisture content than barrow carcasses at each slaughter weight.

Carcasses of pigs from dams sired by Master Lad B had a significantly lower ($P < .05$) percentage of ether extract at each slaughter weight than carcasses of pigs from King Formula dams. Boar carcasses were significantly lower ($P < .01$) in ether extract percent than barrow and gilt carcasses at 225 and 300 pounds, and gilt carcasses had a lower fat content ($P < .01$) than barrow carcasses at each slaughter weight.

Grandsire differences were greater for boars and gilts at 300 pounds than at 225 pounds. Carcasses of barrows from dams by both King Formula and Master Lad B were fatter at 300 than at 225 pounds. Carcasses of boars and gilts from King Formula dams had a much higher percentage of fat at 300 than at 225 pounds; whereas, carcasses of boars and gilts from dams sired by Master Lad B had about the same fat content at 225 and 300 pounds.

The protein content of carcasses from boars and gilts was not significantly different ($P > .10$) at 225 or 300 pounds; however, both boar and gilt carcasses had a significantly higher ($P < .01$) percent of protein than barrows at both 225 and 300 pounds. Carcasses of offspring

TABLE XVII

MEANS OF CHEMICAL COMPOSITION OF CARCASSES
FROM EXPERIMENTAL SUBGROUPS

Component	B1a	G1a	b1a	B1b	G1b	b1b	B2a	G2a	b2a	B2b	G2b	b2b
Moisture (%) whole carcass	52.37	50.89	48.05	52.61	50.83	50.23	49.62	47.06	42.40	52.80	50.64	44.12
Ether extract (%) whole carcass	32.54	34.07	37.91	31.81	34.06	35.22	36.06	38.81	44.92	31.66	34.12	43.15
Protein (%) whole carcass	14.05	14.23	13.05	14.77	14.54	14.05	13.37	12.54	11.75	14.59	14.58	12.10
Moisture (%) muscle sample	72.28	73.49	72.46	73.34	71.68	72.81	73.05	71.86	71.62	72.96	72.01	72.17
Ether extract (%) muscle sample	4.62	3.65	4.30	3.91	4.76	3.97	4.49	5.16	5.78	4.45	4.43	5.18
Protein (%) muscle sample	21.53	21.79	20.84	22.15	22.27	21.31	21.32	21.20	21.50	21.47	22.28	22.02

from dams sired by Master Lad B had a significantly higher ($P < .01$) protein content than carcasses of pigs from King Formula dams.

The end of the "lean period" and the beginning of the "fat period" was reached much sooner by pigs from dams sired by King Formula than by pigs from dams sired by Master Lad B. Boars, barrows, and gilts from dams by King Formula and barrows from dams by Master Lad B must have reached the end of the "lean period" around 240 to 260 pounds; whereas, boars and gilts from dams sired by Master Lad B had not gone beyond the "lean period" at 300 pounds. Zebrowski (1962) reported vast differences between Large White and Pulawska pigs in the ending of the "lean period" and the beginning of the "fat period."

There was no significant grandsire or sex effect upon the percent of moisture in the muscle sample ($P > .10$). Neither was there any significant ($P < .10$) grandsire or sex effect upon the fat content of the muscle sample. There was, however, a significantly higher ($P < .05$) percent of protein in the muscle samples from pigs out of Master Lad B dams than for muscle samples of pigs from King Formula dams. Sex had no significant effect ($P < .10$) upon protein content of the muscle sample.

The grandsire differences observed in these data can be construed only as an indication of the existence of genetic influences on the variables studied. With only two males represented, it is not feasible to estimate the magnitude or relative importance of genetic differences.

II. PERFORMANCE CHARACTERISTICS

Average daily gain. The periodic average daily gains by 21-day periods and the accumulative average daily gains at the end of each period are given for the experimental subgroups in Table XVIII. There was no significant grandsire effect ($P > .05$) upon average daily gain during any period or accumulation of periods. There was, however, a significant sex effect during period 2 ($P < .01$), periods 1 + 2 + 3 ($P < .01$), period 4 ($P < .01$), and periods 1 + 2 + 3 + 4 ($P < .01$). Boars had a significantly higher accumulative average daily gain at the end of period 4 than gilts which is in agreement with the work of Craig et al. (1956), Burgess (1965), and Moore (1966), but in disagreement with the findings of Wagner et al. (1963). Accumulative average daily gain for boars was significantly greater ($P < .01$) than for barrows which is in agreement with the results of Burgess (1965) but is contradictory to the findings of Bratzler et al. (1954) and Moore (1966). The advantage in average daily gain of boars over barrows and gilts became greater at weights beyond 225 pounds.

The accumulative average daily gain of barrows through period 4 was significantly greater ($P < .01$) than that of gilts. This observation is in accord with the findings of Lacy (1932), Bruner et al. (1958), Mulholland et al. (1960), Omtvedt et al. (1962), Cox (1963), Magee (1964), and Moore (1966), but contradicts the results reported by Charette (1961) and Burgess (1965).

Differences in average daily gain between barrows and gilts beyond period 4 were different for pigs from dams by King Formula and Master Lad B. Gilts from King Formula dams had a higher average daily gain than barrows, while gilts and barrows from Master Lad B dams were quite similar in average daily gain. The barrows from King Formula dams became sore-footed at about 250 pounds which may have been partially responsible for a reduction in their average daily gain.

TABLE XVIII

AVERAGE DAILY GAIN FOR EXPERIMENTAL SUBGROUPS

Period	Days	B2a	b2a	G2a	B2b	b2b	G2b	B1a	b1a	G1a	B1b	b1b	G1b
1	21	1.63	1.81	1.48	1.40	1.38	1.40	1.63	1.43	1.68	1.44	1.65	1.65
2	21	2.25	2.14	1.92	1.97	2.13	2.03	2.10	1.89	1.95	2.13	2.30	1.57
3	21	1.90	1.83	2.06	1.84	2.00	1.60	2.16	1.87	1.89	2.25	1.94	1.81
4	21[a]	2.08	1.89	1.43	1.92	1.68	1.48	2.22	1.54	1.59	1.92	1.81	1.40
5	[b]	2.15	1.27	1.50	2.12	1.41	1.39						
1+2	42	1.94	1.98	1.70	1.68	1.75	1.71	1.87	1.66	1.82	1.79	1.98	1.61
1+2+3	63	1.93	1.93	1.82	1.74	1.84	1.68	1.99	1.73	1.84	1.94	1.96	1.68
1+2+3+4	84	1.97	1.92	1.72	1.78	1.80	1.63	2.03	1.68	1.78	1.94	1.92	1.61
c		2.05	1.52	1.68	1.99	1.74	1.51						

[a]Twenty-one days or to slaughter weight of 225 pounds.

[b]From 84 days to slaughter weight of 300 pounds.

[c]Accumulative to slaughter weight of 300 pounds.

Feed efficiency. The periodic pen or experimental subgroup feed efficiencies for 21-day periods and the accumulative feed efficiencies at the end of each period are given in Table XIX. Boars utilized feed more efficiently than either barrows or gilts, and gilts were more efficient than barrows up to 225 pounds.

These findings are in general agreement with those of Bruner et al. (1958), Wagner et al. (1963), and Burgess (1965). Charette (1961) and Moore (1966) found also that boars were more efficient than barrows or gilts, but no significant differences were found between barrows and gilts. These results are in strong disagreement with the findings of Bratzler et al. (1954) that delayed castration or non-castration had no effect on feed efficiency.

The sexes ranked in similar order for accumulative feed efficiency at 300 pounds; however, the differences among the sexes at 300 pounds were much greater than at 225 pounds. Accumulative feed efficiency was only slightly greater for boars at 300 than at 225 pounds (299 and 286 vs. 289 and 277); whereas, the accumulative feed efficiency for barrows and gilts was much greater at 300 than at 225 pounds (370, 358, 346, and 332 vs. 333, 311, 309, and 285, respectively). The fact that both barrows and gilts gained more slowly from 225 to 300 pounds contributed to the increase in pounds of feed required per pound of gain.

Barrows were depositing fat more rapidly from 225 to 300 pounds than were boars and thus it may be reasoned that feed is converted less efficiently to fat than to lean tissue. This explanation, however, does not account for the increase in feed efficiency for the gilts. The fact that barrows and gilts gained more slowly than boars from 225 to 300

TABLE XIX

FEED EFFICIENCY FOR EXPERIMENTAL SUBGROUPS

Period	Days	B2a	b2a	G2a	B2b	b2b	G2b	B1a	b1a	G1a	B1b	b1b	G1b
1	21	243	266	283	264	231	250	243	246	269	233	276	233
2	21	295	287	248	239	262	303	268	300	252	278	280	293
3	21	279	360	324	296	377	263	325	370	300	284	317	327
4	21[a]	325	397	395	306	377	335	278	358	374	303	407	364
5	[b]	336	444	357	311	466	401						
1+2	42	272	279	264	249	249	276	257	275	259	259	278	269
1+2+3	63	275	313	284	267	291	271	279	305	275	268	292	287
1+2+3+4	84	289	333	309	277	311	285	279	314	300	276	322	307
c		299	370	346	286	358	332						

[a]Twenty-one days or to slaughter weight of 225 pounds.

[b]From 84 days to slaughter weight of 300 pounds.

[c]Accumulative to slaughter weight of 300 pounds.

pounds implies that the barrows and gilts utilized a smaller proportion of the feed consumed for growth of body tissues than did boars.

Results of this experiment support the conclusion of Buck (1963) that feed efficiency up to 150 pounds is not necessarily indicative of the feed efficiency from 150 pounds to heavier weights.

III. LIVE-ANIMAL AND CARCASS EVALUATION MEASUREMENTS

Ultrasonic estimates. Correlations between live-animal ultrasonic estimates and carcass measurements taken at congruent sites on pigs slaughtered at 225 and 300 pounds are given in Table XX. Correlations between midline ultrasonic estimates and carcass measurements of fat layer depth are of greater magnitude for the 300-pound group than for the 225-pound group. At the first-rib, last-rib, and last-lumbar locations, there was higher correlation between ultrasonic and carcass measurements of accumulative depth of fat layers 1 + 2 than for the first layer alone.

Correlations are higher between ultrasonic and carcass measurements taken at the last-rib and last-lumbar locations than at the first-rib location. There are two distinct fay layers at the tenth- and last-rib locations and there may be additional layers at the first rib. Location of measurement site is also more critical at the first-rib and last-lumbar locations than at the last-rib location on both the live pig and the carcass. Fat depth at the first-rib area is quite variable, and, thus, differences in carcass and ultrasonic measurements may occur because of difficulty in precisely locating the measurement site. The second fat layer is quite variable at the last-lumbar location due to the presence

TABLE XX

CORRELATIONS BETWEEN LIVE ULTRASONIC ESTIMATES AND CARCASS MEASUREMENTS TAKEN AT CONGRUENT SITES ON PIGS SLAUGHTERED AT 225 AND 300 POUNDS[a]

Live Location	225 pounds	300 pounds
Midline fat		
First rib, layer 1	0.27	0.24
First rib, layer 1 + 2	0.37	0.60
Last rib, layer 1	0.58	0.81
Last rib, layer 1 + 2	0.57	0.88
Last lumbar, layer 1	0.21	0.72
Last lumbar, layer 1 + 2	0.64	0.81
Center of _l. dorsi_ fat		
Tenth rib, layer 1	0.35	0.10
Tenth rib, layer 1 + 2	0.75	0.77
Tenth rib, layer 1 + 2 + 3	0.42	0.88
Last rib, layer 1	0.82	0.57
Last rib, layer 1 + 2	0.89	0.89
Last rib, layer 1 + 2 + 3	0.45	0.88
Loin depth		
Tenth rib	0.69	0.60
Last rib	0.53	0.66
Loin-eye area		
Tenth rib	0.66	0.48
Last rib	0.68	0.74

[a] $r_{.05} = 0.47$, $r_{.01} = 0.59$.

of the "lumbar lean"; therefore, location of the measurement site is critical in this area also. Fat depth at the last rib varies only slightly with moderate changes in selection of the measurement site. Therefore, the correlation between ultrasonically measured fat depth and carcass fat depth should be relatively high at this location even if live-animal and carcass measurements are taken at slightly different sites.

Correlations between ultrasonic and carcass measurements of fat depth over the center of the l. dorsi are generally higher for the 300-pound group than for the 225-pound group at both the tenth- and last-rib locations. Measurements are easily obtained at the bottom of the second fat layer because the fascia that separates the first fat layer from the second, and the second from the third fat layer, are easily detected with the sonoray. This fact may be responsible for the high correlations between ultrasonic and carcass measurements of fat depth at the bottom of the second layer for both weight groups at the tenth- and last-rib locations. The inclusion of the third fat layer for the 225-pound group resulted in a lower correlation between ultrasonic and carcass fat depth measurements at both the tenth- and last-rib locations. This may be explained by the fact that the third fat layer is variable in depth lateral to the spinous processes, thus, making location of the measurement site on the live pig and on the carcass quite critical.

The third fat layer also is multilayered and, thus, the fascia separating this layer and the dorsal edge of the l. dorsi is difficult to detect with the sonoray. However, for the 300-pound group, the correlations between ultrasonic and carcass measurements with the third fat layer included are as high or higher than those involving measurements of the first two fat layers. At this weight, depth of the third fat layer had become almost uniform and was much greater in depth than at 225 pounds. The third fat layer also appeared more consistently to be a single layer at 300 pounds and the fascia between the third fat layer and the dorsal edge of the l. dorsi was less difficult to detect with the sonoray than at 225 pounds. Similar difficulties in measurement of depth of the third fat layer at conventional market weights were reported by Meyer et al. (1966) and Jones et al. (1970).

Depth of the l. dorsi was measured at a single location with the sonoray in a manner similar to that proposed by Ramsey (unpublished data) except that the measurement was taken over the center of the l. dorsi rather than 2.5 inches lateral to the spinous processes. The correlation between ultrasonically measured loin depth and carcass loin-eye area is similar to that reported by Price et al. (1960) and in the range of values found by Ramsey (unpublished data). Locating the center of the l. dorsi was more difficult as the pigs neared slaughter weights of 300 pounds.

The ultrasonic estimates of loin depth and carcass measures of loin depth and loin-eye area at the tenth- and last-rib locations for the experimental subgroups are presented in Table XXI. It is doubtful if such ultrasonic estimates would be of value in a selection program.

Correlations with carcass cutability. Correlations of selected live-animal and carcass measurements with percent lean cuts, percent ether extract, and percent protein in pigs slaughtered at 225 and 300 pounds are shown in Table XXII. Carcass length is more highly correlated with percent lean cuts, percent ether extract, and percent protein of the

TABLE XXI

ULTRASONIC ESTIMATES OF LOIN DEPTH AND CARCASS MEASUREMENTS OF LOIN DEPTH AND LOIN-EYE AREA

Measurement	B1a	B1b	G1a	G1b	b1a	b1b	B2a	B2b	G2a	G2b	b2a	b2b
Ultrasonic loin depth (cm.)												
Tenth rib	5.33	5.50	5.33	6.13	6.00	6.10	5.43	6.28	5.73	5.77	5.13	5.53
Last rib	5.27	5.50	5.27	6.30	5.90	5.87	5.70	6.43	6.13	6.30	5.00	5.87
Carcass loin depth (cm.)												
Tenth rib	4.70	4.90	5.07	6.10	5.17	5.30	5.22	5.88	5.48	5.93	4.98	5.80
Last rib	4.60	4.77	5.25	5.35	4.97	5.47	5.22	5.90	5.57	5.87	5.20	5.70
Carcass loin-eye area (sq. in.)												
Tenth rib	4.82	4.98	5.35	6.34	5.13	5.55	5.89	6.75	6.45	7.30	5.67	6.44
Last rib	4.17	4.56	4.93	5.48	4.81	5.12	5.00	6.04	5.63	6.31	5.15	5.54

TABLE XXII

CORRELATIONS OF SELECTED LIVE-ANIMAL AND CARCASS MEASUREMENTS WITH PERCENT LEAN CUTS, PERCENT ETHER EXTRACT, AND PERCENT PROTEIN OF CARCASSES FROM 18 PIGS SLAUGHTERED AT 225 AND 300 POUNDS[a]

Measurement	Percent Lean Cuts		Percent Ether Extract		Percent Protein	
	225	300	225	300	225	300
Skeletal size						
Poll to root of tail	-.09	0.15	-.41	0.25	0.47	-.07
Circ. right rear leg	-.09	0.33	-.12	-.26	-.10	0.21
Length right rear leg	0.14	-.02	-.54	0.28	0.42	-.17
Carcass length	-.43	0.52	-.15	-.31	0.09	0.53
Ultrasonic fat - midline						
First rib, layer 1	-.33	-.50	0.37	0.28	-.22	-.29
First rib, layer 1 + 2	-.12	-.51	0.75	0.52	-.63	-.58
Last rib, layer 1	-.36	-.80	0.61	0.61	-.58	-.64
Last rib, layer 1 + 2	-.03	-.80	0.71	0.74	-.62	-.80
Last lumbar, layer 1	-.35	-.74	0.46	0.61	-.43	-.58
Last lumbar, layer 1 + 2	-.12	-.79	0.72	0.81	-.52	-.78
Average midline total (layer 1 + 2)	-.08	-.78	0.77	0.76	-.64	-.80
Carcass backfat - midline						
First rib, layer 1	-.61	0.10	0.09	-.01	-.03	-.02
First rib, layer 1 + 2	0.08	-.66	0.44	0.61	0.38	-.58
Last rib, layer 1	-.09	-.69	0.61	0.45	-.46	-.49
Last rib, layer 1 + 2	-.01	-.81	0.50	0.64	-.34	-.66
Last lumbar, layer 1	-.22	-.51	0.59	0.62	-.45	-.54
Last lumbar, layer 1 + 2	-.20	-.51	0.54	0.73	-.40	-.62
Average midline total (layer 1 + 2)	-.07	-.74	0.68	0.74	-.53	-.69

TABLE XXII (continued)

Measurement	Percent Lean Cuts		Percent Ether Extract		Percent Protein	
	225	300	225	300	225	300
Ultrasonic fat - center LD						
Tenth rib, layer 1	-.49	-.49	0.60	0.27	-.65	-.42
Tenth rib, layer 1 + 2	-.32	-.57	0.68	0.59	-.64	-.64
Tenth rib, layer 1 + 2 + 3	-.08	-.72	0.33	0.77	-.22	-.82
Last rib, layer 1	-.52	-.37	0.41	0.26	-.48	-.28
Last rib, layer 1 + 2	-.43	-.85	0.73	0.77	-.66	-.85
Last rib, layer 1 + 2 + 3	-.05	-.81	0.34	0.80	-.15	-.86
Carcass fat - center LD						
Tenth rib, layer 1	-.37	-.15	0.25	0.22	-.25	-.16
Tenth rib, layer 1 + 2	-.14	-.73	0.56	0.78	-.60	-.86
Tenth rib, layer 1 + 2 + 3	-.27	-.60	0.71	0.81	-.76	-.83
Last rib, layer 1	-.62	-.38	0.25	0.43	-.37	-.44
Last rib, layer 1 + 2	-.38	-.83	0.76	0.79	-.79	-.82
Last rib, layer 1 + 2 + 3	-.32	-.76	0.72	0.72	-.76	-.77
Ultrasonic loin depth						
Tenth rib	0.39	0.63	0.29	-.68	-.14	0.64
Last rib	0.29	0.40	0.20	-.73	-.04	0.68
Carcass loin depth						
Tenth rib	0.46	0.37	-.13	-.33	0.29	0.45
Last rib	0.50	0.35	0.09	-.39	0.07	0.36
Carcass loin-eye area						
Tenth rib	0.42	0.30	-.17	-.39	0.38	0.53
Last rib	0.58	0.52	-.04	-.56	0.27	0.55

TABLE XXII (continued)

Measurement	Percent Lean Cuts		Percent Ether Extract		Percent Protein	
	225	300	225	300	225	300
Carcass fat trim (%)	-.28	-.81	0.87	0.81	-.79	-.81
Carcass bone weight	0.21	0.37	-.35	-.54	0.50	0.27
Carcass specific gravity	0.00	0.75	-.59	-.87	0.62	0.88

[a] $r_{.05} = 0.47$, $r_{.01} = 0.59$.

carcasses from the 300-pound group than from the 225-pound group. The trend of these correlations is similar to that exhibited by the correlations of carcass length with backfat thickness and with loin-eye area. Correlations between other skeletal measures and carcass cutability are rather small and inconsistent.

Ultrasonic estimates of fat over the midline of the back are somewhat more highly correlated with percent lean cuts, percent ether extract, and percent protein of the carcasses than are actual carcass midline measurements of fatness. At 225 pounds, both ultrasonic fat estimates and carcass fat measurements are more highly correlated with carcass chemical composition than with percent lean cuts; however, the correlations of ultrasonic fat estimates and carcass fat measurements with percent lean cuts, percent ether extract, and percent protein are similar at 300 pounds. The correlations of the combined depth of the first two fat layers with the three body composition factors are greater than the correlations involving only the first fat layer. Ultrasonic measurements taken at the last-rib location gave the highest simple correlations with the three body composition traits of all the midline ultrasonic and carcass measurements of fatness. The correlations of live-animal and carcass fat measures over the midline with percent lean cuts, percent ether extract, and percent protein are greater at 300 than at 225 pounds.

Ultrasonic estimates and carcass measures of fat depth over the center of the l. dorsi at the tenth- and last-rib location were more highly correlated with percent lean cuts, percent ether extract, and percent protein than were measurements taken over the midline of the back.

These results are in accord with the findings of Hazel and Kline (1959), Rittler et al.(1964), Lauprecht (1965), Meyer et al. (1966), and Jones et al. (1970). Correlations involving ultrasonic estimates and those involving carcass measurements over the center of the l. dorsi were of similar magnitude.

Ultrasonically measured loin depth at both the tenth- and last-rib locations was somewhat more highly correlated with percent lean cuts, percent ether extract, and percent protein for the 300-pound group than were actual carcass measures of loin depth and loin-eye area. For the 225-pound group, all the correlations of loin depth and area with percent ether extract and percent protein were small; however, carcass measures of loin depth and loin-eye area were more highly correlated with percent lean cuts than was ultrasonic loin depth at this lighter weight.

The percent of fat trim in the carcass was very highly correlated with each of the three body composition factors for the 300-pound group and with percent ether extract and percent protein for the 225-pound group. The correlation of percent fat trim with percent lean cuts at 225 pounds was non-significant ($P > .05$).

Carcass bone weight was positively correlated with percent lean cuts and percent protein but negatively correlated with percent ether extract for both the 225- and 300-pound slaughter groups. These results agree with the findings of Buck (1963) that a good percentage of lean is associated with increased bone.

Specific gravity. The average specific gravity value for the 225-pound group (1.049) was significantly greater ($P < .01$) than for the 300-pound group (1.044). These values are greater than the 1.027 reported by Brown et al. (1951) for the average specific gravity of 66 carcasses. The difference may be explained by the fact that the pigs in the present study were much leaner and more heavily muscled than those studied by Brown et al. (1951).

For carcasses from the 300-pound group, the correlations of specific gravity and percent chemical fat and protein were of greater magnitude than correlations of carcass fatness with chemically determined fat and protein content. These findings are in general agreement with those of Brown et al. (1951), Whiteman et al. (1953), Pearson et al. (1956), Price et al. (1957), and Doornenbal et al. (1962). The correlations of specific gravity with chemically determined fat and protein for carcasses from the 225-pound pigs were smaller than those reported by Doornenbal et al. (1962), (-.59 and .62 vs. -.91 and .95).

There were no significant ($P > .05$) differences in specific gravity among carcasses from boars, barrows, and gilts from the 225-pound group which is in accord with the findings of Alexandrawicz et al. (1964) and Joblin (1966), but contradicts the results of Kropf (1959). Carcasses from both boars and gilts, however, had significantly ($P < .01$) higher specific gravity than barrow carcasses from the 300-pound slaughter group.

Body length. The correlations between the live-animal measurement of body length from poll to root of tail and carcass length at 225 and 300 pounds were 0.37 and 0.63, respectively. These correlations are somewhat lower than similar correlations of 0.78 and 0.87 reported by Fogleman (1966) and Spears (1967). A possible explanation for this discrepancy is that there was considerably more variation in body length among the pigs studied by Fogleman (1966) and Spears (1967) than in the present study.

IV. PORK QUALITY CHARACTERISTICS

Quality measures on the carcass. Means of pork carcass quality traits for the experimental subgroups are presented in Table XXIII. Both ham and loin scores for pigs slaughtered at 300 pounds were significantly greater ($P < .05$) than for pigs slaughtered at 225 pounds. There was no significant difference ($P > .10$), however, in marbling score between slaughter groups.

There was no significant grandsire or sex effect ($P > .05$) upon ham score, loin score, or marbling. These findings differ from those of Murray (1934), Judge et al. (1959), Wagner et al. (1963), Burgess (1965), and Moore (1966) who each reported differences in marbling scores among or between sexes.

The average penetrometer reading on the l. dorsi was significantly greater ($P < .01$) for the 225-pound group than for the 300-pound group. There was no significant ($P > .10$) grandsire effect upon the penetrometer reading of the l. dorsi at either slaughter weight and no significant ($P > .05$) sex effect at 225 pounds. Boars, however, had a significantly higher ($P < .01$) l. dorsi penetrometer average than either barrows or gilts at 300 pounds, but barrows were not significantly different ($P > .05$) from gilts.

The average penetrometer backfat reading was significantly greater

TABLE XXIII

PORK CARCASS QUALITY TRAITS

	B2a	b2a	G2a	B2b	b2b	G2b	B1a	b1a	G1a	B1b	b1b	G1b
Ham score	3.0	3.7	3.3	3.0	3.0	3.0	3.0	3.0	2.7	2.7	3.0	2.7
Loin score	3.3	3.0	3.3	2.7	3.3	2.7	3.0	4.3	3.7	3.3	3.7	3.3
Marbling	7.3	6.0	7.3	6.7	6.0	3.3	6.0	7.3	6.7	5.0	5.7	5.0
Penetrometer <u>l. dorsi</u> (av.)	293.3	254.7	242.3	253.7	265.3	226.7	278.3	62.0	108.7	253.3	124.7	91.0
Penetrometer backfat (av.)	191.7	193.0	64.7	209.3	55.3	65.0	53.0	7.3	21.7	62.0	20.0	18.7

($P < .05$) at 225 than at 300 pounds; however, there was no significant ($P > .10$) grandsire or sex effect upon penetrometer backfat readings.

Quality measures on cooked four-rib roasts. Means for Warner-Bratzler shear scores, cooking loss values, and taste panel results from cooked four-rib loin samples are given for each experimental subgroup in Table XXIV.

There was no significant difference ($P > .05$) in Warner-Bratzler shear score due to differences in slaughter weight, grandsire, or sex. Moore (1966) likewise found that sex had no effect upon Warner-Bratzler shear score, but Burgess observed that roasts from barrow carcasses were more tender than those from either boar or gilt carcasses which were not significantly different from one another. Emerson et al. (1964) also observed that roasts from barrow carcasses required less shear force than those from gilt carcasses.

There was no significant difference ($P > .05$) in evaporation loss during cooking attributable to differences in slaughter weight, grandsire, or sex. Realizing that the evaporation loss during cooking is primarily the loss of moisture, no difference should be expected due to slaughter weight, grandsire, or sex effect since there was no significant difference in moisture content of the muscle samples due to these effects. Roasts from the 300-pound slaughter weight group did have a significantly greater ($P < .01$) dripping loss during cooking than roasts from the lighter weight group. This difference seems logical since the dripping loss during cooking is composed primarily of fat, and muscle samples from the heavier weight pigs had significantly higher ($P < .05$) fat content than muscle samples from the lighter pigs. Loeffel et al. (1943) likewise

TABLE XXIV

MEASURES OF PORK QUALITY ON COOKED FOUR-RIB ROASTS

	B2a	b2a	G2a	B2b	b2b	G2b	B1a	b1a	G1a	B1b	b1b	G1b
Warner-Bratzler shear (lb.)	14.6	17.5	14.4	16.1	14.6	11.3	14.8	15.4	16.3	12.5	15.7	17.5
Evaporation loss (%)	19.3	18.9	17.8	17.4	19.2	19.2	17.7	16.8	16.6	19.0	17.7	20.3
Dripping loss (%)	3.7	3.5	3.8	4.5	4.5	3.9	4.4	7.9	5.3	4.6	6.0	4.7
Total cooking loss (%)	23.0	22.4	21.6	21.9	23.7	23.1	21.1	23.8	21.9	23.6	23.7	25.0
Flavor	6.6	6.7	7.3	6.9	7.8	7.2	5.4	7.1	7.4	6.2	6.8	7.6
Juiciness	7.6	7.9	7.3	7.5	6.9	6.5	7.8	7.6	7.2	7.6	7.1	6.7
Tenderness	8.0	7.9	7.3	7.6	8.0	9.3	8.1	8.2	6.6	8.3	7.5	7.5

found that dripping loss of roasts increased with fatness of the roasts. There was no significant difference ($P > .10$) in dripping loss due to grandsire or sex differences, and neither was there a difference in fat content of the muscle sample due to either of these differences. No significant difference ($P > .10$) in total cooking loss (evaporation loss + dripping loss) was found to be attributable to differences in slaughter weight, grandsire, or sex.

There was no significant slaughter weight or grandsire effect on taste panel flavor scores ($P > .10$), but there was a significant sex difference ($P < .01$). Roasts from both barrow and gilt carcasses received higher taste panel scores than did those from boar carcasses ($P < .01$), which is in agreement with the findings of Burgess (1965). However, Moore (1966) found that flavor scores of roasts from boars and gilts were not significantly different from one another ($P > .05$).

No significant difference in taste panel scores for juiciness ($P > .05$) were attributable to differences in slaughter weight or sex. There was, however, a significant ($P < .05$) grandsire effect.

There was no significant difference in taste panel scores for tenderness ($P > .05$) due to differences in slaughter weight, grandsire, or sex, which is in agreement with the Warner-Bratzler shear values. Burgess (1965), however, found that taste panel scores for tenderness were significantly higher ($P < .01$) for barrow roasts than for gilt roasts, but boar roasts were not significantly different ($P > .05$) from either barrow or gilt roasts. Moore (1966) found both barrow and boar roasts to be more tender than gilt roasts.

V. EXPLANATION FOR DIFFERENCES OF RESULTS

The results reported in the present study concerning the rate of deposition of fat and the rate of growth of muscular tissue are somewhat different from those reported by some researchers who have studied the rate of increase in backfat depth and the increase in loin-eye area with changes in weight. Likewise, the chemical composition values in this study differ from some values reported in the literature. Such differences among research studies may be attributable to type (muscle-fat composition) differences among pigs utilized by various researchers. Swine type has fluctuated greatly through the years and, thus, differences found among results in body composition studies may be largely accounted for by differences in the type of pigs utilized in the various studies.

Other differences among results of body composition studies may be accounted for by environmental and nutritional effects. During the transition from the lard-type pig of earlier years to the modern meat-type pig, researchers have observed that nutritional requirements, particularly for protein, have also changed. For optimum muscle development, the meat-type pig must have a higher level of protein than is required for the fat-type pig. Therefore, an inadequate protein level in some studies may have contributed to their results concerning body composition being different from those of the present study and others. A 16-percent protein ration was fed throughout the growth period in this study in order to attain maximum muscle growth, but few, if any, studies reviewed were conducted with pigs fed a 16-percent protein ration throughout the growing period. As a matter of fact, protein percentages of the ration fed are not revealed in most research reports.

Differences in results concerning growth of body regions and limb development may be due to type differences or due to the fact that conclusions of many early researchers were not based altogether upon empirical research findings. The author is well aware that this study could have been strengthened by including composition study of the newborn pig and subsequent growth of similar pigs from birth to 75 pounds.

Pork quality traits are known to be affected by numerous stress factors in pre-slaughter treatment. The true effect which such factors have upon pork quality traits is extremely difficult to measure and is especially difficult to assess over a period of time. Careful uniform handling of all pigs was deemed essential and prevailed throughout the conduct of this experiment. Therefore, the fact that differences in pork quality traits were small and non-significant may be attributed in part to careful pre-slaughter handling of the pigs.

CHAPTER V

SUMMARY

A study involving 36 experimental and 8 observation pigs was conducted to acquire basic knowledge concerning body composition and development patterns of the growing meat-type pig. Linear measurements of muscle, fat, and bone were obtained on two boars, two barrows, and two gilts from each of six litters at three-week intervals up to a weight of 175 pounds and at two-week intervals up to 225 pounds when half of the pigs were slaughtered. Measurements were continued at two-week intervals on the remaining pigs to their slaughter weight of 300 pounds. A boar, gilt, and barrow from each litter were slaughtered at 225 pounds, and the remaining littermates were slaughtered at 300 pounds. Specific gravity, routine carcass data, pork quality determinations, and chemical composition data were obtained on each carcass. In addition, chemical composition data were collected on three pigs comparable to the experimental pigs at each of the observation weights of 75 and 150 pounds.

Boars had a higher accumulative average daily gain than barrows and gilts up to 225 pounds, and barrows gained faster than gilts. The advantage of boars over barrows and gilts became more evident at weights beyond 225 pounds. Boars converted feed more efficiently than barrows. The feed efficiency advantage for boars over barrows and gilts was much greater at 300 than at 225 pounds as boars were only slightly less efficient between 225 and 300 pounds than from 75 to 225 pounds.

Both skeleton and muscle had attained a greater percentage of their final 225- or 300-pound measurement at 75 pounds than had fat. The rate of increase of skeletal size was slower than muscular growth, and both skeleton and muscle developed at a slower rate than fat from 75 to 300 pounds.

The rate of increase in fat depth became more rapid at weights beyond 150 pounds, and, also, differences among individuals and sexes became more apparent. The rapid growth and increase in variation among individuals was largely due to the rapid rate of increase in depth of the second and third fat layers. About 75 to 80 percent of the third fat layer depth at 300 pounds was deposited between 225 and 300 pounds.

Ultrasonic estimates and carcass measures of fatness at the tenth- and last-rib areas were highly correlated with percent lean cuts, percent ether extract, and percent protein in the carcass. Measurements obtained over the *l. dorsi* on both the live animal and carcass were more highly correlated with carcass composition than were midline measurements of live-animal and carcass fatness. At 225 pounds, correlations involving depth of the first two fat layers were higher than those that included all three fat layers. However, at 300 pounds correlations including layers 1, 2, and 3 were as high or higher than those with only layers 1 and 2 included.

The percentages of total body length constituted by each body section (poll to scapula, scapula to last rib, last rib to illium, and illium to root of tail) were similar at all weights.

Correlations between carcass length and measures of fatness and muscling were of much greater magnitude at 300 than at 225 pounds. This indicates that the pigs which continued to grow skeleton from 225 to 300 pounds remained lean and continued to grow muscle; whereas, pigs that had a slower increase in skeletal growth tended to become fat and also had a slower rate of muscular growth than the longer pigs.

These data indicate that individual differences become more evident at heavier weights and that these differences are more observable by practical methods of live-animal evaluation at the heavier weights. Therefore, for most effective results, selection of prospective breeding animals, especially boars, should be conducted at weights beyond 200 pounds.

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LITERATURE CITED

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APPENDIX

TABLE XXV

SUMMARY OF PERFORMANCE TRAITS, SELECTED LIVE-ANIMAL AND CARCASS MEASUREMENTS, CHEMICAL ANALYSES, AND PORK QUALITY FACTORS OF BOARS, BARROWS, AND GILTS AT 225 AND 300 POUNDS

Characteristic	225 B	225 G	225 b	300 B	300 G	300 b
Number of pigs	6	6	6	6	6	6
Performance traits						
Av. daily gain	1.99	1.70	1.80	2.02	1.60	1.63
Feed efficiency	277	303	318	294	339	364
Live-animal measurements (cm.)						
Poll to root of tail	109.6	111.3	110.4	119.4	122.3	122.1
Circ. right front leg	15.4	15.0	14.9	17.8	16.6	17.1
Circ. right rear leg	15.9	15.2	15.7	18.0	17.6	17.6
Circ. tail	7.0	7.0	6.8	8.7	9.0	8.6
Length right front leg	30.2	30.4	29.9	32.6	32.6	32.9
Length right rear leg	21.6	21.6	21.2	22.9	23.5	23.8
Length tail	29.6	27.4	27.9	30.8	33.5	30.6
Carcass measurements (cm.)						
Length	78.3	77.6	76.9	84.0	84.0	83.2
Fat-center of l. dorsi.						
Tenth rib, layer 1	1.03	1.05	1.06	1.26	1.38	1.33
Tenth rib, layer 2	.94	1.00	1.30	1.41	1.29	1.95
Tenth rib, layer 3	.52	.66	.89	.89	.82	1.53
Total (layers 1 + 2 + 3	2.49	2.71	3.25	3.61	3.49	4.81
Last rib, layer 1	1.01	1.01	.94	1.17	1.19	1.32
Last rib, layer 2	.66	.79	.98	.93	.99	1.19
Last rib, layer 3	.64	.85	.78	1.07	.84	1.21
Total (layers 1 + 2 + 3)	2.31	2.65	2.70	3.17	3.02	3.72

TABLE XXV (continued)

Characteristic	225 B	225 G	225 b	300 B	300 G	300 b
Fat - midline (cm.)						
First rib, layer 1	1.52	1.53	1.58	1.85	1.82	1.92
First rib, layer 2	2.45	2.55	2.85	3.02	3.20	3.47
Last rib, layer 1	1.08	1.28	1.22	1.45	1.58	1.58
Last rib, layer 2	1.00	1.52	1.33	1.43	.59	1.90
Last lumbar, layer 1	1.47	1.77	1.55	1.88	2.02	2.22
Last lumbar, layer 2	.86	.98	.93	.95	1.20	1.41
Av. total (layers 1 + 2)	2.82	3.08	3.15	3.53	3.80	4.18
Loin - eye area (sq. in.)	4.90	5.84	5.34	6.32	6.88	6.06
% Fat trim	12.0	13.4	14.2	14.0	15.6	16.9
% Ham + Loin	39.0	38.7	39.3	37.8	37.9	37.1
% Ham + Loin + Shoulder	57.3	57.5	57.8	57.3	55.9	55.5
Dressing percent	72.1	74.4	74.5	71.5	74.7	74.6
Skin weight (lb.)	3.6	2.8	2.8	5.1	4.2	3.9
Bone weight (lb.)	8.3	8.5	8.2	10.2	9.6	9.5
Specific gravity	1.050	1.050	1.046	1.052	1.044	1.036
Carcass quality measures						
Ham score	2.8	2.7	3.0	3.0	3.2	3.3
Loin score	3.0	3.0	3.3	3.2	3.5	4.0
Marbling	7.0	5.3	6.7	5.5	5.8	6.5
Penetrometer - LD av.	273.5	234.5	260.0	265.8	99.8	93.3
Penetrometer - fat av.	200.5	64.8	124.2	57.5	20.2	13.7

TABLE XXV (continued)

Characteristic	225 B	225 G	225 b	300 B	300 G	300 b
Cooking results						
Av. shear score	15.35	12.87	16.07	13.62	16.87	15.55
Evaporation loss (%)	18.33	18.47	19.05	18.35	18.43	17.23
Dripping loss (%)	4.10	3.85	4.02	4.52	5.00	6.48
Total cooking loss (%)	22.43	22.32	23.07	22.87	23.43	23.72
Flavor	6.78	7.27	7.23	5.80	7.50	6.93
Juiciness	7.53	6.92	7.43	7.70	6.93	7.32
Tenderness	7.77	8.52	7.93	8.20	7.03	7.85
Chemical composition (%)						
Moisture (whole carcass)	52.49	50.86	49.14	51.21	48.85	43.26
Fat (whole carcass)	32.17	34.06	36.57	33.86	36.47	44.04
Protein (whole carcass)	14.41	14.38	13.55	13.98	13.56	11.92
Moisture (muscle sample)	73.81	72.59	72.63	73.01	71.93	71.90
Fat (muscle sample)	4.27	4.20	4.14	4.47	4.79	5.48
Protein (muscle sample)	21.84	22.03	21.07	21.39	21.74	21.76

TABLE XXVI

CORRELATIONS AMONG SELECTED LIVE-ANIMAL AND CARCASS MEASUREMENTS, CHEMICAL ANALYSES, AND QUALITY FACTORS AT 225 POUNDS

Characteristic[b]	(29)	(28)	(27)	(26)	(25)	(24)	(23)	(22)	(21)	(20)	(19)	(18)	(17)	(16)	(15)	(14)	(13)	(12)	(11)	(10)	(9)	(8)	(7)	(6)	(5)	(4)	(3)	(2)	(1)
(1) Poll to root of tail	0.03	0.23	-.03	0.47	-.41	0.39	0.55	-.22	-.07	-.05	-.11	-.71	0.10	0.38	0.05	0.19	-.20	-.12	-.14	0.25	-.19	-.02	-.24	-.24	0.37	-.32	-.34	0.00	1.00
(2) LD depth, tenth rib	0.01	-.13	-.11	-.14	0.29	-.26	0.26	-.21	0.21	0.01	0.40	-.09	-.31	-.04	0.39	0.24	0.14	0.20	-.37	0.66	-.36	-.14	0.24	0.66	-.25	0.08	-.04	1.00	
(3) LD fat, layer 1 + 2, last	-.23	0.01	0.10	-.67	0.73	-.74	-.29	0.16	0.16	0.29	-.13	0.23	-.45	-.30	-.44	-.59	0.83	-.13	0.12	-.16	0.23	0.41	-.07	0.47	-.14	0.89	1.00		
(4) LD fat, layer 1 + 2, last	-.34	0.06	0.01	-.79	0.78	-.78	-.18	0.23	-.05	0.23	-.04	0.17	-.50	-.48	-.38	-.57	0.84	-.05	0.21	-.13	0.17	0.34	-.01	0.50	-.23	1.00			
(5) Length	0.02	0.37	0.07	0.09	-.15	0.18	0.21	0.17	-.02	-.06	-.22	-.13	-.11	0.10	-.43	-.20	-.07	0.18	0.15	-.25	0.07	0.01	-.11	-.13	1.00				
(6) Av. backfat	-.14	0.21	-.21	-.53	0.68	-.66	0.22	0.06	0.23	-.12	0.21	0.00	-.31	-.08	-.07	-.12	0.62	0.07	-.36	0.23	-.05	0.19	0.18	1.00					
(7) Ham score	-.53	0.22	-.44	-.28	0.28	-.26	-.15	0.46	0.46	-.18	-.09	0.43	0.17	0.17	-.08	0.13	-.01	-.20	0.06	-.13	0.49	0.62	1.00						
(8) Loin score	-.53	0.35	-.27	-.29	0.33	-.33	-.15	0.41	0.23	-.20	-.28	0.15	0.22	0.30	-.59	-.28	0.30	-.36	0.08	-.28	0.74	1.00							
(9) Marbling	-.39	0.33	-.07	-.23	0.19	-.20	-.43	0.70	0.06	-.16	-.62	0.30	0.34	0.10	-.57	-.44	0.17	-.09	0.05	-.61	1.00								
(10) LEA, tenth	0.42	-.29	-.10	0.29	-.17	0.16	0.43	-.71	0.08	0.01	0.50	-.42	0.06	0.12	0.42	0.28	-.16	-.10	-.47	1.00									
(11) Av. LD, penetrometer	-.40	0.01	0.03	-.23	-.02	0.07	-.13	0.22	-.10	0.30	-.10	0.15	-.39	-.14	-.23	0.04	-.10	-.04	1.00										
(12) Av. Fat penetrometer	0.21	-.18	0.53	-.11	-.09	0.12	-.37	0.06	-.48	-.25	0.26	0.17	-.16	-.52	-.07	-.37	-.07	1.00											
(13) Fat trim (%)	-.33	0.14	0.01	-.79	0.87	-.88	-.15	0.30	0.22	0.22	-.03	0.22	-.53	-.32	-.28	-.54	1.00												
(14) % Ham + Loin	0.00	0.08	-.44	0.47	-.36	0.36	0.52	-.33	0.20	0.03	0.13	-.28	0.08	0.42	0.57	1.00													
(15) % Ham + Loin + Shoulder	0.24	-.48	0.09	0.32	-.25	0.24	0.12	-.28	0.29	0.31	0.36	0.00	0.00	0.21	1.00														
(16) Bone weight	-.12	0.08	-.15	0.50	-.35	0.37	0.29	-.02	0.48	-.14	-.01	-.24	0.42	1.00															
(17) Specific gravity	0.24	0.14	-.18	0.62	-.59	0.55	0.00	-.05	-.09	-.47	-.05	-.20	1.00																
(18) Av. shear score	-.28	-.37	0.32	-.52	0.45	-.44	-.79	0.42	0.33	0.03	0.01	1.00																	
(19) Evaporation loss	0.18	-.33	0.10	0.06	-.12	0.15	0.00	-.48	0.00	-.16	1.00																		
(20) Dripping loss	0.20	-.34	0.16	-.07	0.11	-.11	-.04	-.13	0.27	1.00																			
(21) Flavor	-.25	-.08	-.12	-.08	0.29	-.27	-.08	0.13	1.00																				
(22) Juiciness	-.72	0.44	-.14	-.50	0.38	-.37	-.33	1.00																					
(23) Tenderness	0.13	0.43	-.57	0.28	-.17	0.16	1.00																						
(24) % Moisture (whole carcass)	0.44	-.13	0.12	0.89	-.99	1.00																							
(25) % Fat (whole carcass)	-.46	0.11	-.10	-.91	1.00																								
(26) % Protein (whole carcass)	0.51	-.08	0.01	1.00																									
(27) % Moisture (muscle sample)	0.33	-.72	1.00																										
(28) % Fat (muscle sample)	-.46	1.00																											
(29) % Protein (muscle sample)	1.00																												

[a] $r_{.05} = 0.47$, $r_{.01} = 0.59$.

[b] Variables 1 - 3 = live-animal measurements; variables 4 - 29 = carcass measurements.

TABLE XXVII

CORRELATIONS AMONG SELECTED LIVE-ANIMAL AND CARCASS MEASUREMENTS, CHEMICAL ANALYSES, AND QUALITY FACTORS AT 300 POUNDS

Characteristic[b]	(29)	(28)	(27)	(26)	(25)	(24)	(23)	(22)	(21)	(20)	(19)	(18)	(17)	(16)	(15)	(14)	(13)	(12)	(11)	(10)	(9)	(8)	(7)	(6)	(5)	(4)	(3)	(2)	(1)
(1) Poll to root of tail	0.32	0.30	-.36	-.07	0.25	-.26	-.34	-.47	0.13	0.10	0.20	0.45	-.18	-.08	0.15	0.37	0.07	-.46	-.46	0.39	0.12	0.08	-.19	0.06	0.63	-.16	-.17	0.26	1.00
(2) LD depth, tenth rib	0.10	-.40	0.27	0.64	-.68	0.69	-.08	-.25	-.17	-.58	0.51	0.02	0.66	0.50	0.63	0.68	-.80	0.45	0.27	0.48	-.41	-.11	-.32	-.63	0.53	-.71	-.82	1.00	
(3) LD fat, layer 1 + 2, last	-.33	0.47	-.31	-.85	0.77	-.78	-.13	0.26	0.12	0.46	-.63	0.08	-.85	-.36	-.85	-.80	0.91	-.42	-.23	-.53	0.58	0.11	0.32	0.81	-.57	0.89	1.00		
(4) LD fat, layer 1 + 2, last	-.36	0.45	-.30	-.82	0.79	-.80	-.16	0.11	0.15	0.51	-.71	0.08	-.77	-.42	-.83	-.71	0.82	-.37	-.31	-.38	0.44	0.05	0.26	0.81	-.55	1.00			
(5) Length	0.31	-.13	0.02	0.53	-.31	0.32	-.05	-.22	-.17	-.25	0.29	0.10	0.38	0.00	0.52	0.50	-.41	0.11	0.01	0.45	-.36	-.19	-.74	-.31	1.00				
(6) Av. backfat	-.01	0.30	-.27	-.70	0.74	-.74	-.22	0.02	0.40	0.47	-.49	0.12	-.84	-.56	-.74	-.62	0.88	-.47	-.34	-.10	0.30	0.00	0.01	1.00					
(7) Ham score	-.22	0.38	-.20	-.52	0.24	-.26	-.02	0.01	0.14	0.21	-.10	-.05	-.35	0.17	-.32	-.26	0.25	-.29	-.20	-.45	0.50	0.46	1.00						
(8) Loin score	-.02	0.21	-.20	-.30	0.16	-.16	0.14	0.30	0.03	0.18	-.17	-.15	-.21	0.10	0.04	0.09	-.02	-.37	-.39	-.33	0.40	1.00							
(9) Marbling	-.39	0.57	-.32	-.64	0.46	-.46	0.04	0.35	0.10	0.39	-.30	-.02	-.51	0.17	-.53	-.42	0.47	-.36	-.19	-.33	1.00								
(10) LEA, tenth	0.42	-.41	0.04	0.53	-.39	0.38	-.06	-.52	0.32	-.24	0.54	0.19	0.44	0.08	0.30	0.56	-.31	0.07	-.01	1.00									
(11) Av. LD penetrometer	-.35	-.41	0.51	0.37	-.56	0.57	0.32	0.46	-.61	-.50	0.17	-.46	0.50	0.54	0.22	0.00	-.36	0.86	1.00										
(12) Av. fat penetrometer	-.28	-.42	0.48	0.55	-.65	0.66	0.36	0.35	-.50	-.50	0.11	-.48	0.64	0.47	0.27	0.06	-.59	1.00											
(13) Fat trim (%)	-.14	0.48	-.38	-.81	0.81	-.82	-.36	0.01	0.29	0.51	-.52	0.23	-.91	-.53	-.81	-.71	1.00												
(14) % Ham + Loin	0.38	-.47	0.21	0.62	-.49	0.49	0.16	-.32	-.16	-.25	0.66	0.09	0.67	0.42	0.88	1.00													
(15) % Ham + Loin + Shoulder	0.29	-.49	0.34	0.73	-.59	0.60	0.31	-.03	-.32	-.31	0.58	-.11	0.75	0.37	1.00														
(16) Bone weight	-.22	-.36	0.43	0.27	-.54	0.55	0.34	0.19	-.47	-.35	0.43	-.28	0.51	1.00															
(17) Specific gravity	0.13	-.61	0.43	0.88	-.87	0.87	0.32	-.05	-.37	-.57	-.59	-.15	1.00																
(18) Av. shear score	0.42	-.04	-.05	-.12	0.25	-.25	-.70	-.58	0.19	-.14	0.33	1.00																	
(19) Evaporation loss	0.65	-.59	0.46	0.57	-.58	0.59	0.02	-.42	0.02	-.43	1.00																		
(20) Dripping loss	-.05	0.51	-.34	-.50	0.71	-.72	0.09	0.10	0.33	1.00																			
(21) Flavor	0.44	0.13	-.22	-.15	0.23	-.24	-.18	-.38	1.00																				
(22) Juiciness	-.54	0.00	0.24	-.38	-.02	0.02	0.43	1.00																					
(23) Tenderness	-.04	-.10	0.16	0.18	-.20	0.21	1.00																						
(24) % Moisture (whole carcass)	0.11	-.67	0.52	0.85	-.99	1.00																							
(25) % Fat (whole carcass)	-.10	0.66	-.50	-.86	1.00																								
(26) % Protein (whole carcass)	0.26	-.64	0.39	1.00																									
(27) % Moisture (muscle sample)	0.21	-.82	1.00																										
(28) % Fat (muscle sample)	-.36	1.00																											
(29) % Protein (muscle sample)	1.00																												

[a] $r_{.05} = 0.47$, $r_{.01} = 0.59$.

[b] Variables 1 - 3 = live-animal measurements; variables 4 - 29 = carcass measurements.

VITA

Gordon Ferrell Jones was born in Lafayette, Tennessee, on August 9, 1944. He attended elementary and high school in Macon County, Tennessee, and was graduated from Macon County High School in 1962. In September, 1962, he entered The University of Tennessee and received a Bachelor of Science degree in Animal Husbandry in 1966. While an undergraduate, he served as president of the Block and Bridle Club and chancellor of Alpha Zeta. He won the National Block and Bridle Merit Trophy Award in 1967.

In September, 1967, he received a National Defense Education Act Fellowship and began study toward a Doctor of Philosophy degree with a major in Animal Science. He received the degree in March, 1971. He is a member of Gamma Sigma Delta and Phi Kappa Phi Honorary Fraternities.

He is married to the former Myra Susan McClard of Lafayette, Tennessee.