ACCURACY OF ULTRASONICS AT VARIOUS WEIGHTS IN SWINE AND ADJUSTMENT OF LOIN EYE AREA TO A STANDARD LIVE WEIGHT

by

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INTRODUCTION

Swine producers and breeders have greatly changed the type of animals sent to market in the past few years. Reduced need for fat in the diet has emphasized the production of animals yielding carcasses with less fat and more lean. The swine industry has used many methods to aid in the selection of the animal that will produce a leaner carcass. The methods of evaluating carcass characteristics in the live hog which have been used with varying degrees of success include visual observations, specific gravity, lean meter, X-ray photographs, thermistor thermometer, photogrammetry, linear measurements, metal ruler, gamma ray and ultrasonics. Each selection technique developed had certain disadvantages and limitations which encouraged new and better methods to be introduced.

Most of the methods being used estimate leanness, fatness, or a combination of the two in the carcass. Loin eye area, a measurement indicating meatiness in the carcass, has been estimated by several methods, including ultrasonics, with fair to excellent accuracy.

Ultrasonics were used during World War II as echo sounding equipment in detecting enemy ships and submarines. In 1956 ultrasonics were introduced into the area of animal science as a devica for estimating carcass value by using certain observations obtained from the live animal. By 1962 the use of ultrasonics had become rather common.

Controllad feeding and management of swine at test stations have given animals included in each test an equal chance to express their gaining ability, feed efficiency, conformation traits, and carcass characteristics at a specific weight. Since weight is an important factor and varies considerably under nonregulated conditions at the time of measurement, a method for correcting certain characteristics to a common weight is necessary. A characteristic measured in most carcass studies and one which receives considerable emphasis is loin eye area.

In this study an attempt is made to obtain a method of standardizing loin eye area to a 200-pound live animal weight and to test the accuracy of the ultrasonic method of estimating fat thickness and loin eye area in live swine.

REVIEW OF LITERATURE

Animal scientists throughout the world have exerted effort to improve the effectiveness of existing methods of evaluating the live animal so they can more accurately select the animal possessing the superior genotype.

Loin eye area has received more attention than any other area of the animal partially because the loin is a valuable primal cut, also because it indicates meatiness in the carcass, and because loin eye area is easily measured on the carcass. Loin eye area and fat thickness have been estimated subjectively and objectively in the live animal as well as in the carcass before it has been "broken down" into wholesale cuts. Methods of estimating loin eye area and fat thickness are discussed along with factors which affect these characteristics.

Live Animal Evaluation

Visual Estimates. One of the first methods used to appraise the animal was by visual evaluation. Leanness of the carcass, dressing percent, and other measures have been estimated by actual contact with the animal and by observational estimates of fat deposition. Bratzler and Margerum (1953) studied the efficiency of three experienced livestock judges who scored a large number of hogs. None of the three judges were consistently accurate in estimating all three characteristics: body length, backfat thickness, and preferred cut yield. Similar results were reported by Brown et al. (1964) who found graders were not consistently accurate in their appraisals. Experienced judges, according to Harrington et al. (1960), attempting to predict percentage of lean cuts, were unable to rank carcasses or hogs more accurately than the ranking based on the use of backfat thickness. The judges were more accurate in predicting relative lean cuts than relative loin eye area or percentage yield of untrimmed loin. Tuma et al. (1958) found visual appraisers could predict backfat thickness and carcass length in hogs with accuracy, but no scorer's estimation of percent lean cuts was significantly correlated with actual percentages (correlations ranged from 0.07 to 0.25).

Linear Measurements. Relatively low correlations, ranging from 0.02 to 0.50, between measurements of body dimensions and yield of five cuts were found by Hetzer et al. (1950). Hetzer et al. (1956) reported the accuracy of body measurements on the individual were such that the measurements could not be used effectively in swine improvement.

Wilson _et al_. (1958) found very little relationship between shape of animal as measured by relative widths at shoulder, loin, and ham, and yield of lean cuts. The only positive correlations observed were between yield of lean cuts and loin width ($r = 0.22$) and between yield of lean cuts and average width of hog ($r = 0.25$) when weight and live probe were held constant. Working with cattle, Green (1953) found width at the shoulders was the only body measurement significantly correlated with dressing percent. Green believed an objective study of judging practices is needed.

Photographs, from which life sized projections were used to take measurements, were taken by Phillips and Dawson (1936) in their studies with swine. They also used calipers and tapes to make direct measurements which were more accurate and faster than the measurements obtained from the photographs. Brinks _et al_. (1964) reported the use of stereophotographs of the live animal to estimate wholesale cuts was reliable.

Mechanical Probe. A method of measuring backfat thickness on the live hog by the use of a mechanical probe was introduced by Hazel and Kline (1952). They reported the measurement of fat thickness, by using a metal probe, was slightly more accurate than actual carcass measurements in estimating leanness and percentage primal cuts. The most accurate locations were found to be just behind the shoulder and the middle of the loin an inch and a half off the midline. Hazel and Kline (1953) studied eight sites on the live animal and found some to be as accurate as carcass measurements in predicting percent lean cuts and percent fat cuts. The sites behind the shoulder, over the loin and top of the ham were the most reliable. The two sites, behind the shoulder and over the loin were taken over the longissimus dorsi muscle. A table for adjusting backfat thickness to a standard live weight of 200 pounds was developed by Durham and Zeller (1955) from data resulting from probing hogs at various weights. The sum of probes at three sites were used, (1) behind the shoulder (2) juncture of last rib and vertebrae and (3) perpendicular to stifle joint. Hetzer et al. (1956) reported a range of significant correlations from 0.42 to 0.54 between percentage fat cuts and live hog probes. Correlations between percentages of lean in hams and live measurements were negative and significant (r's = -.17 to -.42). Live probe measurements were more accurate than backfat measurements on the carcass (DePage and Whatley, 1956). In partial contradiction, Holland and Hazel (1958) reported the measurement behind the shoulder was the poorest indicator of total backfat. They found the average backfat probe to be a more reliable indicator of percent lean cuts than carcass measurements, length, area of loin eye at 10th and last rib, and backfat measurements. While the live probe is a good indicator of backfat thickness and can be performed rapidly with very little discomfort to the animal, it still can not be used to estimate area or the shape of the loin eye.

Lean Meter. The lean meter was introduced by Andrews and Whaley (1954) as reported by Pearson et al. (1957). It operated on the basis of a difference in electrical conductivity between fat and lean tissue as the probe was inserted into the animal. Pearson _et al_. (1957) reported the lean meter was no more accurate than the live animal probe for estimating backfat thickness, percent lean cuts or percent primal cuts. Accuracies of the live animal probe and the lean meter were compared by Pearson _et al_. (1956c) for predicting carcass characteristics. A correlation of 0.78 was found between lean meter and live probe for predicting fat depth at the same site. Correlations of -.58 and -.40 were reported between loin lean area at the 10th rib, and live probe and lean meter predictions, respectively. Pearson _et al_. (1956c) concluded the usefulness of the two techniques for predicting carcass cut-out was essentially the same but live probe was slightly more reliable because of a closer relationship with specific gravity, loin eye area at 10th and last rib, and with fat trim. An electrical type lean meter was used by Guelph (1958) at three sites on pigs; shoulder, middle of back, and loin. Correlations of 0.57, 0.48, and 0.50, respectively, were found between predicted and actual measurements.

Needle Probe. The idea of a probe being inserted into the animal's back was extended by Holland and Hazel (1958) when they used a six-inch ice pick to measure muscle thickness and fat thickness in swine. Measurements were taken over the supraspinous fossa and the ibium by inserting the finely sharpened pick until there was a marked increase in resistance indicating the pick had reached the muscle. This depth was recorded as the fat depth. The pick was then forced through the muscle until it stopped again at which time the pick reached bone, and this depth was measured. The difference between the two measurements was the estimate of the loin eye depth. Matthews et al. (1960) used a similar approach when they measured longissimus dorsi depth and fat depth in lambs at the last lumbar vertebra by using a needle probe. The needle was inserted to the point where it stopped when it reached the muscle, then was inserted until it passed through the muscle and to the vertebra. Both distances were recorded and the difference was the depth of the longissimus dorsi. Correlations between depth of probe and actual depth were 0.43 and 0.63 for the first and second trial respectively, both being significant. The correlations between depth of probe and area of longissimus dorsi at the right transverse process of the second lumbar vertebra were 0.56 and 0.59 for the two trials, respectively.

Thermistor Probe. Estimation of fat thickness on steers in vivo was reported by Warren et al. (1959) when they used a hypodermic thermistor probe attached to a thermistor recorder. The probe was inserted dorsally in the longissimus dorsi directly over the 13th rib until a temperature change from fat to lean was reflected on the thermistor thermometer, therefore indicating the depth of the fat. Correlations between live probe and carcass fat thickness were 0.75, 0.47, and 0.84 for the three trials studied by Warren et al. (1959). Brackelsberg et al. (1965) also used a hypodermic thermistor probe, with a temperature dial attached, to record fat depth over the 12th rib on cattle. Three live animal probes were made and averaged at the same place carcass measurements were taken, producing correlations 0.37, 0.58, and 0.53 between the two measurements for bulls, steers and heifers respectively. Brackelsberg et al. (1965) reported correlations ranging from 0.35 to 0.82 for all trials involving cattle of "average" fat deposition. In a smaller group of fatter more variable animals, a correlation of 0.90 was reported.

X-ray and Gamma-ray. Wussow and Weniger (1953) used a series of X-ray photographs to determine backfat thickness in swine. They stated thickness of backfat, estimated by X-ray photographs, did not give a reliable estimate of overall fat deposition. A low level gamma-ray detector was used to measure the net counts per minute from potassium-40, in studies by Kulwich *et al*. (1961), in an attempt to determine the amounts of separable lean and fat, bone and skin in swine. Individual hams were measured for potassium-40, then dissected manually for determination of separable fat and lean, bone and skin. The separable lean per ham was highly correlated with the net count per minute of potassium -40 ($r = 0.96$). Kirton *et al*. (1961) reported correlations between gamma-ray counts and separable fat in sheep ranged from -.38 to -.79, some being highly significant. The correlation values between gamma-ray counts and separable lean were not significant. The use of potassium -40 counts for determination of body composition was also employed by Judge *et al*. (1963). They found separable fat could be predicted accurately (r's $= -.72$ to $-.89$), as well as bone content, and edible portion of the carcass, in some cases. Smith *et al*. (1964) reported on the use of a whole body counter for measuring potassium -40 (K-40) in the animal. The gamma-ray emitted from K-40 was measured by the device, and then used to calculate the total potassium in the body. Since the level of potassium within a species is constant for lean tissues the total lean in the body could be computed. The method used by Smith *et al*. (1964) was employed in studies with sheep, swine, and cattle. No definite accuracy had been established at that time.

Ultrasonics. The use of ultrasonics in carcass evaluation is relatively new. Hazel and Kline (1959) reported that Temple (1956) applied ultrasonic reflectance techniques to the problem of measuring fatness in beef cattle. Temple suggested the approach appeared promising but was not accurate enough to be recommended for use at that time. In the same paper Hazel and Kline (1959) reported that Smith (1957) had found the mechanical probe and the electrical probe were not accurate enough, at that time, for use on cattle. The Sperry Reflectoscope was introduced by Price *et al*. (1958) for use on hogs and cattle to measure depth of subcutaneous fat and depth of lean muscles. Estimates of muscle depth in swine were reliable but were less accurate in cattle. Another ultrasonic device called the somascope was used by Campbell *et al*. (1959) to measure depth of the longissimus dorsi muscle over the last rib in sheep. Highly significant correlations between estimated rib eye depth and actual depth as measured from the loin eye tracings, were found for the two groups of sheep studied ($r = 0.68$ and 0.49 respectively). The sum of three somascope readings of lean (1", 1½", and 2" off the midline) was correlated significantly with rib eye area for both groups, ($r = 0.62$ and 0.44). The sum of the tracing depths, on the carcass, at the same locations was correlated with rib eye area for the two groups in the study, the values being

0.76 and 0.79.

East et al. (1959) and Schmidt (1959) found ultrasonic estimates to be closely associated with measurements on the swine carcass. The ultrasonic probe was reported by Urban et al. (1959) to be no more accurate in estimating fat thickness in swine or predicting carcass characteristics than the live probe. In a study by DuMont and Destandau (1962) four techniques were compared in an effort to obtain an objective measurement of fat thickness in hogs. The four techniques used were radiographic, ultrasonic, lean meter, and ruler probe. The correlations observed were 0.99, 0.99, 0.86, and 0.48, respectively. Hazel and Kline (1959) found ultrasonics to be as accurate as the mechanical probe in predicting fat thickness when using a Kelvin and Hughes Mark V flaw detector with a 2.5 mc./s. and 1.5 mc./s. transducer. Work was continued by Price et al. (1960b) with the Sperry Reflectoscope, using a 2.5 mc. crystal type transducer and they found a highly significant relationship ($r = 0.90$) between live metal probe estimate of backfat thickness and carcass backfat thickness in swine. Common probing techniques were as accurate as the ultrasonic device; however, when the three methods, ultrasonic estimates, backfat thickness and live probe were compared by Price et al. (1960b) the methods were found to be equal in predicting lean and primal cut-out. Ultrasonic estimates of the depth of loin eye over the center of the back in live hogs were significantly related to depth and area of the actual loin eye. The correlation coefficient between actual loin eye area at the 10th rib and depth of loin lean measured ultrasonically was

0.34. Actual area of loin eye was correlated, 0.71, with percentage lean cuts on live basis. Price et al. (1960a) found significant correlations between area of loin eye estimated in the live hog at the last rib, but the method was time consuming and at that time was restricted in its use to research. Studies by Stouffer et al. (1959) produced favorable results for estimating loin eye area in cattle and hogs when employing ultrasonics. Lauprecht et al. (1960b), Zobrisky et al. (1960), Hedrick et al. (1962), Davis and Long (1962), Alsmeyer et al. (1963), Otto and Sieg (1963), Brown et al. (1964), J. K. Davis et al. (1964), Davis et al. (1965), Moody et al. (1965), and Ramsey et al. (1966) all found significant correlations between ultrasonic measurements and actual carcass measurements. Stouffer et al. (1961) and Lauprecht (1960a) reported higher correlations in pigs than in cattle. Quieter animals were reported to give better results by Sumption et al. (1964). Lucas (1965) found Yorkshires and Durocs could be read more accurately than Hampshires and Polands. Animal variation according to Temple et al. (1965) could cause errors in making estimates with ultrasonic measuring devices.

Other complications and disadvantages, besides a few mentioned above, should be pointed out concerning the use of ultrasonics. D. L. Davis et al. (1964) reported visual appraisal appeared to be more accurate for evaluating loin eye area than ultrasonics in lambs. Temple et al. (1965) pointed out various errors that could cause readings to be less reliable than desired. The errors included (1) animal variation (2) tissue change during slaughter (3) interpretations and (4) machine manipulation. Also very fat animals or very firm animals may cause difficulty in making accurate readings.

Carcass Evaluation

Specific Gravity. The use of specific gravity as a measure of pork quality is generally restricted to carcass evaluation. Brown et al. (1949) reported highly significant positive correlations involving specific gravity with area of loin eye, carcass length, percentage primal cuts and percentage lean cuts. Highly significant negative correlations were found between specific gravity and backfat thickness, chilled weight, weight per inch of carcass length and percentage of fat trim. Brown et al. (1949) found specific gravity, of the carcass, to be more closely correlated with the above measurements than backfat thickness or loin eye area. Specific gravity of a ham was compared with specific gravity of the entire carcass by Pearson et al. (1956a) in an attempt to measure carcass leannes.. The accuracy of the two appeared similar and both were superior to backfat thickness as indicators of leanness in the carcass. Specific gravity of loin and shoulder were also relatively closely correlated with lean cuts of the carcass ($r = 0.65$ and 0.64 respectively). Price et al. (1957) also found specific gravity of the right untrimmed ham was highly correlated ($r = 0.86$) with specific gravity of entire carcass. Although specific gravity of the entire carcass was more accurate than specific gravity of the ham in predicting cut out percentages, chemical composition of ham (moisture, ether extract, and protein), loin lean area, and fat thickness, specific gravity of the ham was a more reliable indicator of muscling than was the live probe or actual backfat thickness. In (1951) Brown *et al*. found the average specific gravity of the pork carcass to be 1.027 and was correlated with loin eye area, percentage primal cuts, percentage lean cuts and carcass length, 0.46, 0.68, 0.84 and 0.56, respectively. Specific gravity of the carcass was negatively correlated with average backfat thickness, percentage fat cuts, and chilled carcass weight ($r = -.68$, $-.78$, and $-.42$ respectively).

Though favorable results have been obtained by using specific gravity as a measure of carcass quality, there are certain disadvantages and limitations in its use. Whiteman *et al*. (1953) reported the following disadvantages that can affect accuracy: daily variations in water purity, temperature of carcass, and the length of time after slaughter the reading is taken. Fredeen *et al*. (1955a) found the percent area of lean in the ham surface exposed when the ham is cut from the carcass, is a more reliable measure of ham leanness than the specific gravity method.

Backfat. Aunam and Winters (1949) reported average backfat depth on swine was associated with lean content of the carcass, percent primal cuts, and dressing percent. A coring device was successfully used by Aunam and Winters (1952) in taking a sample of fat and lean tissue from the carcass for estimation of leanness. Five coring sites were used and the lean and fat separated. The most valuable site for predicting lean in the carcass was between the 5th and 6th rib.

Backfat thickness, measured by the metal probe, can be used to estimate the amount of fat on the animal. Zobrisky et al. (1953) found a significant negative association between fat thickness in the live hog as indicated by the probe and the percentage of the carcass consisting of the four lean cuts. Significant positive correlations were reported between live animal probes and total fat in the carcass. Prediction equations were developed by Judge et al. (1966) to estimate percent edible portion of the carcass. The mean of three fat thickness measurements over the longissimus dorsi muscle at the 12th rib on ewes and wethers plus kidney and kidney fat weight, and chilled carcass weight were used in the equation. Backfat measurements can be taken rapidly and easily but they alone are of little value in carcass evaluation in sheep.

Loin Eye Area. Loin eye area has been emphasized for several years, resulting in much effort to increase the size of the loin eye in swine. The longissimus dorsi muscle is the largest muscle in the body and constitutes a large portion of the loin, a high priced wholesale cut. The loin and the ham are the two highest priced wholesale cuts of the swine carcass. Many workers have compared loin eye area and other carcass characteristics to determine the merit of selecting for larger loin eyes. Very little additional accuracy is obtained by evaluating the carcass using the whole longissimus dorsi. Topel et al. (1961) reported a correlation value of 0.82 between loin eye area and volume of the loin muscle. Topel et al. (1965) reported loin eye area appeared to be nearly as reliable as the total weight of the longissimus dorsi muscle for predicting weight of lean cuts ($r = 0.64$ and 0.70 respectively). It was reported by Zobrisky _et al_. (1953) that total lean in the carcass was closely related to ham and loin eye area. Fredeen _et al_. (1955b) reported loin eye area was closely associated with percent lean in the ham ($r = 0.79$) and ham weight ($r = 0.66$). A correlation of 0.69 between loin eye area and weight of lean cuts, was found by Lasley _et al_. (1956). According to Pearson _et al_. (1956b), loin eye area at the 10th rib was almost as reliable ($r = 0.53$) as the ratio of fat to lean for estimating percent lean cuts on a live basis ($r = -.62$). Zobrisky _et al_. (1959a) found the cross sectional area of the loin at the 10th rib was more closely correlated with total lean than any other single measurement they studied. Just as loin eye area is the best indicator of total lean, backfat thickness was reported by Zobrisky _et al_. (1959b) to be the best indicator of fat yield. Topek _et al_. (1961) published a correlation coefficient of 0.54 between loin eye area and weight of lean cuts. Williams and Krider (1943) found a highly significant correlation between loin eye area and the area of lean in the end cut of the ham. Studies by Fletcher (1964) produced correlations, for loin eye area at the tenth rib and percent edible portion of carcass of 0.81; percent fat, -.77; backfat, -.66; edible ham, 0.83; and trimmed loin, 0.64. In contrast to several of the above studies, Pearson _et al_. (1959) found that loin eye area was not closely related to actual cut-out value. Trials with cattle by Cahill _et al_. (1956) revealed a significant relationship between area of rib eye and percentage of edible portion of the carcass for steers and bulls (r = 0.85). Topel et al. (1961) however concluded weight of ham was not related to loin eye area. Merkel (1964) reported loin eye area was not highly related to carcass leanness.

The larger loin eye area is continually selected by practically everyone associated with swine improvement, with justification, because of its relationship with carcass leanness and consumer acceptance.

Photographs. Photographic grids were used to measure rib eye area in beef by Schoonover and Stratton (1957). The advantage of this method was elimination of a planimeter reading. Shrewsburg and Wideman (1961) used actual size photographs of the cross-section of the loin from which the planimeter reading was taken, thus reducing the chance for error in obtaining actual shape and size. Similar studies by Fredeen and Jarmoluk (1962) showed photographs could reduce error in tracing and cost in the process of finding loin eye area.

Total Growth

Body Development. Detailed studies of growth in swine were conducted by McMeekan (1939) and (1940a). Most of his work was with bacon breeds of hogs but his findings possibly can be applied to the American breeds with reasonable justification. Body parts, according to McMeekan, essential to life processes and body functions appear relatively well developed at birth; therefore, they make much smaller amounts of growth in post-natal life compared to the body as a whole. Functioning parts of the body used for nutrient stores develop later in the growth period. The body develops anteriorly early, posteriorly later. McMeekan concluded live weight was not a good measure of growth, rather growth was a more complex phenomena including a combination of differential growth of the various parts. Later developing characters generally are more variable than those developing earlier, with loin eye area being an example of the former. The total growth of an animal, according to Brody (1945), makes a change from an increasing rate of increase to a decreasing rate at about 200-250 pounds in swine. Elson et al. (1963) described three periods of growth in swine: (1) period of rapid growth extending from birth to about 80 days, (2) period of transition, 80 to 120 days, and (3) fattening period, 120 days to maturity. These three periods coincide rather closely with bone development, muscle development, and fat deposition.

Muscle Formation. Bourne (1960) reported the number of fibers in a muscle increase greatly during the later stages of embryonic development as does the total weight of the embryo. Each fiber is an individual cell and the number of fibers, according to Bourne, is thought to be established at birth. The growth of the total muscle is therefore due to fiber enlargement rather than cell multiplication. This was substantiated by McMeekan (1940a) and Joubert (1954). McMeekan found no evidence of an increase in muscle fiber number during postnatal life. Copenhauer (1964) also reported that increase in muscle size is due to an increase in size of fiber, not fiber number.

Muscle Growth

Various factors can influence the amount and rate of growth of the muscle fibers. Each factor will be considered in a discussion of how it influences fiber growth.

Nutrition. The effect of four nutritional planes during the two periods of growth, weaning to 100 pounds and 100 pounds to market, was studied by McMeekan (1940c). The nutritional planes used were a high plane during both periods, high during the early period then low, low level during both periods, and low level early then high level, represented by HH, HL, LL, and LH respectively. Pigs during the periods HH and LH showed greater development of late-developing parts of the body, namely fat deposition. This idea was pursued by Winters *et al*. (1949), Whatley *et al*. (1951), Merkel *et al*. (1953), Crampton *et al*. (1954), Jordan *et al*. (1956), Cunha (1963), and Babatunda *et al*. (1965), all reporting an increase in lean and a decrease in fat deposition due to restricted feed intake in the later period of growth. Wallace *et al*. (1963) studied protein levels and concluded higher protein levels in the ration produced leaner carcasses. Very little difference due to protein levels was observed by Ashton *et al*. (1955) although a tendency toward leanness was found with increased protein levels. Merkel *et al*. (1958) reported no significant differences in loin eye area, ham butt, or the percentage of belly when fibrous rations were fed to swine, thus restricting feed intake. McMeekan (1940b) stated that the plane of nutrition does affect muscle fiber diameter.

Age. Growth of muscle has been related to age by several workers including Joubert (1954) who claimed muscle fiber development is essentially a function of an age-weight relationship and not strictly of chronological age. The physiological age is more important than the chronological age. Tuma et al. (1962) found a gradual increase in fiber diameter associated with age in beef cattle over a range of ages varying from 6 to 90 months. When Bruner and VanStovern (1961) compared barrows and gilts for loin eye area and percent lean cuts and the association of these traits with age at 200 pounds, the barrows showed no significant relationship with age at 200 pounds. Gilts increased in loin eye area and percent lean cuts with an increase in age at 200 pounds. Three groups of hogs at 200 pounds when ages, 126-145, 146-165, and 166-185 days were used for the study. Elson et al. (1961) reported an estimated 70% of the muscle fiber growth in the longissimus dorsi was present in a 180 day old hog. As age increased, the fiber size and fat content increased, therefore causing the total muscle to increase in volume. Elson et al. (1963) made a few changes in their estimation of the degree of maturity of the longissimus dorsi at certain ages. They reported the longissimus dorsi to be 50% mature in size at 80 days, 75% at 120 days, and 85% at 180 days. At about 120 days the fiber diameter begins to increase at a slower rate.

Weight. The relationship between several carcass characteristics and weight were studied by Willman and Krider (1943). They found some correlation between loin muscle and weight but the association between these two variables was less than that between several other factors studied. Carcass weight and percent loin were found to be correlated by Henning and Evans (1953). The correlation values decreased as body weight increased, indicating the loin is mainly developed by the time the hog has reached a "normal market weight." As live weight increased from 170-230 pounds, so did carcass length and average backfat thickness according to McCampbell and Baird (1961). Loin eye area increased only slightly with an increase in live weight between 170-230 pounds and the increase in loin eye area was not linear. Studies with lamb carcasses by Esplin _et_ _al_. (1964) resulted in an adjustment for loin eye area for differences in carcass weights. The regression equation, $\hat{Y}_1 = \bar{Y} - b\ (X_1 - \bar{X})$, was used to determine the amounts of adjustment necessary to place all animals on a common weight basis.

Sex. Gilts tend to have a larger loin eye area than barrows at a given weight. This fact is substantiated by Bennett and Coles (1946), Wallace _et_ _al_. (1959) and Charette (1961) as reported by Fletcher (1964). Judge _et_ _al_. (1959) reported gilts have a larger amount of marbling in the loin eye area than barrows which could account for some of the superiority in size.

Genetic Variation. Most muscling characteristics are fairly highly heritable. Craft (1958) estimated heritability coefficients of loin eye area to be 0.48 and percent ham 0.58. Ensminger (1961) reported heritabilities for loin eye area ranging from 0.30 to 0.40. A greater range was found by Carroll _et_ _al_. (1962) depending on the method used for estimating heritability. They reported a range from 0.16 to 0.79 with an average of 0.48. The heritability estimate for depth of eye muscle in bacon breeds was found to be 0.29 by King (1957). Wilson *et al*. (1954) calculated a heritability coefficient of 0.58 for loin eye area. When using a paternal half-sib correlation, Whatley and Enfield (1957) found heritability for loin eye area to be 0.79. There is variation in the many reported estimates, but in general heritability of loin eye area appears relatively large.

Other Factors. In addition other influencing agents should be considered in understanding the phenomenon of muscle growth. There is a breed difference in loin eye area although this difference probably is not a large one. The type, use, and location of the muscle affects the time and magnitude of development. Environment can influence fat thickness therefore resulting in a variation in percent of certain muscles of the body especially among animals of similar live weights.

Growth of the longissimus dorsi muscle was studied by Elson *et al*. (1963) relating it to age. At all of the various ages studied the longissimus dorsi contained larger fibers than the muscles, psoas major, semitendinosus, and semimembranosus. The difference in fiber area continued to increase as age increased. Elson *et al*. (1963) assumed all muscles had the same percent rate of fiber growth; however, the loin muscle developed earlier than those making up the entire body. Elson *et al*. (1963) also reported the longissimus dorsi began increasing at a slower rate near the beginning of the fat deposition period. The total body weight does not begin to increase at a slower rate until the animals weigh 200 pounds or more. As reported earlier, about 75% of the fiber development is present at

120 days of age which would generally correspond to about 100 to 125 pounds body weight.

All of the above factors which affect growth are either extrinsic or genetic factors. Somatotropin, the growth hormone, influences body growth also, mainly during the home development period of growth. Ganong (1965) reported linear growth can not occur once the epiphyses of bone are closed. Growth of the body after closure of the epiphysis is mainly due to muscle and fat tissue increase.

MATERIALS AND METHODS

Ultrasonics

The portion of the present study concerning ultrasonics involved 110 animals, 95 barrows and 15 gilts; 54 Durocs, 18 Poland Chinas, 15 Yorkshires, 4 Hampshires and 19 Crossbreds.

Thirty-eight barrows were from the Kansas Swine Improvement Association Test Station; 18, from the 1965 spring and summer test and 20, from the fall 1965 and winter 1966 test. All animals were fed the same type of ration and managed similarly until a weight of 200 pounds was attained. Sixty head, 51 barrows and 9 gilts, were from the Kansas State University swine farm. They were fed and managed in a similar manner until they reached weights ranging from 183 to 265 pounds.

Twelve Durocs from Kansas State University, 6 barrows and 6 gilts were divided into two groups, each containing 3 barrows and 3 gilts. The first group was placed on test at an average weight of 169 pounds, the second 144 pounds. Each pig was weighed and loin eye area and backfat thickness were estimated weekly by sonoray. The first group was sonorayed six times during a five-week period while the second group was sonorayed five times over a four-week period.

A Branson Sonoray Model 12 Ultrasonic animal tester was used to estimate the backfat and cross-sectional area of the longissimus dorsi muscle at the 10th rib. High frequency sound waves emitted through the transducer into the animal and were reflected back into the transducer and were interpreted to estimate fat and muscle depth in the live animal. The time required for the sound waves to pass from the transducer through the tissues of the animal and return to the transducer was translated into distance by the ultrasonic device. The reading of depth of tissue was produced on a screen in the form of an echo or "blip." Each body tissue has a different density; therefore, the speed that sound travels through the tissue varies accordingly.

Each pig was weighed immediately before being sonorayed, then restrained, and a four inch band of hair was clipped six inches laterally from the midline over the 10th rib. Locating the 10th rib caused some difficulty due to varying lengths, weights and rib number. As a rule the first rib was located fairly accurately at the top of the shoulder. The point one-third the distance from the top of the shoulder to the top of the ham was near the 10th rib. A piece of solder wire was pressed along a line laterally from the midline to obtain the curvature of the back. The solder wire was then transferred to the data sheet and the curvature was traced. From the midline ½", 1", 1½", 2", 3", and 4" were marked with an indelible pencil along the same line where the solder wire had been placed. Motor oil was applied to the surface of the skin to assure an adequate bond between the transducer and the animal. The transducer used was ½" diameter 2.0 mc./s. The angles of sound penetration taken were as follows: ½", 90°; 1", 90°; 1"-80°; 1" 80°; 1½", 80°; 2", 90°; 2",-80°; 2", 80°; 3", 60°; and 4", 50°. A protractor attached to the transducer registered a positive angle when the transducer was aimed into the animal's body and a negative angle when the transducer was aimed away from the center of the animal's body. A reading for fat depth and for muscle depth were recorded at the same time. The machine was calibrated for an average of sound velocity for fat and lean tissue so a new calibration was not needed for each reading. Each pig was probed with a six-inch metal probe at 1", 90° to verify the ultrasonic estimate of backfat thickness and to identify the location of the readings on the carcass. The cross-sectional area of the longissimus dorsi muscle was estimated by plotting the readings on paper and connecting the points thus forming the shape and size of the loin eye. A planimeter was used to measure the estimated loin eye area. Ninety-one of the animals were taken to the Kansas State University meat laboratory the afternoon prior to slaughter the next morning, and only received a limited supply of water until slaughter. The other 19 were taken to Maurer-Neuer Packing Company, Arkansas City the day before slaughter. The following day they were slaughtered and at the end of approximately a 24 hour, 35°F, cooling period, carcass cut-out data and tracings of the loin eye area were obtained. A planimeter reading of the tracing was made and used as the actual loin eye area. The estimated loin eye area and actual loin eye area both measured to the nearest one-hundredth of a square inch were recorded for the right side of each animal. The data were punched on IBM cards for correlation and regression analyses.

Growth of Loin Eye Area

This part of the study involved data from 3024 barrows, 119 Berkshires, 244 Durocs, 756 Hampshires, 212 Poland Chinas, 187 Yorkshires, 294 Crossbreds, and 220 other (including Chester Whites, Landrace and Tamworth). The breed of the remaining 992 barrows was not specified in the data. Practically all the barrows were from swine testing stations or entered in barrow carcass shows in a five state area including Kansas, Missouri, Illinois, Minnesota, and Iowa. The main sources of the carcass data were: Kansas Spring Barrow Show, Arkansas City; Wichita Barrow and Carcass Contest; Missouri Barrow Show, Columbia; Missouri Swine Evaluation Station, Columbia; International Livestock Exposition, Chicago; National Barrow Show, Austin, Minnesota; several county shows in Iowa reported by Rath Packing Co.; and several county shows in Kansas. All data were collected during the period 1963-1966.

Live weights at the time of slaughter ranged from 159 to 280 pounds with 1141 of the live weights being adjusted to a standard fill from the carcass weight. The general procedure for the other 1883 barrows was to weigh them the day before slaughter. The loin eye area was traced at the 10th rib and a planimeter reading was taken to the nearest one-tenth or one-hundredth square inch. The percent of the live weight represented by trimmed ham was recorded to the nearest one-hundredth at several carcass shows as was the percent loin plus ham based on carcass weight, at other shows. Age at 200 pounds was also recorded for a few groups of pigs.

All data were placed on IBM cards and correlations, regressions, means, sums of squares, variances and an adjustment table were obtained by use of an IBM 1410 computer.

RESULTS AND DISCUSSION

Ultrasonics

Ultrasonic Estimate of Loin Eye Area. The 110 pigs used in the sonoray experiment were divided into six groups according to their involvement in other experiments. Loin eye area at the 10th rib, for each pig, was estimated ultrasonically and the estimated area was compared with actual loin eye area obtained from the carcass. The six simple correlation coefficients between estimated and actual loin eye areas obtained from the respective groups ranged from -.20 to 0.66. Due to the rather large range in the simple correlations for the groups, the correlation values were tested to see if they could have been drawn from the same population. At the 5% level the Z transformation method of testing (Snedecor 1964) showed the six sample correlation coefficients could have been drawn from the same population.

Since the values were not statistically different an average correlation could be obtained by using the Z transformation combining all groups. The average correlation was 0.25, significant at the 1% level. An overall correlation coefficient was also computed using all 110 pigs ($r = 0.37$). The reason for the difference in the two correlation coefficients originated from the fact that difference among the correlation values was significant at the 10% level but not at the 5% level. Although the correlation coefficients between estimated loin eye area and actual loin eye area were highly significant, they were not as high as those reported by several other workers. Zobrisky _et_ _al_. (1960) and Price _et_ _al_. (1960a) reported correlation coefficients of 0.84 and 0.74 respectively between ultrasonically estimated loin eye area and actual loin eye area in swine. Hedrick _et_ _al_. (1961), Hedrick _et_ _al_. (1962), Stouffer _et_ _al_. (1961), Davis and Long (1962), Brown _et_ _al_. (1964), Davis _et_ _al_. (1964), and D. L. Davis _et_ _al_. (1965) reported correlation coefficients ranging from 0.22 to 0.93 in their studies with beef cattle comparing ultrasonically estimated loin eye area with actual loin eye area on the carcass.

The average error in estimating the loin eye area (difference between the estimated loin eye area and actual loin eye area) in this study, ignoring sign was 0.38 square inches. As the variance in actual loin eye areas in groups increased, the accuracy of sonoray estimation decreased. The correlation coefficient between actual and estimated loin eye area, and the average error of estimation, decreased and increased respectively as the variance of the actual loin eye areas increased.

When the range in actual loin eye area increased the accuracy of estimation decreased also.

The extremely small and large loin eye areas were the ones that caused the largest errors of estimation. Actual areas between 4.0 and 5.0 square inches were seldomly missed more than 0.38 square inch. One reason is the method of plotting the estimated loin eye area. The method used was described by Massey et al. (1964). When the estimation is made a set of standard angles are used to identify the ends of the eye. This restricts the prediction of an extremely long (length of eye being the distance from the medial to the lateral end of the eye) loin eye or a very short loin eye. No readings were taken beyond four inches off the midline on most of the pigs. Therefore an extremely long eye was consistently underestimated. A few pigs were experimented with by taking an ultrasonic reading at four and one half and five inches off the midline in an attempt to identify the lateral end of the loin eye. These additional readings were beneficial in some cases but caused larger errors in others. If the pig had a long loin eye, the additional readings helped locate the lateral end but if the eye was shorter than average the two readings sometimes missed the eye and other tissue was interpreted as the end of the loin. The longissimus costarum muscle was easily confused with the lateral end of the longissimus dorsi muscle in case of a short loin eye when the additional readings were taken. It appeared the operator tended to predict a loin eye length near average, therefore estimating the size nearer the mean than the actual length in loins differing greatly from the average. This was verified by observing the variance of the actual areas and the variance of the estimated areas. Estimated loin eye areas exhibited only about one half as much variance as the actual areas. Of course the variance was not entirely due to the length of the eye, since depth varied also. The estimates appeared to be either quite near the actuals (within one half a standard deviation) or the area was missed by more than a standard deviation. Since the dorsal readings were accurate, this implies the operator interpreted the ventral boundary incorrectly by reading a series of echoes all either too shallow or too deep thus giving a gross error. Stouffer *et al*. (1961) reported similar errors were observed by misinterpretation of the lateral boundary of the loin eye on beef cattle. In the interpretation of the ventral boundary of the loin eye, the operator usually chose the set of echoes on the machine that more nearly represented the average depth of loin eye. Some animals were much more difficult to read than others, especially in instances where the readible echoes were so close together the correct ones were very difficult to identify.

Estimated backfat thickness was subtracted from the estimated distance to the ventral boundary of the loin eye and used as the estimated loin eye depth at two inches off the midline at 90°. Estimated loin eye depth was correlated with actual loin eye area ($r = 0.07$). Price *et al*. (1960b) reported a correlation coefficient 0.34 between the ultrasonic estimate of loin eye depth and actual loin eye area. Loin muscle diameter and actual loin eye in beef were correlated

($r = 0.60$) according to Otto and Sieg (1963). The main reason for the correlation coefficient being so low in this study was probably due to the misinterpretation of the ventral boundary of the loin eye.

The backfat thickness at the location where the readings were taken, appeared to have some effect on the accuracy of the estimation of loin eye area. For pigs where the metal probe depth was from one to one and one-half inch, the average error in estimating loin eye area was 0.29 square inch. However, for pigs where the metal probe depth was less than one inch and over one and one-half inch the errors averaged 0.76 and 0.43 square inch, respectively. Temple et al. (1965) reported very thin or very fat cattle caused difficulty in obtaining ultrasonic readings.

Live weight of the hog when sonorayed affected the accuracy of the estimate of loin eye area. The correlation between the weight range for each of the six groups of pigs described above, and the average error for each group was 0.72, which approached significance but was nonsignificant at the 5% level. Hunziger et al. (1964) reported sonoray estimates were most accurate in estimating loin eye area for hogs weighing 175 and 225 pounds. The author found the correlation between estimated loin eye area and actual loin eye area for all pigs under 225 pounds to be 0.41, highly significant, whereas the correlation coefficient for pigs 225 pounds and over was reduced to 0.27, nonsignificant.

In this study the average error of estimation was the smallest in the case of Durocs and Yorkshires and largest for Hampshires and

Poland Chinas. Crossbreds were about average. There were only four Hampshires included in this study; therefore a valid conclusion can not be made concerning this breed. Lucas (1965) reported that ultrasonic estimates on Durocs and Yorkshires were more accurate than those on Hampshires and Polands.

The average estimated loin eye area at the 10th rib for the 110 pigs in this portion of the study was 4.52 square inches and the actual loin eye area on the carcasses at the 10th rib averaged 4.50 square inches, shown in Table 1. Lucas (1965) and Sumption et al. (1964) reported the estimate tends to be higher than the actual area. The average loin eye area for the six groups was found to be correlated with the average error of estimation ($r = 0.66$), although not significantly. The value approached significance at the 5% level, however. In this study loin eye areas in 63 of the 110 pigs were overestimated. Since the actual and estimated areas were essentially the same, the underestimations in 46 cases had to be larger than the overestimations. The average overestimate and underestimation respectively were 0.35 and 0.44 square inch. In only one case were the estimated and the actual loin eye areas identical. The fact that more pigs were overestimated for loin eye area and that the average underestimation was larger than the average overestimation was partly explained by the method of plotting the estimated area. The range of actual loin eye areas was from 3.38 to 6.37 square inches. Therefore if the operator estimated the loin eye area near the mean 4.50 square inches, as was often done, and the actual area was near one of the extremes the

TABLE 1

MEANS AND STANDARD DEVIATIONS OF SOME TRAITS STUDIED

Item	Mean	Standard Deviation
Live weight (lbs.)	213.10	17.1
Actual loin eye area (sq. in.)	4.50	0.54
Estimated loin eye area (sq. in.)	4.52	0.38
Metal probe estimate of B.F. 1", 90° (in.)	1.30	0.28
Ultrasonic estimate of B.F. 1", 90° (in.)	1.30	0.27
Total estimated distance to bottom of loin eye at 2", 90° (in.)	3.02	0.33
Total estimated distance to bottom of loin eye at 3", 60° (in.)	3.06	0.37
Estimated loin eye depth 2", 90° (in.)	1.74	0.25

overestimation would be less than the underestimation.

In Table 2 are various correlation coefficients between certain live animal measurements. Depth of loin eye (difference between estimated ventral boundary and estimated backfat thickness) at 2 inches off the midline measured at 90°, was correlated with the ultrasonic backfat estimate at one inch, 90° and mechanical probe estimate of backfat at one inch, 90°. Simple correlations of -.21 and -.09, respectively, were observed. The second correlation was nonsignificant but the first was significant at the 5% level, indicating an association between the two variables, loin eye depth and backfat thickness.

TABLE 2

CORRELATION COEFFICIENTS FOR CERTAIN LIVE ANIMAL MEASUREMENTS

	Live wt.	Actual LEA	Est. LEA	Probe BF 1", 90°	Est. BF 1", 90°	Bottom of eye 2", 90°
Actual loin eye area	0.11	--				
Ultrasonic estimate of loin eye area	0.06	0.37**	--			
Metal probe estimate of BF at 1", 90°	0.32**	-.14	-.17	--		
Ultrasonic estimate of BF at 1", 90°	0.29**	-.18	-.20*	0.93**	--	
Distance to bottom of loin eye at 2", 90°	0.25**	-.01	0.13	0.58**	0.61**	--
Distance to bottom of loin eye at 3", 60°	0.27**	-.01	0.13	0.57**	0.58**	0.69**
Ultrasonic estimate of loin eye depth 2", 90°	--	0.07	--	-.09	-.21*	--

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

As backfat depth increased loin eye depth decreased, which would be expected in pigs of near the same weight. Estimated loin eye depth was not significantly related to the actual loin eye area as mentioned earlier. The mean estimated loin eye depth at two inches, 90° was 1.74 inches $\pm$0.25 inch. Massey et al. (1964) reported a mean depth of 1.74 inches $\pm$0.22 inch. Neither ultrasonically estimated distances to the ventral boundary of the loin eye at two inches, 90° nor three inches, 60° were significantly correlated with the actual loin eye area (r = -.01 and -.01).

Ultrasonic Estimate of Backfat Depth. Average depth of backfat for the 110 pigs was estimated by the sonoray to be 1.30 inches at one inch, 90°. The mean metal probe measurement of backfat at the same location was 1.30 inches also. The correlation between the two estimates was 0.93, very highly significant. Eighty-six pigs were estimated ultrasonically within 0.10 inch of the metal probe measurement. Alsmeyer *et al*. (1963) reported ultrasonic fat measurements were correlated (r = 0.80) with average backfat thickness on the swine carcass. Hedrick *et al*. (1961), DuMont and Destandau (1962), and Otlo and Sieg (1963) reported correlation coefficients between ultrasonically estimated backfat thickness and actual backfat thickness on the carcasses of swine, ranging from 0.70 to 0.99.

The regression coefficient of the estimated backfat, measured by the sonoray, on the estimated loin eye area was nearly twice as large as that of backfat, measured by the metal probe, on the actual loin eye area. The corresponding correlations were -.20 and -.14, the first being significant at the 5% level. The ultrasonically estimated backfat depth was slightly more accurate than the depth estimated by the metal probe in predicting actual loin eye area. All four regressions and correlations were small however.

Growth of Loin Eye Area

This part of the study involving data from 3024 barrows was mainly designed to investigate the relationship between loin eye area and live weight in swine.

Simple correlation coefficients were obtained between loin eye area, and actual live weight and adjusted live weight (live slaughter weight minus weight of stomach and intestines, times 112.5%). The correlation coefficients respectively were 0.17 and 0.28, both significant at the 1% level. The corresponding linear regression coefficients of loin eye area on live weight and adjusted live weight were 0.009 and 0.012. For each pound increase in live weight, loin eye area increased nearly one-hundredth of a square inch in animals weighing from 159 to 280 pounds. The 1141 barrows for which carcass weight was used to obtain an adjusted live weight (group 1) indicated a closer relationship between live weight and loin eye area than the 1883 barrows for which live weight was known (group 2). The relationship was higher in group 1, partly because adjusted live weight was not affected by the variable, fill. Group 2 was subdivided into four smaller groups according to live weight at slaughter; 180-199 pounds, 200-219 pounds, 220-239 pounds, and 240-259 pounds. A linear regression coefficient was computed for each of the four smaller groups to see if the rate of increase in loin eye area appeared to be linear over the range of live weights 180 to 259 pounds. The regression coefficients for the four subgroups were 0.022, 0.009, -.008, and -.002 respectively (Table 3).

TABLE 3

REGRESSION COEFFICIENTS FOR CERTAIN CARCASS AND LIVE ANIMAL MEASUREMENTS

Loin eye area on adjusted live weight	0.012
Loin eye area on actual live weight	0.009
Logarithm of loin eye area on actual live weight	0.001
Loin eye area on actual live weight for weights 180 to 199 pounds	0.022
Loin eye area on actual live weight for weights 200 to 219 pounds	0.009
Loin eye area on actual live weight for weights 220 to 239 pounds	-.008
Loin eye area on actual live weight for weights 240 to 259 pounds	-.002
Loin eye area on age at 200 pounds	-.017

This indicated the rate of increase in loin eye area decreased after the pig reached 200 pounds, therefore the growth of the loin eye area is not linear for the range 180-259 pounds. Sampling error and the large variation in data within subgroups caused the last two regression coefficients to be negative. The correlation coefficients corresponding to the four subgroups were tested, by the Z transformation method, to see if they could have been drawn from the same population. At the 5% level the differences among the four sample correlation coefficients were nonsignificant, although approaching significance; therefore they could have been drawn from the same population. Loin eye area growth was reported not to be linear by McCampbell and Baird (1961), Varney et al. (1962) and Babatunda et al. (1965), when related to live weight between 159 and 230 pounds.

The author postulated loin eye area increased at a percentage rate rather than in a linear manner; therefore, the overall linear regression coefficient of 0.009 was not used in the construction of the loin eye area adjustment table (Table 4). The regression of the logarithm of the loin eye area on live weight was obtained for the weight range 180 to 260 pounds. The equation $\hat{Y}_{200} = \log Y_1 - b\ (X_1 - 200)$ was used in constructing Table 4. The adjusted loin eye area equals the logarithm of the observed loin eye area minus the regression coefficient 0.0009 times the observed weight minus 200. The table can be used to adjust all loin eye areas to a standard 200 pound equivalent. Large loin eye areas were therefore adjusted more in relation to live weight than smaller ones. Some error may have been present in adjusting animals near 180 or 260 pounds because regression coefficients pertaining to these animals appeared to vary from the overall regression coefficient used in the table. If the error occurred it was relatively small and a linear adjustment could be used in a rather rough manner if the table were not available. For each pound the pig varied from 200 pounds the loin eye area could be adjusted one-hundredth of a square inch. Deal (1966) reported one-tenth of a square inch was used for an adjustment per 10 pounds live weight for boars and gilts up to 250 pounds.

The age of most of the barrows was not indicated in the data; therefore, several of the animals could have been fed a restricted diet or fed a specially designed ration which could have influenced loin eye area.

TABLE 4

AN ADJUSTMENT OF BARROW LOIN EYE AREA AT 10TH RIB TO A STANDARD WEIGHT OF 200 POUNDS

IF ACTUAL WEIGHT IS	AND ACTUAL LOIN EYE AREA IN SQUARE INCHES IS																						
	3.40	3.50	3.60	3.70	3.80	3.90	4.00	4.10	4.20	4.30	4.40	4.50	4.60	4.70	4.80	4.90	5.00	5.10	5.20	5.30	5.40	5.50	5.60
	READ 200 POUND EQUIVALENT MEASUREMENTS FOR A GIVEN WEIGHT AND LOIN EYE AREA BELOW																						
180	3.54	3.64	3.75	3.85	3.95	4.06	4.16	4.27	4.37	4.47	4.58	4.68	4.79	4.89	4.99	5.10	5.20	5.31	5.41	5.51	5.62	5.72	5.83
185	3.50	3.61	3.71	3.81	3.91	4.02	4.12	4.22	4.33	4.43	4.53	4.64	4.74	4.84	4.94	5.05	5.15	5.25	5.36	5.46	5.56	5.67	5.77
190	3.47	3.57	3.67	3.77	3.88	3.98	4.08	4.18	4.28	4.39	4.49	4.59	4.69	4.79	4.90	5.00	5.10	5.20	5.30	5.41	5.51	5.61	5.71
195	3.43	3.53	3.64	3.74	3.84	3.94	4.04	4.14	4.24	4.34	4.44	4.54	4.65	4.75	4.85	4.95	5.05	5.15	5.25	5.35	5.45	5.55	5.66
200	3.40	3.50	3.60	3.70	3.80	3.90	4.00	4.10	4.20	4.30	4.40	4.50	4.60	4.70	4.80	4.90	5.00	5.10	5.20	5.30	5.40	5.50	5.60
205	3.37	3.47	3.56	3.66	3.76	3.86	3.96	4.06	4.16	4.26	4.36	4.46	4.55	4.65	4.75	4.85	4.95	5.05	5.15	5.25	5.35	5.45	5.54
210	3.33	3.43	3.53	3.63	3.73	3.82	3.92	4.02	4.12	4.22	4.31	4.41	4.51	4.61	4.71	4.80	4.90	5.00	5.10	5.20	5.29	5.39	5.49
215	3.30	3.40	3.49	3.59	3.69	3.79	3.88	3.98	4.08	4.17	4.27	4.37	4.47	4.56	4.66	4.76	4.85	4.95	5.05	5.15	5.24	5.34	5.44
220	3.27	3.36	3.46	3.56	3.65	3.75	3.85	3.94	4.04	4.13	4.23	4.33	4.42	4.52	4.61	4.71	4.81	4.90	5.00	5.09	5.19	5.29	5.38
225	3.24	3.33	3.43	3.52	3.62	3.71	3.81	3.90	4.00	4.09	4.19	4.28	4.38	4.47	4.57	4.66	4.76	4.85	4.95	5.04	5.14	5.24	5.33
230	3.20	3.30	3.39	3.49	3.58	3.68	3.77	3.86	3.96	4.05	4.15	4.24	4.34	4.43	4.52	4.62	4.71	4.81	4.90	5.00	5.09	5.18	5.28
235	3.17	3.27	3.36	3.45	3.55	3.64	3.73	3.83	3.92	4.01	4.11	4.20	4.29	4.39	4.48	4.57	4.67	4.76	4.85	4.95	5.04	5.13	5.23
240	3.14	3.23	3.33	3.42	3.51	3.60	3.70	3.79	3.88	3.97	4.07	4.16	4.25	4.34	4.44	4.53	4.62	4.71	4.81	4.90	4.99	5.08	5.17
245	3.11	3.20	3.29	3.39	3.48	3.57	3.66	3.75	3.84	3.93	4.03	4.12	4.21	4.30	4.39	4.48	4.57	4.67	4.76	4.85	4.94	5.03	5.12
250	3.08	3.17	3.26	3.35	3.44	3.53	3.62	3.71	3.81	3.90	3.99	4.08	4.17	4.26	4.35	4.44	4.53	4.62	4.71	4.80	4.89	4.98	5.07
255	3.05	3.14	3.23	3.32	3.41	3.50	3.59	3.68	3.77	3.86	3.95	4.04	4.13	4.22	4.31	4.40	4.49	4.58	4.66	4.75	4.84	4.93	5.02
260	3.02	3.11	3.20	3.29	3.38	3.46	3.55	3.64	3.73	3.82	3.91	4.00	4.09	4.17	4.26	4.35	4.44	4.53	4.62	4.71	4.80	4.89	4.97

It is probably justifiable to assume several of the barrows had received special rations in an attempt to increase the loin eye area at a given weight. Crampton et al. (1954) reported any reduction in rate of gain, thus causing an older pig at market weight, will cause the meatiness of the carcass to increase, indicating relatively more muscle growth. A larger loin eye area at a given weight near 200 pounds was generally the result of restricting feed intake. Deal (1966) reported when adjusting loin eye areas to 200 pounds, loin eye areas from older hogs should be adjusted at a greater rate than ones from younger hogs at the same weight. In this study age at 200 pounds was correlated ($r = -.23$) with loin eye area for 371 barrows (Table 5). The regression coefficient of loin eye area on age at 200 pounds was -.02. The correlation and regression coefficients indicated that as age at 200 pounds decreased the loin eye area at 200 pounds increased. This appears to be in disagreement with Crampton et al. (1954), Cunha (1963) and others who have reported restricting feed intake reduced rate of gain. The negative association between age and loin eye area at 200 pounds was probably due to the faster growing pig reaching market weight before the fat deposition period of growth became prominent. Cummings and Winters (1951) reported a weight of 200 pounds may be obtained before excessive fat is deposited. The average age at 200 pounds in this study for the 371 barrows was 166 days ± 8.7 days (Table 6). It was theorized, since the management practices of the barrows were not recorded in the data, that most of the pigs were full fed; therefore, the pigs reaching 200 pounds earliest were still

TABLE 5

CORRELATION COEFFICIENTS FOR CERTAIN CARCASS AND LIVE ANIMAL MEASUREMENTS

	Loin eye area	Actual live weight	Adjusted live weight
Age at 200 pounds	-.23**	--	--
Percent ham and loin of the carcass	0.55**	--	--
Percent ham of live weight	0.37**	-.31**	0.07

**Significant at .01 probability level

TABLE 6

MEANS AND STANDARD DEVIATIONS OF SOME TRAITS STUDIED

Item	Mean	Std. Dev.
Adjusted live weight (lbs.)	215.5	15.5
Actual live weight (lbs.)	211.2	14.9
Loin eye area (sq. in.)[a]	4.39	0.67
Loin eye area (sq. in.)[b]	4.50	0.75
Percent ham of live weight	14.93	1.28
Percent ham and loin of carcass	40.23	2.36
Age at 200 pounds (days)	166.5	8.71

[a]Loin eye area for group of pigs where live weight was estimated by an adjustment.

[b]Loin eye area for group of pigs where actual live weights were available.

in the muscle development period of growth.

Twelve pigs, two groups of six each, were sonorayed weekly in an attempt to estimate the growth rate for loin eye area. The first six pigs over a five week period gained 52 pounds (170 to 222 pounds) and the loin eye area was estimated to increase 0.96 square inch, on an average per pig. Once a week each pig was weighed and sonorayed and the average weight and estimated loin eye area for the six pigs were recorded. For the first group the regression coefficient for weekly average estimate of loin eye area on the weekly average live weight was 0.018. The corresponding regression coefficient was 0.025 for the second group which gained 47 pounds (159 to 206 pounds), estimated loin eye area increased 1.34 square inches over a four week period. When the two groups were combined the regression coefficient for weekly average estimated loin eye area on weekly average weight was 0.020. The average weight of all pigs during the five week period was 187 pounds. The regression coefficient of 0.020 agrees with the regression coefficient (0.022) reported earlier in this discussion for the 180 to 199 pound range of weights, where the average weight was 193 pounds. The relationship between estimated loin eye area and live weight, for the twelve pigs, can be seen in Figure 1. A sound conclusion cannot be made concerning the growth rate of loin eye area, based on the data from only twelve pigs. However the regression coefficient of 0.02 indicates loin eye area increased at a rate larger than 0.01 square inch per pound increase in live weight in animals weighing less than 200 pounds.

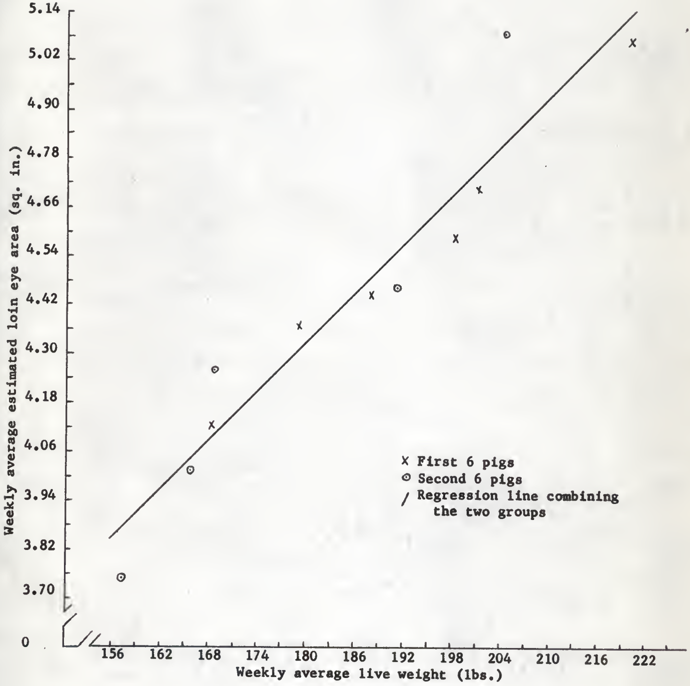

Figure 1. Relationship between live weight and estimated loin eye area in pigs.

Table 5 presents some additional correlations between certain live and carcass characteristics. Loin eye area was correlated with percent ham and loin of the carcass ($r = 0.55$) for 1358 barrows, indicating loin eye area is related to the weight of these two wholesale cuts. Zobrisky *et al*. (1954) reported percent live weight of ham, loin and shoulder was correlated with loin eye area ($r = 0.60$). The correlation coefficient between loin eye area and percent ham on a live weight basis was 0.37 for 1358 barrows in this study. It appeared loin eye area was not a good indicator of ham as a percent of live weight. Fredeen *et al*. (1955) found loin eye area at the last rib was correlated with ham weight ($r = 0.50$ to 0.66) while Topel *et al*. (1961) measuring loin eye area at the 10th rib, reported a correlation coefficient of only 0.08. Percent ham of live weight was correlated with actual live weight ($r = -.31$) and adjusted live weight ($r = -.07$) for 272 and 1086 barrows respectively, indicating weight of ham did not increase at the same rate as live weight for the weight range 159 to 280 pounds.

The averages for each characteristic for breeds plus the standard deviations and number of observations are presented in Table 7. Hampshires had the largest average loin eye area and percent ham and loin of carcass. Spots, Chester Whites, Landrace, and Tamworths combined had the largest average percent ham of live weight. Hampshires had the smallest average age at 200 pounds, although the advantage was slight. There was very little variation among breeds in adjusted and actual live weights.

TABLE 7

MEANS, STANDARD DEVIATIONS, AND NUMBER OF OBSERVATIONS FOR CERTAIN CARCASS CHARACTERISTICS FOR BREEDS OF SWINE

Breed		Adjusted live weight	Actual live weight	Loin eye area	Percent ham of live weight	Percent ham and loin of carcass	Age at 200 pounds
	Mean	216.6	207.7	4.15	14.05	38.43	168.8
Berkshire	Std. dev.	14.8	13.5	0.62	0.99	2.04	8.76
	No. obs.	80	39	119	82	28	52
	Mean	218.2	207.0	4.29	14.98	40.00	169.0
Duroc	Std. dev.	14.0	12.5	0.66	1.19	2.78	9.36
	No. obs.	82	162	244	104	43	37
	Mean	214.4	208.1	4.76	14.80	41.50	163.5
Hampshire	Std. dev.	14.6	13.1	0.69	1.22	2.15	8.99
	No. obs.	361	395	756	362	180	80
	Mean	216.8	211.0	4.61	15.26	39.86	166.2
Poland	Std. dev.	14.7	13.1	0.72	1.32	1.69	8.35
China	No. obs.	136	76	212	148	49	61
	Mean	216.4	209.1	4.19	14.38	39.98	165.1
Yorkshire	Std. dev.	17.3	13.6	0.62	1.21	1.67	10.13
	No. obs.	126	60	186	136	34	40
	Mean	216.2	211.0	4.45	14.55	40.18	165.7
Crossbred	Std. dev.	17.2	13.3	0.76	1.22	2.75	7.31
	No. obs.	185	109	294	211	70	34
All other	Mean	215.1	209.6	4.14	15.44	39.84	168.3
breeds	Std. dev.	16.0	15.4	0.62	0.97	2.10	6.91
combined	No. obs.	138	82	220	152	45	67

SUMMARY AND CONCLUSIONS

This study evaluated the use of ultrasonics for predicting backfat thickness and loin eye area and included a study of the growth of loin eye area in swine as related to live weight. An estimation of loin eye area at the 10th rib was made on 110 pigs weighing from 183 to 265 pounds to test the accuracy of ultrasonics at weights other than 200 pounds. A Branson Sonoray Model 12 Ultrasonic Animal Tester was used to estimate loin eye area on the 95 barrows and 15 gilts. In most cases the estimates were made the day before the animals were slaughtered. Estimates of backfat depth were obtained ultrasonically and by use of a metal probe at one inch off the midline at a 90° angle over the 10th rib. In the carcass the loin was cut at the 10th rib, the loin eye area traced, and a planimeter was used to measure the loin eye area indicated by the tracing. The correlation coefficient between estimated loin eye area and actual loin eye area was highly significant ($r = 0.37$). Actual loin eye area was not significantly correlated with estimated backfat thickness at one inch, 90° ($r = -.18$). Estimated depth of the loin eye at two inches, 90°, was essentially independent of actual loin eye area ($r = 0.07$).

The average error in estimation (difference between the estimated loin eye area and actual loin eye area) was 0.38 square inch. The average error was greater for pigs weighing over 225 pounds and for pigs with less than 1.0 inch backfat or over 1.5 inches backfat over the 10th rib at one inch, 90°. The average error increased as the variance of the actual loin eye areas per group increased. Variance in estimated loin eye area was only half as large as the variance in actual loin eye areas. This was a result of the operator estimating loin eye areas nearer the average than the large actual areas.

The lateral and ventral boundaries of the loin were the most difficult to identify with the ultrasonic device. Length of the loin eye (distance from the medial boundary to the lateral boundary) was underestimated often on pigs with long loin eyes. Loin eye area was overestimated more often than it was underestimated although the average estimated area was 4.52 square inches and the average actual loin eye area was 4.50 square inches.

Durocs and Yorkshires were estimated more accurately than Poland Chinas or Hampshires, while Crossbreds were estimated with near average accuracy.

A correlation coefficient of 0.93 was observed between ultrasonic estimate of backfat depth and backfat depth measured by the metal probe over the 10th rib of the longissimus dorsi muscle at one inch, 90^{o}. The average ultrasonic estimate of backfat depth at one inch, 90^{o} was 1.30 inches and the average estimate obtained using a metal probe at the same location was also 1.30 inches.

The accuracy of the ultrasonic device in this study depended on live weight, backfat thickness, shape and size of loin eye, and breed. Due to these variables and the cost in time and money to obtain the estimate, in the immediate future, use of ultrasonics will be restricted mainly to the producer employing the services of an experienced operator to interpret the results.

Data from 3024 barrows were obtained and used to study the growth of loin eye area between 180 to 260 pounds and to develop an adjustment table for correcting loin eye area to a standard live weight of 200 pounds. The relationship between loin eye area and live weight adjusted to a standard fill and actual live weight at slaughter was significant but rather low. The correlation coefficients between loin eye area and adjusted and actual live weights were 0.28 and 0.17 respectively. The corresponding regression coefficients were 0.012 and 0.009. An adjustment table was developed using the equation $\hat{Y}_{200} = \log Y - b\ (X_1 - 200)$. The table can be used to adjust loin eye areas at a rate near 0.01 square inch per pound of live weight above or below 200 pounds. Growth of loin eye area was not linear for the weight range 180 to 260 pounds but an average regression for the entire range was used for developing the table.

Loin eye areas were ultrasonically estimated for twelve pigs weekly and compared to the live weights at the time the estimates were made. The regression coefficient was essentially the same as the one obtained for barrows in the 180 to 199 pound weight range in the group of 3024 barrows. The adjustments were greater for pigs below 200 pounds than for those above 200 pounds, therefore the table was somewhat biased since the overall regression coefficient was used. Both loin eye area and weight are a function of age which appeared to affect loin eye area at a given weight. The regression coefficient of loin eye area on age at 200 pounds was -.017 for 371 barrows; indicating the faster growing hogs had larger loin eye areas. This is probably partially explained by the fact the faster growing hogs apparently reached a weight of 200 pounds before excessive fat was deposited.

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ACCURACY OF ULTRASONICS AT VARIOUS WEIGHTS IN SWINE AND ADJUSTMENT OF LOIN EYE AREA TO A STANDARD LIVE WEIGHT

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Accuracy of ultrasonics in estimating loin eye area and backfat depth at the 10th rib in swine of various weights was studied. The growth of the loin eye area and its relationship to live weight was also investigated. A Branson Sonoray instrument was used on 110 pigs to estimate the area of the longissimus dorsi muscle and backfat depth at the 10th rib. The actual loin eye area obtained from the carcass and the backfat depth measured by the metal probe at the same location were highly significantly correlated with the corresponding ultrasonic estimates ($r = 0.37$ and 0.93 respectively). The average error in estimating loin eye area (difference between estimated and actual loin eye area) was 0.38 square inch. More animals were overestimated than underestimated although the average estimate and average actual loin eye areas were 4.52 and 4.50 square inches, respectively. Average error for pigs over 225 pounds was greater than for pigs between 175 and 225 pounds. The average error increased for pigs having less than one inch backfat or more than 1.5 inches of backfat at the 10th rib. Very small or large loin eye areas increased the average error also. It appeared the operator tended to predict loin eye areas nearer the average, thereby restricting the variance of the estimates to one half the variance of the actual measurements. Estimated loin eye depth at two inches off the midline at 90° was only slightly related with actual loin eye area ($r \doteq 0.07$). The correlation between actual loin eye area and the ultrasonic estimate of backfat thickness at two inches, 90°, was not significant ($r \geq -.18$). The ultrasonic estimates of loin eye area were more accurate on Durocs and Yorkshires than on Hampshires and Poland Chinas.

Data from 3024 barrows entered in several carcass contests were collected to study the growth of loin eye area and its relation to live weight. Loin eye area was regressed on live weight for four groups, 180-199, 200-219, 220-239, and 240-259 pounds. Increase of loin eye area was not linear for the live weight range of 180 to 259 pounds because loin eye growth rate was greater in animals weighing less than 200 pounds than for those above 200 pounds. Twelve pigs each were sonorayed and weighed once a week to estimate the loin eye area as related to live weight. The regression coefficient between the weekly average estimated loin eye area on the weekly average live weight was 0.02, which agreed with the coefficient for carcass contest barrows weighing from 180 to 199 pounds. The regression coefficient of the logarithm of loin eye area on live weight was used in an equation for adjusting all loin eye areas to a 200 pound live weight basis. The equation, $\hat{Y}_{200} = Y_1 - b\ (X_1 - 200)$, was used to develop a table for adjusting loin eye areas in hogs of various weights to a live weight basis of 200 pounds. The simple regression coefficient of the logarithm of loin eye area on live weight for the weight range 180 to 260 pounds, used in the table, adjusted loin eye area approximately 0.10 square inch per 10 pounds change in live weight.

Breed differences, correlation coefficients, and regression coefficients between several of the characteristics studied were reported.