THE USE OF ULTRASOUND IN MEAT ANIMAL EVALUATION

By

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AN ABSTRACT

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ABSTRACT

Improvement of slaughter livestock through breeding and selection programs has been hampered by difficulty in recognizing desirable carcass traits in the live animal. This study was instigated to determine the practical applicability of an ultrasonic reflection method for measuring fatness and muscling in live meat animals.

A Sperry Reflectoscope (Type UR, Style 50E401) was applied to measurement of subcutaneous fat thickness and depth of the Longissimus dorsi muscle of cattle and hogs. In cattle, the relationship of ultrasonic estimates of fat thickness to actual carcass measurements was low. In an attempt to measure the depth of the rib eye muscle of cattle, depth estimates were positively associated with actual depth measurements, but the relationship was too low to be of practical value.

Fat thickness of live swine was accurately determined by the ultrasonic technique. Correlation coefficients for ultrasonically determined fat depth with mechanically measured fat depth were .72 to .91 for two different groups of swine. Experience with the first group (Group A) seemed valuable, since higher correlation values were found in the second group (Group B). Considering the data from both groups, it was concluded that fat thickness estimates made with the ultrasonic probe were equal to mechanical probe values or carcass measurements for prediction of lean cut yield. Correlation coefficients for a variety of fat depth determinations with lean cuts (carcass basis) were in a range from .70 to .80.

Regardless of the method used for measuring fat thickness, these indirect measures of leanness based on fatness were the most accurate indicators of total leanness in swine. Correction for slaughter weight improved the relationships slightly.

The velocity of ultrasound (2.25 megacycles per second) through the fatty tissues of live swine as computed from regression equations ranged from 1525 to 1800 meters per second with an average of 1660 m/sec. when live mechanical probe values were used as the basis of calculation. Velocity varied within and between animals, and it was concluded that a range of 1500 to 1900 m/sec. probably existed in this study. The velocity of ultrasound through the fat of unchilled swine carcasses appeared to be greater than that in live pigs.

The ultrasonic device proved to have little value for measuring the depth of the loin eye muscle of swine when using a quartz crystal transducer. Lean cut yield was not accurately predicted from ultrasonic estimates of loin eye muscle depth.

Loin eye area was highly related to lean cut yield in Groups A and B. Combining loin eye area and backfat thickness for the prediction of lean cut yield resulted in some improvement in the relationship in Group B.

Rough approximations of the velocity of ultrasound through lean tissues of swine were within the range found for the velocities in fatty tissue. Animal movements, velocity variations, live animal and carcass position differences, softness of flesh, and inherent errors within the ultrasonic equipment could have resulted in erroneous measurements with the ultrasonic device.

A transducer made with a ceramic crystal (Type Z) facilitated more accurate measurement of lean depth. The depths of tissue layers and angles of radiation of ultrasound were valid in one group of cattle (Group III) and one group of hogs (Group C). Plots resembling a loin cross section was made from data collected by means of the ultrasonic equipment. The area of the rib eye muscle of cattle was not accurately estimated by this procedure, but the loin eye area of swine was closely predicted, with a correlation coefficient of .74 with actual area.

It was postulated that improvements in equipment design along with adequate familiarization will make possible accurate measurement of fat thickness and the size and shape of certain muscles in both live swine and cattle.

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INTRODUCTION

Over the past few decades changes in consumer demands have resulted in a shift in the emphasis placed on factors considered desirable in a meat animal. Decreased demand for lard and other fat products, together with consumer discrimination against fat meat, has led to selection programs designed to foster the production of meat animals with optimum fat to muscle ratios. More recently, the aim has been not only to reduce fatness in meat, but also to select for desirable muscling.

In order to evaluate the relative merit of an animal or carcass, edible yield and eating quality have become primary considerations. Since eating quality is a rather evasive property, many evaluation procedures rely principally upon the proportion of fat to lean and upon the size and distribution of muscles. Chemical analysis of the entire carcass, complete physical separation into different components, or muscle by muscle dissection have been considered the basic techniques for measuring relative values. These methods are partly or totally destructive and greatly lower the value of the experimental carcass. The method of separation into trimmed retail cuts is less destructive and has also served as a basic method for evaluating slaughter livestock. A multitude of simpler or less costly indices and techniques have been proposed and compared to the basic methods. Analysis of sample cuts, measurement of external fat thickness, carcass measurements, and the ratio of fat to lean in sample cuts have all been used in evaluation studies.

In order to incorporate carcass evaluation in selection of breeding stock, it has been necessary to slaughter the sibs or progeny of the sires and dams under test. Among the methods that may be applied to field use, the live probe, lean meter, live measurements, and subjective judgments are techniques which allow evaluation without necessitating slaughter. However, these procedures are often unsatisfactory in yielding precise information on ultimate carcass value and quality, and give little insight into the amount of muscling in living animals.

Whether it be on the carcass in a slaughter plant or in living animals, most commercial evaluations rely upon subjective judgments of fatness and body conformation. Researchers in the livestock selection and carcass evaluation areas have been seeking procedures that are simple, accurate, and complete for objective information that may lead to more rapid progress in livestock improvement.

European workers (Lauprecht, 30; Dumont, 11; and Claus, 5) and Temple et al. (55) in this country have successfully applied ultrasonic reflection methods to measuring subcutaneous fat depth in live meat animals. Ultrasonic measurements of fatness have been shown useful in swine evaluation, and this technique is now being employed as a regular procedure in testing programs of some European countries.

This study was undertaken to determine the merit of a commercially available ultrasonic metal testing instrument for measuring not only the subcutaneous fat of swine and beef animals, but also to determine its applicability for determining the depth and size of certain muscles.

REVIEW OF LITERATURE

Livestock and Carcass Evaluation

Harrington (17), citing 373 references, has published an excellent review on methodology and comparison of techniques in swine carcass evaluation. Live hog scores and carcass measurements did not prove adequate for precise prediction of pork cutting yields (2). Chemical separation of a carcass into fat, protein and moisture has been postulated as the most accurate evaluation technique (57) and this method has been extensively employed in comparison with other methods (46, 58, 48, 37, 47).

Physical dissection or separation of a carcass or sample joint into fat, lean and bone has been utilized as a basis for many evaluation studies (7, 16, 35). In pork, the yield of the lean cuts (43, 41, 46, 40, 48, 42) and other cutting yields tend to parallel the prediction of fatness and leanness by other methods. In beef, the yield of certain wholesale cuts (38) and other cutting percentages (27, 29) have been utilized as indices of carcass value.

Many indices of carcass traits have been studied with the aim of simplifying evaluation procedures (40, 42, 45, 46, 41, 43, 37). Of these indices, fat thickness measures, loin eye area, and density determinations have come into somewhat consistent usage.

Fat and body water dilution techniques have shown promise as methods of determining fat and lean (48, 58, 28). However, Saffle *et al.* (48) indicated that the simple live probe was as adequate as creatinine measures for prediction of carcass composition.

Eye appraisal of fatness (2) and the live probe techniques (46, 44, 22) have served as the methods in principal use for live animal evaluation.

Principle of Ultrasound Generation and Its Application in Non-Biological Fields

Nelson (36), in a review article, summarized the properties of sonic waves and reported that sonic wave vibrations of frequencies between 16 and 20,000 cycles per second are audible to the human ear. Vibrations above 25,000 cycles/sec. are inaudible and fit into the ultrasonic range. Wood (62) stated that a voltage applied to the faces of crystals (i.e. quartz or Rochelle salt) produces corresponding changes in dimensions. Alternating the voltage causes alternating stresses and strains. When the frequency of such alternating voltages coincides with one of the possible modes of vibration of the crystal slice, a large resonant vibration will occur (62). Nelson (36) stated that the most widely used methods employed a piezo electric crystal, but he pointed out several other modes of generating ultrasound. Quartz discs may be mounted and placed in oil as a transmitting substance or cemented directly to the diaphram of the transducer or "sound head" (36).

Sonic and ultrasonic waves can not pass through a vacuum but require some material for their propagation. They travel approximately four times as fast in liquids and up to twenty times as fast in solids as in air. Ultrasonic waves have unique properties not observed in audible sound waves. They travel in straight lines, are completely reflected at the interface between two media if the critical angle is exceeded, exhibit interference phenomena and are refracted. In some respects ultrasonic waves may be said to have optic properties (36).

Firestone (12), describing the principle of the supersonic reflectoscope, stated, "a quartz crystal making contact with the work through a film of oil sends into the work a wave group consisting of a few sound waves of short wave length. This wave group is reflected from the side of the work most distant from the crystal, and upon striking the crystal generates in it a voltage where time of arrival is indicated on a cathode ray oscilloscope."

"A quartz crystal makes effective contact with the work through a thin film of oil on the surface. The upper and lower faces of the crystal are provided with conductive coatings and the crystal has the property that when an oscillatory voltage is applied between these coatings the crystal grows thicker and thinner in synchronism with the electrical oscillations. This causes the lower face of the crystal to vibrate and thereby radiate sound waves through the oil film into the solid. By proper choice of the thickness of the crystal, it will give a thickness resonance, and correspondingly increase the strength of the sound waves radiated. The sound waves are not radiated continuously but only for a short time interval; typical operation would consist in applying 500 volts to the crystal at 5 megacycles per second (mc.) for 1 microsecond. Thus, a group of only 5 waves is radiated, the wavelength in steel or aluminum at this frequency being approximately .050 inch and the total length of the wave group .250 inch. If the crystal is .5 inch square, the waves will be radiated in a beam, like a searchlight beam whose cross section is .5 inch square. Since the longitudinal velocity of sound waves in steel or aluminum is approximately 250,000 inches/sec., the waves travel 1 inch in 4 microseconds and in a block 4 inches deep the wave group will be approaching the bottom about 15 microseconds after leaving the crystal. This wave group will be reflected and return to crystal in 32 microseconds after its generation. The pressure of the returning waves generates a small voltage in the crystal, which is amplified and indicated on a cathode ray oscilloscope."

Firestone et al. (13) described a circuit for generation of the high frequency voltage trains whereby ultrasonic waves were generated for supersonic reflectoscopy. Butler and Vernon (3) applied an ultrasonic technique to measuring minute differences in metal thickness for non destructive inspection of forgings and castings. They reported that all measurements were accurate within 2 percent and in some instances the reflectoscope appeared more accurate than a micrometer.

Sau-chih Liu and Hsien Wu (54) observed that oxidation was promoted by ultrasonic radiation. They found that oxygen was directly activated by ultrasonic moderation which readily formed hydrogen peroxide and liberated iodine from iodide. Szent-Györgyi (53) observed that highly polymerized compounds such as starch, gum arabic and gelatin were easily dipolymerized by 723 kilocycle per second (kc.) ultrasonic radiation. However, he concluded that ultrasonic radiation was not the direct cause of breaking chemical bonds.

The Application of Ultrasonics in Allied Biological Fields and the Properties and Effects of Ultrasound in Tissues

Ultrasound has been applied in both medical therapeutics and diagnostics (36, 56, 26). Coupled with medical research, the effects and properties of ultrasound on living matter have created considerable interest (19, 18, 32, 61, 10, 14).

Both vibrations and the heat produced by ultrasound have been utilized in medical therapy (36, 8). Nelson (36) and Van Went (56) have reviewed the applications of ultrasonics in physical medicine. However, this aspect is not so closely allied to meat evaluation to warrant a complete review.

Closely related to the use of ultrasonics for evaluating meatiness has been its application in medical diagnostics or for location of certain tissues or objects in vivo. Ludwig and Struthers (33), Wild (59, 60) and Ballantine _et al._ (1) have shown that ultrasound can be used to detect the denser tissues in vivo, and thus it was possible to detect tumors, gallstones, and other abnormalities by sonic methods. Howry and Bliss (23), by an appropriate design of instruments, were able to produce cross sectional pictures of living tissues. Their methodology involved not only the simple sonic reflection as produced in reflectoscopic studies, but also a sweep scan technique where it was possible to visualize a portion of the cross section on the oscilloscope.

Using modified techniques, Howry _et al._ (29) have shown that it is possible to produce three dimensional photos of living tissues. By a stereoscopic technique, they were able to reduce the artifacts or false echos on cross sectional pictures of tissues. More recently Kelly (26) has published the presentations of various workers on ultrasonics as applied to biological and medical studies. Wild and Reid, as cited by Kelly (26), presented findings on detection and visualization of tumors and cysts in the human body by an ultrasonic scanning method. Two dimensional echograms enabled these workers to visualize internal parts of soft tissues. In the same text (26), Howry has shown clear cross sectional diagrams of various body parts obtained by the somascope. Much of Howry's presentation dealt with the development of instrumental modifications which allowed simultaneous horizontal and circular scanning. As a result of the improved design, false echoes were eliminated from the final picture. A discussion of instrumental design and considerations involved in ultrasonic visualization of tissues was presented.

The study of the effects of ultrasonic waves on various tissues and living organisms has proceeded over a number of years. Wood and Loomis (63) in 1927 showed that sound waves of .3 to .5 mc. generated by a piezo electric crystal operated at 50,000 volts caused unicellular organisms to swell, become immobile and die. Some bacteria were not killed. Small fish and frogs were killed by 2 minutes exposure, although the temperature was held constant. A mouse was immobilized by 20 minutes exposure, but recovered after treatment was stopped.

Working in the range of frequencies from 300 to 2,500 kc., Harvey (19) has observed a variety of effects on living cells, "a drop of water is broken into a fine mist. Elodea cells show rapid whirling of the chloroplasts and breaking up of these bodies and the plasma membrane. Blood corpuscles are laked. - - - - -. Skeletal muscle, nerve and luminous cells are not readily stimulated. Small fish can be killed, - - -." Harvey and Loomis (20) observed heating and great agitation of media by ultrasound, but luminous bacteria were killed even when the temperature was controlled.

Nelson's review (36) pointed out that the physiologic effects of ultrasonic waves were not well understood. Various tissue changes could be produced depending on the dosage. Tissues were found to be heated by propagation of ultrasonic vibrations through them (8, 1). Severe tissue damage could be produced, yet it was stated that this damage was due to heat only (8), and pain served as a protective measure. Nelson's review (36) revealed that pain is related to frequency. Ballantine (1) found that 800 kc. ultrasound injured the skin when applied at 5 watts/sq. cm. for 10 minutes. Pain occurred in deep tissues at 2 watts/sq. cm. for 40 sec. No pain was observed at 1.8 watts/sq. cm., and Ballantine (1) reported Dussik's work where no brain damage was observed at 1 watt/sq. cm. regardless of the duration. Nelson (36) reported that one of the drawbacks in the use of ultrasonics in medical therapy was the difficulty of accurately measuring applied intensities or dosage. Ballantine (1) with 2.4 mc. ultrasound at 3 watts/sq. cm. for 11.5 min. produced no evidence of histological damage. He concluded that valuable data on brain tumors could be obtained using ultrasonic transmission at intensities and durations below the pain threshold.

Fry _et al._ (14), studying the non-temperature effects of ultrasonic radiation on tissue, reported that 1 mc. ultrasound at 35 watts/sq. cm. was without effect on the wave form of the spike potential or propagation velocity of an excised peripheral nerve, even after prolonged exposure. However, frogs positioned so that ultrasound was indicent on the dorsal surface over the spinal cord exhibited paralysis of the hind legs after 4.3 seconds exposure at room temperature and after 7.3 seconds at 1.0 to 2.0°C. Histological examination showed extensive nerve degeneration. Fry's (14) studies indicated that paralysis may occur in the absence of high temperature levels.

Gersten (15) noted a reversible decrease in the creatine phosphate level of frog muscle exposed to 1 mc. ultrasound at 3 watts/sq. cm. Prolonging the exposure time produced no further decrease and the changes were independent of temperature. He postulated that the effect on creatine phosphate might have been due to the effect of ultrasonic waves on membranes.

A symposium (26) on the effects of ultrasound, dosage studies, and biological considerations was not summarized. However, it was apparent that gross tissue damage was produced by ultrasound at certain intensities and the problem of correct dosages for particular applications was debatable. The damaging effects of ultrasound at certain intensities was unquestionable (34). However, the question of permanent damage at higher frequencies and lower intensities where no pain results remains uncertain.

Ludwig (32) stated, "The choice of frequency for medical purposes involves many considerations, - - - -. In diagnostic applications, where resolution is of great importance, the choice of frequency must be a compromise, low enough to offset the increasing attenuation with increase in frequency and high enough to provide sufficient resolution." Previous experiments (32) showed that the 1.0 to 2.5 mc. was the most desirable frequency range. Claus (5) found a frequency of 2.5 mc. proved especially satisfactory for use on swine.

Claus (5) reported that the velocity of ultrasound in water was 1400 meters/sec. (m/sec.) at 25°C. and varied with temperature. Ludwig (32) found the velocity of ultrasound through various internal hog tissues was fairly consistent, ranging from 1500 to 1558 m/sec. The velocity in human muscle was reported as 1540 m/sec. In boneless beef, Ludwig (32) reported velocities of 1575 and 1585 m/sec. He stated that the effect of fiber direction did not show a significant effect on velocity.

The velocity of ultrasound in fat of living swine was reported to vary with body location (11). Hazel and Kline (21) stated that the velocity of sound through aluminum was 4.125 times as great as in warm pork fat. Stouffer (51) has assumed 1520 m/sec. to be the average velocity in live animal tissue.

Application of Ultrasonics to Live Animal and Carcass Evaluation.

Temple *et al.* (55), using the somascope of Howry and Bliss (23), found highly significant correlation values between actual fat thickness and somascope estimates on 60 beef animals. The total correlation coefficient was .39 and when the effect of sex was removed a value of .63 resulted. They concluded that with these values the ultrasonic device gave a fairly accurate means of estimating fat thickness in live cattle.

Lauprecht *et al.* (30) obtained accurate measures of backfat thickness in swine using an echo sounding device similar to the reflectoscope (12). There was considerable fluctuation in sounding measurements due to variations in positioning the sound head along the backline. Thus, it was necessary to mark the exact site of sounding for comparison with ruler measurements. There was approximately .40 cm. difference between average fat thickness as measured by sound on the live animal and as measured on the hanging carcass with a ruler. However, sounding measurements taken on the hanging carcasses differed only .01 cm. from the corresponding ruler measurements, indicating that the spacial orientation of the animal and/or properties of the fat were important considerations in the comparisons. Lauprecht *et al.* (30) concluded that the adapted impulse-sound device could be used to measure fat thickness of living swine with sufficient accuracy for usefulness in selection.

In connection with problems of calibrating an ultrasonic instrument and choice of optimum investigation conditions, Claus (5) has shown that the temperature of the water influenced the velocity of ultrasound propagated through it, and that the water content of swine fat influenced the ultrasonic velocity. Dumont (11), who has found variations in sound velocity from one location to another on pigs, reported that sounding thickness measurements may vary in accuracy due to individual animal, location or temperature differences.

Johnson and Platt (25) reported that measurements of fat thickness on swine via an ultrasonic reflection device compared favorably with existing methods for fat measurement. Ultrasonic estimates of average fat thickness were correlated (.79) with carcass ruler measurements. They reported that softness of flesh, animal movements, and velocity variations may have been introducing errors in ultrasonic determinations of fat thickness.

Hazel and Kline (21) found that an ultrasonic porbing device was equal in accuracy to a mechanical probing procedure on the live animal, or to carcass backfat measurements for predicting the percentage of lean cuts for swine. Using a 2.5 mc. frequency, they obtained a partial correlation coefficient of -.90 between ultrasonic measurements of fat thickness and percentage lean cuts. Measurements on beef cattle were reported as "not very successful".

Dumont (11) discussed the principles of ultrasound and their application to swine evaluation. His studies showed, in general, a good relationship between soundings on live pigs and measurements taken after slaughter. Variations in "average velocity" from one anatomical location to another were proposed to explain deviations. He reported that average velocities in fat of pigs at three locations were 1730 m/sec. over the neck, 1850 m/sec. over the last rib and 1980 m/sec. over the last lumbar vertebra. The agreement of sounding measurements and carcass measurements at a single location was illustrated by a correlation value of .975.

Stouffer (51) described a procedure for determining the area of the rib eye of beef or the loin eye of swine from data collected by using an ultrasonic probe. The method consisted of plotting fat and lean depth readings at recorded angles of radiation. Stouffer et al. (50, 52) reported simple correlation values from data collected on several groups of cattle and hogs. Fat thickness in live swine was measured with seemingly consistent accuracy with correlations between sounding and ruler measurements ranging from .91 to .98. The area of the loin eye in swine as estimated from ultrasonic data was significantly correlated with carcass tracing measurements; with correlations ranging from .40 to .84. The depth of the loin eye as predicted by ultrasonic probing was not consistently accurate. Ultrasonically measured fat depth of cattle was not as highly correlated with actual measurements as in swine. However, the ability to accurately predict rib-eye area was illustrated in beef animals (52) with correlation values of .49, .22 and .85 for three different groups of animals.

Campbell et al. (4) utilized the somascope to measure the depth of the Longissimus dorsi muscle of sheep at several distances off the spinal column. These measurements were significantly correlated with depth measurements taken from carcass tracings. Correlation values of .68 and .49 were obtained for two different groups of animals. The sum of muscle depth measured ultrasonically was significantly related to loin eye area.

EXPERIMENTAL PROCEDURE

Experimental Animals and Grouping

Three groups of beef animals and three groups of swine were used in this study. All of the beef animals had been on feeding trials at the Michigan Agricultural Experiment Station. The swine for this experiment came from a variety of sources and breeds. Some had been used in feeding trials, others came from progeny testing experiments, and some had been produced under normal farm conditions. No attempt was made to segregate the animals according to source or environmental background.

The 16 steers in Group I were used in a preliminary trial to familiarize the workers with the ultrasonic equipment and possible applications. With the 38 steers of Group II, an attempt was made to measure fat and lean depth with ultrasonics. A procedure designed to estimate the loin eye area was applied to the 14 steers in Group III.

The techniques of handling and measuring the 74 hogs of Group A differed from those applied to the 84 animals of Group B, thus, the data were treated separately. Group A consisted of 12 Yorkshire, 9 Chester White, 22 Duroc, 2 Tamworth, 4 Hampshire and 25 crossbred pigs. Group B consisted of 7 Yorkshire, 14 Duroc, 3 Chester White, 20 Hampshire, 3 Poland China, 7 Berkshire, 11 Yorkshire-Chester White crossbred, and 19 miscellaneous crossbred pigs. Only the procedure for determining the eye muscle size was used on the 41 hogs of Group C.

Slaughtering

All of the animals were slaughtered in the University Meats Laboratory using standard procedures (6, 9). Live and carcass weights or cutting yields were not recorded for any of the beef animals. The hogs were weighed and taken off feed approximately 24 hours prior to slaughter, but allowed free access to water. The weight taken just prior to slaughter was used for computing all yields based on live weight.

The hogs were dressed packer style; i.e. head off, jowls attached, leaf fat removed, ham faced but with the facing left attached. The carcasses were chilled at approximately 35°F. for 48 hours before cutting.

Ultrasonic Equipment

The ultrasonic device used in this study was a Sperry Reflectoscope, Type UR, Style 50E401. In all procedures a straight beam crystal transducer was employed. For Groups I, II, A and B, the 2.25 mc., 1 inch diameter transducer furnished by the manufacturer was employed. One and 5 mc. frequencies were tried but were not as aatisfactory as 2.25 mc. For estimation of eye muscle area, a type Z, 2.25 mc., $\frac{1}{2}$ inch diameter transducer manufactured by Branson Instruments, Inc., and made of a new ceramic crystal material was used. The new transducer allowed greater penetration of tissues and gave greater resolution of reflection peaks.

In the earlier studies (Groups I, II, A and B), no attempt was made to set the sweep length so that the depth of tissue layers could be read directly from an inch scale pasted on the oscilloscope. Instead, the instrument was set so that the reflection peak for the 6 inches of aluminum corresponded to a standard mark on the scale. The standard setting was held constant in each group of animals, but was varied between groups as experience dictated, in order to more confidently distinguish the fat and lean interfaces.

After sufficient data had been collected for an estimate of the average velocity of ultrasound in fat and lean, the machine was set for direct reading in inches of fat or lean. This was the case in Groups III and C. The reject, pulse length, and sensitivity or power settings were adjusted for each animal, in attempting to obtain clearer resolution of the peaks and to confidently select the reflection from the deeper loin eye interface.

Live Animal Measurements

In Group I, the depth of fat and depth of the rib eye muscle over the last rib, 3-4 inches off the midline was recorded in arbitrary units from a linear scale, which was attached to the oscilloscope. The sweep length was set so that the peak for 6 inches of aluminum read 1.05 inches on the scale. The last rib was located, the hair clipped closely, and an abundance of motor oil applied to the skin for sonic contact.

In Group II, the procedure was the same except that the peak for 6 inches of aluminum was set at 3.0 for fat readings and at 1.5 for lean depth readings. This yielded an enlarged conception of fat thickness.

The procedure for estimating the rib eye muscle area as described by Stouffer (51) was used in Group III. The transducer was fastened in one end of a hollow tube to which was attached an angular scale and indicator needle (see Fig. I). A strand of lead solder wire was formed to the shape of the cross-sectional contour of each steer's back and the shape transferred to a sheet of paper. The left side of each animal was marked at 1 inch intervals from 1-10 inches from the midline. Each reflection was recorded along with the angle of radiation at each mark. Using the contour line previously made, the data was plotted and the eye muscle

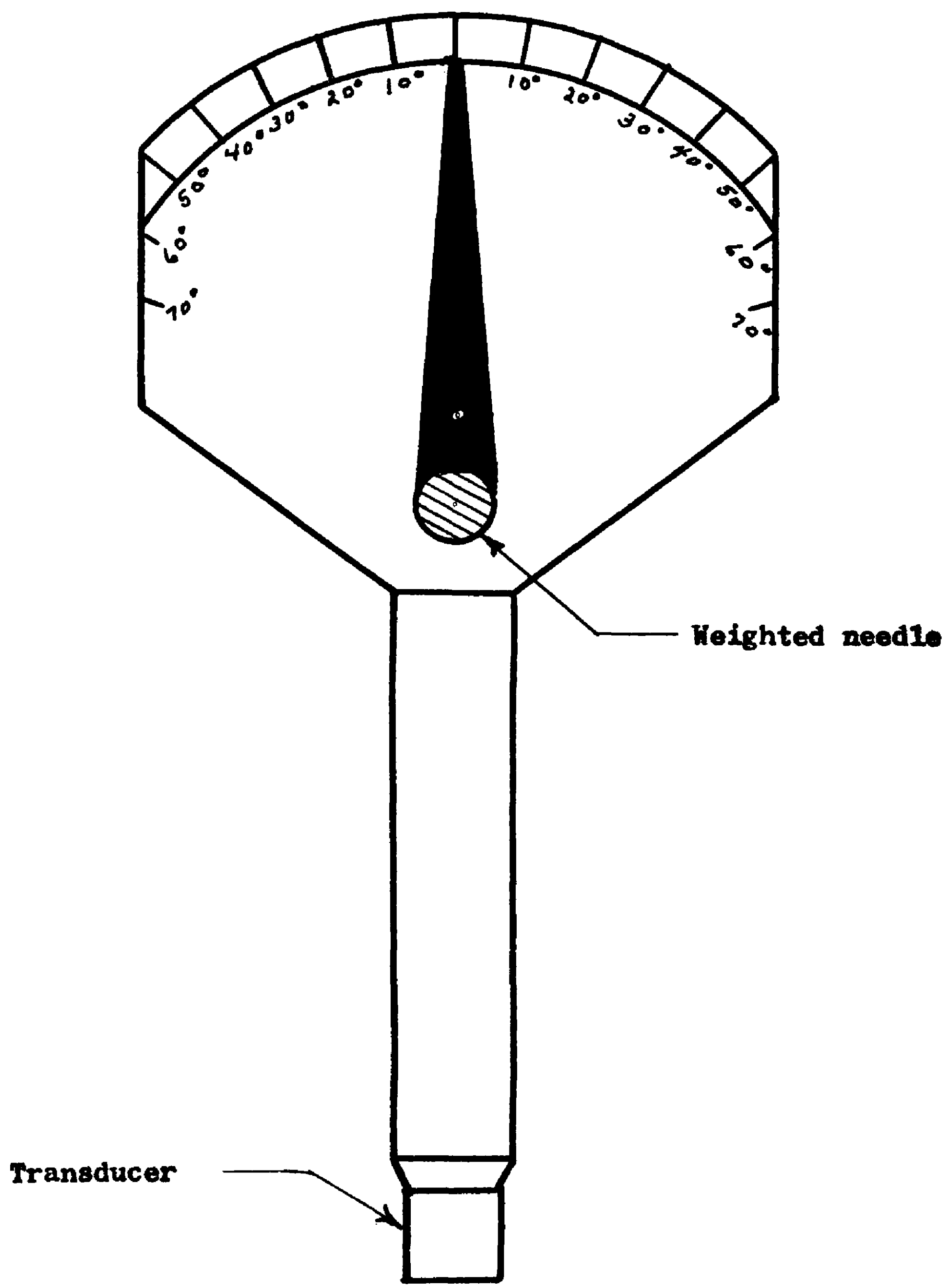

Figure I. Transducer and Angular Scale

perimeter drawn by following the most logical sequence of points. (see Fig. II). For these measurements, the sweep setting placed the peak for 4 inches of aluminum at 1.0 on the oscilloscope scale. This setting had been determined from the average velocity of sound in lean tissues of swine.

Each pig in Group A was restrained in a bleeding crate which hoisted the animal by a belly support while ultrasonic readings were taken. The depth of fat and lean was estimated at three sites along the animal's back approximately $1\frac{1}{2}$ inches off the midline. Measurements were made on the right side just behind the shoulder, over the center of the back and on the loin above the forward edge of the rear leg. The arbitrary machine setting for 6 inches of aluminum corresponded to 3.0 on the scale for fat measurements and 1.5 for lean depth determinations. After the soundings were completed, each pig was probed (22) with a 1/4 x 6 inch steel ruler at the same three sites while being held by a nose loop.

The pigs of Group B were not restrained while ultrasonic probes were being made, but were fed and allowed to stand naturally. Ultrasonic probes for fatness were made at the same three locations as outlined above. In Group B, the depth of the loin eye muscle was estimated only at the center location due to the difficulty in getting meaningful results in Group A. Machine settings in terms of 6 inches of aluminum were 3.0 for fat and 1.0 for lean depth. In addition, live probes were made at the same three sites.

A series of ultrasonic reflection readings and corresponding angles of radiation were noted from the hogs in Group C. The hair was clipped over the loin just above the last rib of each pig. The same procedure as outlined for Group III steers was followed except that about 10 readings

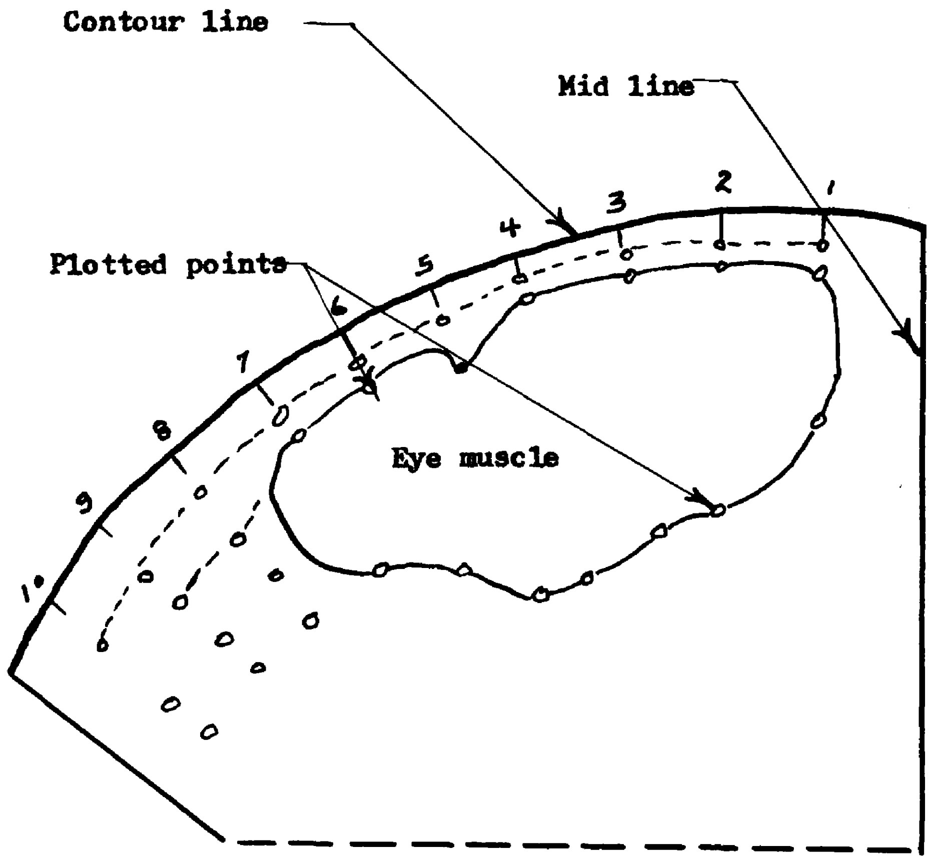

Figure II. Plot of Beef Loin Cross Section from Ultrasonic Data
Half Scale

were made at $\frac{1}{2}$ inch intervals in most cases, proceeding to a point 6 inches off the midline. Cross sectional plots of the loin were made and the area was measured with a compensating polar planimeter.

Carcass Measurements

The measurements made on all beef carcasses, (Groups I, II, and III) were taken from cross sectional tracings of lean, fat and bone between the 12th and 13th ribs. Subcutaneous fat thickness and lean depth at the approximate site of ultrasonic probing were measured on tracings from Groups I and II. The area of the rib eye muscle (*Longissimus dorsi*) was measured on tracings from Group III with a compensating polar planimeter.

Ultrasonic soundings for fat thickness at the three probe sites and lean depth at the center of the back were made on the warm carcasses of Group B hogs. The machine setting was the same as for the live measurements in Group B. In Group A carcasses, three probes of fat thickness were made with a steel ruler just adjacent to the live probe sites, and three probes for lean plus fat depth were made at the same places with a metal skewer. In Group B the lean plus fat probe was made at the center site only. The only carcass measurements from each carcass in Group C was the loin eye area at the last rib, which was taken from a tracing of the right loin.

The leaf fat and kidney were removed and the chilled carcasses of Groups A and B weighed to the nearest .5 pound for calculation of yields. The leaf fat was included in fat trim. Backfat thickness was measured opposite the first, seventh and last ribs, and oppostie the last lumbar vertebra and an average value was computed.

Weights were recorded for fat trimmings, the trimmed shoulder, ham, loin and belly for each carcass in Groups A and B. Cross sectional tracings were made on the right rough loins just anterior to the tenth and last ribs. The area of the *Longissimus dorsi* was determined from each tracing with a planimeter using the average of three values which did not vary over .1 square inch.

The specific gravity of the untrimmed right ham for each carcass in Group A and B was determined by a method previously employed (46). The untrimmed ham was weighed in air to the nearest .1 pound and in water to the nearest gram. The weight of the hook and string used to attach the ham to the gram balance had to be counter weighted. Cold tap water in a large can was used for underwater weighing.

Cutting Procedure; Groups A and B.

The chilled carcasses were broken into rough cuts by a conventional procedure (6). The hind foot was removed by sawing through the bony projection inside the hock, and the front foot was cut off approximately ½ inch above the knee joint. The ham was removed by sawing across the 4th sacral vertebra perpendicular to the hind shank, and cutting through the meaty portion with a knife leaving most of the flank meat on the rough belly. The rough shoulder with the jowl attached was cut off across the third rib perpendicular to the general line of the back. The jowl was removed from the rough shoulder, cutting parallel to the loin side about 2 inches posterior to the indentation where the ear was removed. The rough loin and belly were separated by cutting from a point just below the *Psoas major* muscle on the ham and to a point approximately one inch below the juncture of the ribs and backbone on the blade end. The ribs were lifted from the rough belly by cutting through the secondary flank muscle and as close to the ribs as possible. The belly was trimmed by cutting through the teat line and squaring the flank and loin edges.

The surface fat from all cuts was removed leaving only about 1/4 inch of fat on the ham and loin. A New York style shoulder was made, trimming through the false lean, leaving about 1/4 inch of fat covering. The lean and fat trimmings were separated. Fat trim included all cutting fat and the leaf fat. The lean cuts included the trimmed ham, shoulder, and loin. Primal cuts included these cuts plus the belly.

Calculations

The weight of the lean cuts and primal cuts was computed as percent of both chilled carcass weight and slaughter weight of each hog in Groups A and B. The specific gravity of the untrimmed ham was computed from weights as follows:

$$\text{Specific gravity} = \frac{\text{wt. in air}}{\text{wt. in air} - \text{wt. in water}}$$

The average velocity of 2.25 mc. ultrasound through fat and lean was computed from regression equations obtained from data collected on Group B. These average velocity values were used to compute a standard setting for direct reading of tissue depth in inches by the ultrasonic method.

Statistical Analysis

Simple correlation coefficients, regression equations, standard partial regression coefficients, and analysis of variance were computed by standard procedures as outlined by Snedecor (49).

RESULTS AND DISCUSSION

Cattle - Groups I, II and III

Table 1 shows the means and standard deviations of the various measurements on the three groups of cattle. The data of Groups I and II were not combined, since different settings and operators were employed. Therefore, conversion to the same units of measurement could not be accomplished with confidence.

Table 1. MEANS AND STANDARD DEVIATIONS FOR VARIOUS MEASUREMENTS ON THE THREE GROUPS OF CATTLE

	Group I N = 16		Group II N = 38		Group III N = 14	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Fat depth-tracing (in.)	0.81	0.23	0.89	0.20	--	--
Lean depth-tracing (in.)	2.55	0.31	2.40	0.27	--	--
Area of rib eye-tracing (sq. in.)	--	--	--	--	10.22	0.62
Fat depth-ultrasonic[1]	0.34	0.045	1.24	0.21	--	--
Lean depth-ultrasonic[1]	3.00	0.21	2.81	0.43	--	--
Area of rib eye-ultrasonic (sq. in.)	--	--	--	--	14.00	1.40

1/Readings for depth of fat and lean by ultrasonics were in arbitrary units according to the machine setting (see procedures)

Fat depth - The relationship between fat thickness as measured with the Reflectoscope and as measured on the carcass with a ruler was not high, but was significant in Group II (Table 2). Correlation coefficients of .41 and .31 were not of sufficient magnitude to indicate that fat thickness of cattle could be measured accurately with ultrasonic equipment.

Depth of rib eye - The correlation of depth of rib eye estimated with the Reflectoscope and actual depth of lean (table 2) indicated that reflection peaks from the lower surface of the rib eye were not correctly selected from the maze of reflections on the oscilloscope in Group I. In Group II, the correlation coefficient was positive and significant, indicating that reflections from the lower muscle surface were often distinguishable. However, this correlation value (.36) was low, indicating the operator's inability to consistently select the proper reflection peak.

Table 2. CORRELATION COEFFICIENTS IN BEEF CATTLE RELATING ULTRASONIC FAT AND MUSCLE MEASUREMENTS WITH TRACING MEASUREMENTS AT THE LAST RIB

	Ultrasonic Measurements				
	Group I 16 cattle		Group II 38 cattle		Group III 14 cattle
	Fat	Lean depth	Fat	Lean depth	Rib eye area
Fat depth, tracing	.41	---	.31*	---	---
Lean depth, tracing	---	-.18	---	.36*	---
Rib eye area, tracing	---	---	---	---	-.02

*Significant at 5% level

Rib eye area - Plots of the rib eye muscle from data of Group III were larger than the actual muscle area as measured on tracings (table 1). This could have been due to erroneous machine setting or miscalculation of the velocity of ultrasound in beef muscle, but the relationship was not high. The correlation coefficient for estimated rib eye area from ultrasonic data and actual area (table 2) indicated that there were too many errors and deviations involved to reach any valid conclusions as to its usefulness. There was no relationship between rib eye as estimated from plots and actual rib eye area in this study with cattle.

Sources of error - Certainly, animal movements, errors in reading the oscilloscope scale, and the softness or compressability of beef fat all may have been sources of error in any of the ultrasonic measurements. Erroneous settings and difficulties in getting penetration in some animals may have contributed to the errors in rib eye muscle estimates. Also, the dimensions of fat and muscle may not be the same in the live animal as in the carcass hanging from the rear leg.

Swine - Group A.

The various measurements made on hogs of Group A are listed in table 3. Means and standard deviations are shown. Many of the yields and carcass measurements reported were taken in the same manner for all hogs in Groups A and B. However, experience with Group A led to probable improvements in ultrasonic probing techniques and changes in setting and reading the Reflectoscope. For sonic probing, the hogs of Group A were placed in a bleeding crate, while those of Group B were not. Therefore, sonic measurements on Group A were not combined with those of Group B (table 6). For these reasons, correlation values were reported separately for each group.

Fat depth - The correlation coefficients for fat thickness estimated ultrasonically and for fat thickness measured with a ruler on live hogs and carcasses at the same locations are shown in table 4. The relationships between mean values were equally as high as the relationships at individual points. Correlations of .72 and .81 indicated that sonic

Table 3. MEANS AND STANDARD DEVIATIONS FOR VARIOUS MEASUREMENTS - GROUP A HOGS (74 animals)

	Mean	Std. Dev.
Slaughter weight, 24 hrs. off feed (lbs.)	207.25	13.43
Fat depth-ultrasonic, shoulder1/	3.61	0.58
Fat depth-ultrasonic, center of back1/	2.26	0.37
Fat depth-ultrasonic, loin1/	2.60	0.40
Fat depth-ultrasonic, av. of three1/	2.82	0.38
Fat depth-live probe, shoulder (in.)	1.96	0.30
Fat depth-live probe, center of back (in.)	1.38	0.26
Fat depth-live probe, loin (in.)	1.32	0.19
Fat depth-live probe, av. of three (in.)	1.55	0.22
Fat depth-carcass probe, shoulder (in.)	1.82	0.24
Fat depth-carcass probe, center of back (in.)	1.44	0.24
Fat depth-carcass probe, loin (in.)	1.46	0.25
Fat depth-carcass probe, av. of three (in.)	1.57	0.21
Backfat thickness, av. of four (in.)2/	1.71	0.21
Fat depth-from tracing, center of back (in.)	1.52	0.27
Fat trim, percent of carcass	25.57	3.31
Lean depth-ultrasonic, shoulder1/	0.94	0.30
Lean depth-ultrasonic, center of back1/	1.09	0.46
Lean depth-ultrasonic, loin1/	0.98	0.34
Lean depth-ultrasonic, av. of three1/	1.00	0.30
Lean depth-carcass probe, shoulder (in.)	2.81	0.31
Lean depth-carcass probe, center of back (in.)	1.74	0.29
Lean depth-carcass probe, loin (in.)	2.29	0.34
Lean depth-carcass probe, av. of three (in.)	2.35	0.22
Lean depth-tracing, center of back (in.)	1.69	0.29
Lean cuts, percent of carcass3/	51.93	2.63
Lean cuts, percent of slaughter weight	37.99	1.87
Primal cuts, percent of carcass3/	64.96	2.18
Primal cuts, percent of slaughter weight	47.54	1.71
Area of loin eye at 10th rib (sq. in.)4/	3.60	0.53
Area of loin eye at last rib (sq. in.)4/	3.71	0.51

1/Units of ultrasonic reflectoscope measurements were arbitrary depending upon machine setting (see procedure).
2/Measured at 1st rib, 7th rib, last rib, and last lumbar vertebra.
3/Based on weight of chilled carcass without leaf fat.
4/Area of *Longissimus dorsi*.

probing yielded a fairly accurate estimate of fat thickness. Assuming that the same fat depth was being measured by each method, higher relationships would be expected.

Table 4. CORRELATION COEFFICIENTS FOR ULTRASONIC READINGS ON THE LIVE PIGS AND CORRESPONDING CARCASS MEASUREMENTS AT INDIVIDUAL SITES: GROUP A[1/]

	Ultrasonic measures			
	Shoulder	Center of back	Loin	Mean
Fat - carcass probe	.66	.64	.61	.72
Fat - tracing	---	.76	---	---
Fat - live probe	.74	.63	.81	.81
Lean depth - carcass probe	.00	-.01	-.02	---
Lean depth - tracing	---	-.04	---	-.03

1/Correlation coefficients between .23 and .30 significant at 5% level and correlation coefficients above .30 significant at 1% level.

Velocity consideration - Applying the data to regression equations for estimating live probe fatness from the arbitrary scale units of the Reflectoscope, the following regression equations were used to estimate the velocity of ultrasound through swine fat at each individual site.

Shoulder probe - $\hat{Y} = 0.380X + 0.593$

Center probe - $\hat{Y} = 0.446X + 0.252$

Loin probe - $\hat{Y} = 0.377X + 0.340$

Assuming that the sound waves and probe were penetrating to the same fascis layer, the following approximate velocities were deduced in meters per second using 6220 m/sec. as the velocity in aluminum.

Over the shoulder - velocity $\approx$ 1800 m/sec.

Over the center of the back - velocity $\approx$ 1650 m/sec.

Over the loin - velocity $\approx$ 1525 m/sec.

Providing the sound probe was measuring to the same depth as backfat measurements, the mean velocity was approximated to be 1850 m/sec. ($\hat{Y} = 0.444X + 0.460$). All these velocities as deduced from regression equations should be considered as rough approximations, since the site of ultrasonic probing may not have corresponded precisely to the site of measurement. The mean velocity of 1850 m/sec. from the latter approximation was essentially the same as reported by Dumont (11). The approximate velocities over the center of the back and loin sites using the live probe as a basis were lower than reported by Dumont (11). Also, the velocity of sound in swine fat tended to decrease from the shoulder to the loin in this study, which contradicts Dumont's (11) findings.

Lean depth - Correlation coefficients for lean depth as determined by the Reflectoscope and by carcass measurement (table 4) indicated that the procedures and equipment used in Group A were not adequate for determination of lean depth. Table 5 shows that lean depth as estimated ultrasonically in Group A was negatively and non-significantly correlated with cutting yields and loin eye area. Since ultrasonic estimates of lean depth were negatively related to yields and positively related to percent fat trim, it seemed probable that something other than actual depth of lean was being measured. Correlations for carcass measurements of lean depth and cutting percentages indicated that lean depth was inadequate as a tool in the selection of hogs for high cut-out yields.

Fatness and carcass value - Fat depth as estimated ultrasonically when correlated with backfat thickness, live probe, and fat thickness

Table 5. CORRELATION COEFFICIENTS FOR VARIOUS FAT AND LEAN MEASUREMENTS AND CARCASS CUT-OUT: GROUP A[1]

	Fat ult. live	Fat live probe	Fat carcass probe	Lean ult. live	Lean carcass probe	Back-fat	Area L. D. 10th rib	Area L. D. last rib	Lean depth tracing
Backfat	.82								
Fat-live probe	.81								
Fat-tracing	.72								
Lean cuts, carcass	-.70	-.80	-.74	-.22	.13	-.72	.59	.61	.04
Lean cuts, live	-.58	-.72	-.67	-.21	.26	-.66	.41	.71	.10
Primal cuts, carcass	-.72	-.81	-.77	-.16	.07				
Primal cuts, live	-.48	-.63	-.59	-.10	.22				
Fat trim	.77	.87	.85	.12	-.04				
Area L.D. 10th rib	-.33	-.45	-.33	-.13	.55				
Lean depth, tracing				-.03	.47				

1/Correlation coefficients between .23 and .30 significant at 5% level and correlation coefficients between .30 significant at 1% level.

from a tracing yielded highly significant values of .82, .81 and .72, respectively (table 5). The live probe values tended to be more highly related to lean and primal cut-out computed on the live or carcass basis than fatness by the ultrasonic method. Mechanical probing of the carcass for fat depth offered little advantage over sonic measurement for predicting cut-out value. Highly significant, negative correlation coefficients were found for all lean and primal cutting percentages and fat depth measured by any of the three methods. Live and carcass measurements of fat thickness were highly related to the percent fat trim (table 5). In general, fat thickness was significantly and negatively related to the area of the loin eye at the 10th rib. Correlation values of -.33 to -.45 were not of sufficient magnitude to be useful for prediction of eye muscle size from fat depth measurements.

Loin eye area and cut-out - The relationships between the loin eye area at the 10th and last ribs and percentage lean cuts on the live and carcass bases (table 5) were positive. Highly significant correlation coefficients of .61 and .71 (table 5) indicated that roughly 37 to 50 percent of the variation in percentage lean cuts was accompanied by a similar variation in loin eye area at the last rib. These correlation coefficients were slightly higher than those reported by Pearson (45), and considerably higher than reported by Price (46) with other groups of swine. In the latter study, only 15 percent of lean cut-out was accounted for by measurements of the loin eye area at the last rib. The relationship for the 10th rib measurement of area and lean cut-out was not very different from that of previous studies (45, 46). Fat thickness measured ultrasonically had approximately the same predictive value for lean cut-out as loin eye area at the last rib.

Swine - Group B

The averages for fat thickness measured by various methods and single measurements made at the center of the back for fat and lean depth are given in table 6. Means and standard deviations of all measurements are also shown. Ultrasonic estimates of fat depth were taken on the warm carcasses of Group B, after the dressing operation had been completed. Lean depth estimates were made only at the center of the back of each hog in Group B. Ultrasonic measurements of lean depth were made utilizing a different machine setting than for Group A.

Table 6. MEANS AND STANDARD DEVIATIONS FOR VARIOUS MEASUREMENTS ON HOGS

GROUP B HOGS (84 animals)

	Mean	Std. Dev.
Slaughter weight, 24 hrs. off feed (lbs.)	196.6	12.32
Fat depth - ultrasonics, av. of 3 live measures1/	2.62	0.39
Fat depth - ultrasonics, center of back, live1/	2.04	0.34
Fat depth - ultrasonic, av. of 3 carcass measures1/	2.78	0.43
Fat depth - ultrasonic, center of back, carcass1/	2.26	0.37
Fat depth - live probe, av. of three (in.)	1.39	0.24
Fat depth - carcass probe, av. of three (in.)	1.37	0.20
Backfat thickness, av. of four (in.)	1.58	0.21
Fat depth - from tracing, center of back (in.)	1.27	0.23
Lean depth - ultrasonic, center of back, live1/	1.30	0.14
Lean depth - ultrasonic, center of back, carcass1/	1.58	0.20
Lean depth - carcass probe, center of back (in.)	2.01	0.19
Lean depth - tracing, center of back (in.)	1.88	0.18
Lean cuts, percent of carcass3/	53.68	3.17
Lean cuts, percent of slaughter weight	39.58	2.43
Primal cuts, percent of slaughter weight	49.37	2.12
Primal cuts, percent of carcass	66.94	2.62
Specific gravity of right untrimmed ham	1.050	0.0065
Area of loin eye at 10th rib (sq. in.)4/5/	3.82	0.59
Area of loin eye at last rib (sq. in.)4/	3.98	0.56
Shape index - ratio of the square of the perimeter of loin eye to area, 10th rib5/	14.87	0.70

1/Units of ultrasonic reflectoscope measurements were arbitrary depending upon machine setting (see procedure).
2/Measured at 1st rib, 7th rib, last rib, and last lumbar vertebra.
3/Based on weight of chilled carcass without leaf fat.
4/Area of *Longissimus dorsi*.
5/Based on 83 animals.

Fat depth - Table 7 contains correlation coefficients for a variety of fat depth measurements and other indicators of total leanness in Group B. The relationships between fat thickness estimated by the Reflectoscope, either on live pigs or on the carcasses of Group B, and average backfat thickness measured on the split carcasses were highly significant. Similar positive and highly significant relationships existed for live probe fatness measures and sonic estimates. Apparently the experience gained on Group A and improved techniques resulted in slightly higher correlation coefficients for Group B. Correlation coefficients ranging from .88 to .91 indicated that roughly 80 percent of the variation in actual fat thickness could be accurately predicted from soundings on live pigs or their carcasses.

Fat thickness along the backline of swine whether measured by ultrasonic techniques or by a ruler, either on carcasses or on live pigs, was highly correlated with all cutting percentages and the specific gravity of the ham. No matter how fat depth was measured, its relationship to each cut-out percentage was essentially the same. For example, the correlations for fat depth measured by several methods (table 7) and percentage lean cuts (carcass basis) ranged from -.74 to -.80. With the possible exception of the carcass probe for fat depth, there was obviously no essential difference in the accuracy of estimating cut-out yields by any of the various methods of measuring fat thickness. Surprisingly enough, a single determination of fat depth at the center of the back, either by sounding techniques or carcass measurement, provided as accurate an estimate of lean cut yield as did average fat thickness in Group B. Due to the greater probability for error in a single determination, it is

Table 7. CORRELATION COEFFICIENTS FOR VARIOUS FAT MEASUREMENTS AND CARCASS CUT-OUT - GROUP B[1/]

	Back-fat	Fat live probe	Fat carcass probe	Fat ult. live	Fat ult. carcass	Fat depth tracing	Fat ult. center live	Slaughter wt.	Area L.D. 10th rib	Area L.D. last rib
Backfat								.34	-.40	
Fat-live probe								.47		
Fat depth, tracing							.85			
Fat ult., live	.88	.91						.37		
Fat ult., carcass	.89	.89		.93						
Lean cuts, carcass	-.80	-.79	-.74	-.78	-.78	-.77	-.78	-.21	.62	.61
Lean cuts, live	-.73	-.73	-.68	-.72	-.71	-.70	-.70	-.18	.71	.69
Primal cuts, carcass	-.80	-.80	-.77	-.79	-.78			-.23		
Primal cuts, live	-.67	-.68	-.66	-.67	-.66			-.17		
Spec. gravity, ham	-.61	-.62	-.57	-.66	-.66	-.71	-.71	-.12		

1/Correlation coefficients between .21 and .27 significant at 5% level; values above .28 significant at 1% level.

believed that more confidence can be placed in averages of fat depth. Approximately 61 percent of the variation in lean or primal cuts as a percentage of carcass weight was accompanied by similar variation in fat depth. Roughly 50 percent of the variation in percentage lean or primal cuts (live basis) was accounted for by fat thickness variations. Of all the factors studied in Group B (tables 7 and 9), fat thickness seemed to be the most accurate for prediction of lean cut yield.

Loin eye area and yields - The area of the loin eye muscle measured in the carcass at the 10th and last ribs was highly correlated with lean cut yield (table 7). The correlation coefficient (.71) for lean cuts (live basis) and area of the loin eye at the 10th rib showed that 50 percent of the variation in lean cut yield was accounted for by variations in muscle area. Therefore, it was postulated that combining eye muscle area and backfat thickness for prediction of lean cuts (live basis) might prove valuable. The multiple correlation coefficient for the combination of backfat thickness and loin eye area at the 10th rib with lean cut-out on the live basis was .85. This value was slightly higher than either simple correlation value (.71 and .73). Therefore, by combining eye muscle area and fat thickness, lean cut yield was more closely predicted in this particular group of animals than by either backfat thickness or loin eye area alone.

Slaughter weight effects - Slaughter weight was highly related to fat thickness measures (table 7). Low, negative correlations were found for slaughter weight and cut-out percentages. Therefore, the relationships of some cutting yields and a few measures of fatness and leanness with the direct effect of slaughter weight removed was tested by means of standard partial regression coefficients (table 8). Removal of the effect of slaughter weight had little effect on the relationship between carcass cut-out and backfat thickness or fat depth measured by ultrasound. However, the relationship of live probe with carcass cut-out was improved by deleting live weight effects. As could be expected, the area of the loin eye showed a slightly higher relationship with lean cuts when the direct effect of slaughter weight was eliminated (table 8). However, the improvement in the prediction of cutting yields by correcting for slaughter weight was so slight that correction for live weight differences need not be considered for pigs within a 30-40 pound weight range. However, the weight range of Group B was from 162 to 245 pounds, which accounted for the improvement in the relationships when weight was held constant.

Table 8. STANDARD PARTIAL REGRESSION COEFFICIENTS FOR FAT MEASURES AND CUT-OUTS WITH THE EFFECT OF SLAUGHTER WEIGHT REMOVED - GROUP B

	Backfat	Fat live probe	Fat ultrasonic live	Area L.D. 10th rib
Fat - ultrasonic, live	.88	.85		
Lean cuts, carcass basis	-.82	-.89	-.81	.67
Primal cuts, carcass basis	-.82	-.89	-.82	
Lean cuts, live basis				.76

Lean depth - Simple correlation coefficients for the depth of the loin eye muscle as estimated ultrasonically and several determinations of lean depth and area by carcass measurement were positive. (table 9). Although many of the correlation values for ultrasonic estimates of lean depth with carcass measurements were statistically significant, they were low, indicating that actual loin eye depth and area were not accurately predicted from ultrasonic measurements. The depth of loin eye measured by the Reflectoscope on live pigs showed very low, non-significant relationships with lean cut percentages and specific gravity of the ham. Actual lean depth as measured on tracings was significantly correlated with cut-out and loin eye area. It was concluded that the ultrasonic method was not adequate for measuring lean depth on live pigs. It may be important to point out that soundings in Groups A and B were made with the quartz crystal transducer, and it was often difficult to obtain complete penetration through the loin eye. Therefore, selection of the reflection peak from the lower surface of the loin eye muscle was accomplished with little confidence on live pigs.

Lean depth soundings on the carcasses showed that the reflection peak from the lower surface of the loin eye was usually distinguished with ease. Often, reflections from both the muscle and bone surface could be distinguished. However, correlation coefficients for ultrasonic and ruler measurements of lean depth on the carcass were low (.23 and .43, table 9). Also, lean depth measured by the Reflectoscope on the carcass was negatively correlated with lean cut-out and positively correlated with ultrasonic determinations of fatness. These factors indicated that either the method of computing lean depth from ultrasonic data was in error or a difference in the velocity of ultrasound through fat and lean was introducing a bias. Similar errors may have been affecting the accuracy of sonic estimates of lean depth on live pigs, since actual lean depth was negatively correlated with sounding measurements of fat, while ultrasonic estimates of lean depth showed very low relationships with

Carcass probing for lean depth showed little value for predicting the depth or area of the loin eye as measured on a tracing. The relationships of lean depth, whether taken from a tracing or by probe, with percentages of lean cuts were so low that lean cut-out could not be accurately predicted from lean depth measurements (table 9).

Shape index - The ratio of the square of the loin eye perimeter to its area (10th rib) was computed as the shape index. Since the ratio of the square of the circumference of any circle to its area is a constant value (4π), the shape index indicated deviation from circular shape. The correlation coefficients for the shape index with percentage lean cuts on the live and carcass bases, respectively, were -.29 and -.33. These values were low but highly significant. The negative values indicated that loin eye muscles more nearly circular in shape were often associated with high lean cut yields. However, the correlation values were too low to be useful for prediction of yield from shape index values.

Velocity considerations and errors - In order to compute a setting whereby the depth of fat and lean could be read directly from the oscilloscope scale, and in an attempt to explain some of the difficulties in estimating lean depth in Group B, the velocity of 2.25 mc. ultrasound through fat and lean was approximated from several regression equations. Since the methods employed in Group B seemed more accurate than those used in Group A, the estimated velocities from Group B were believed to be more nearly valid. Assuming that the sound waves were reflected from the same fascia layer which stopped penetration of the live probe, the mean velocity of ultrasound through fat was computed to be 1660 m/sec. The regression equation for predicting average live probe fat thickness from sounding data at the setting used was: $\hat{Y} = 0.563X - 0.085$. For predicting average backfat thickness from data collected with the Reflectoscope in Group B, the following regression equation was computed: $\hat{Y} = 0.48X + 0.324$. Using this equation, the velocity of ultrasound through fat of live swine was approximately 1830 m/sec. It was apparent that the average fat depth immediately over the spinal column was greater than fat depth taken $1\frac{1}{2}$ to 2 inches off the midline. Since live probes are taken off the midline, this may be an explanation for the usually observed higher relationship of live probe to cut-out than that for backfat thickness to cut-out. The average velocity as computed from live probe regression (1660 m/sec.) was probably more nearly correct. However, the velocity of ultrasound through the fat layer of live swine at the center of the back was estimated to be 1780 m/sec. as computed from measurements taken from a tracing and Reflectoscope data. Repeated observations of the reflection peaks resulting from fascia layers over the muscles along the backline of pigs led to the conclusion that there were three distinct layers of fatty tissue over the eye muscle. The top or outermost layer represented about half the total fat thickness. The second layer extended to within 0.1 to 0.4 inch from the top of the eye muscle. The third was a thin layer of spongy fat tissue immediately over the muscle. The reflection peaks from the top of the third fatty layer and from the muscle surface were often indistinguishable on the oscilloscope. Thus, it was concluded that the velocity of ultrasound through the fatty tissues of live swine may range from 1500 to 1900 m/sec. The different layers may have different velocities.

An estimate of the velocity of ultrasound through the fat layers of the warm carcasses was computed ($\hat{Y} = 0.517X + 1.60$). This value, 2220 m/sec., was higher than that for fat on live pigs. Soundings for fat depth on the warm carcasses were made after the animals had been dressed and split. The difference in estimated velocities was assumed to be due to temperature differences. It was impossible to get reflections using the quartz crystal on chilled carcasses, so differences in velocities resulting from extreme temperature differences could not be estimated.

The correlation coefficients for estimates of lean depth by ultrasound and actual lean depth from carcass measurements were low (table 9). Due to rather wide deviations from the regression lines, computation of the velocity of ultrasound through the lean of pigs from regression equations could have involved considerable error. However, the best estimate of ultrasonic velocity through lean was obtained from regression equations in this study. The regression equations for predicting carcass measurements of lean depth from ultrasonic estimates are shown with their corresponding velocity approximations.

1. Velocity $\approx$ 1830 m/sec.
   Lean depth, tracing - $\hat{Y} = 0.384X + 1.38$
   where X = live sounding.

2. Velocity $\approx$ 2010 m/sec.
   Lean depth, mechanical carcass probe - $\hat{Y} = 0.230X + 1.71$
   where X = live sounding.

3. Velocity $\approx$ 1710 m/sec.
   Lean depth, tracing - $\hat{Y} = 0.393X + 1.26$
   where X = carcass sounding.

4. Velocity $\approx$ 1900 m/sec.
   Lean depth, mechanical probe - $\hat{Y} = 0.210X + 1.63$
   where X = carcass sounding.

All measurements of lean depth were made at the center probe sites only. These values of velocity along with correlation coefficients and means (tables 9 and 6) indicated that the mechanical carcass probe was penetrating to a deeper layer, probably to bone. Since the carcass probe of lean depth did not closely predict tracing measurements, velocities computed from the regression of carcass probe values were more likely in error than the other values. It appeared that the velocity of ultrasound through the loin eye muscle of live pigs was approximately 1000 m/sec. greater than through the warm muscle of the carcasses. The values (1710 and 1830 m/sec.) for the velocity in lean did not differ sufficiently from the range of values found for the velocity of ultrasound in fat to have introduced gross errors in lean depth readings. Even if the values reported by Ludwig (32) for the velocity of ultrasound through various swine tissues (approx. 1500-1560 m/sec.) were considered accurate, differences in average velocity did not explain deviations in lean depth estimates by the Reflectoscope. Therefore, it was possible only to speculate on the factors contributing to the errors. As well as animal movements, machine errors, human errors, and velocity variations, the changes in fat and muscle dimensions due to position differences between the live hog and its carcass may have been affecting the accuracy of lean depth estimates.

Swine - Group C.

The use of the type Z transducer made possible greater penetration into swine tissues and resulted in clearer reflection peaks from tissue layers. For direct reading of fat and lean depth in inches, the velocity of ultrasound through live swine tissues was taken to be 1/4 that through aluminum or 1552 m/sec. Thereby, the reflection peak for a depth of 4 inches of aluminum could be set at 1.0 on the oscilloscope scale quickly and repeatably. This assumed velocity may have been slightly lower than the actual mean velocity of ultrasound through swine tissues as shown by the regression equations discussed under Group B. This velocity value was selected by considering the values reported by other workers (32, 21, 51) and the approximations reported in this study, as well as the convenience of the 4 to 1 ratio.

The means and standard deviations of the loin eye areas obtained from carcass tracings and from plots of reflection data are shown in table 10. The means illustrated a tendency to over estimate the eye muscle size from an ultrasonically determined plot. This could have been due to an error in the assumption on velocity, differences in muscle size in the live animal as compared to the carcass, or a tendency to sketch a more rounding perimeter than actually existed. Incomplete resolution of tissue layers introduced some subjectivity in lean depth measurements. It was observed that 3 of the areas were overestimated by .9 sq. in. or more, 1 was underestimated by 1.0 sq. in., while the remainder of the area estimates fluctuated slightly over and under the area of the corresponding tracing. A typical plot is shown by Figure III.

Table 10. MEANS, STANDARD DEVIATIONS, F VALUE, AND CORRELATION COEFFICIENT FOR ACTUAL AND ESTIMATED LOIN EYE MUSCLE AREA - GROUP C

	Mean	Std. dev.	F value	Correlation coefficient
Area from plot	3.85 in.	0.64		
Area from tracing	3.65	0.58		
Between methods			2.57 1/	0.74 2/

1/F value indicated no significant difference at 5% level.
2/Correlation coefficient significant at 1% level.

The .2 sq. in. difference in the means of muscle area as measured by two methods was not statistically significant. This indicated that the assumed velocity was not grossly in error, or that deviations intro-

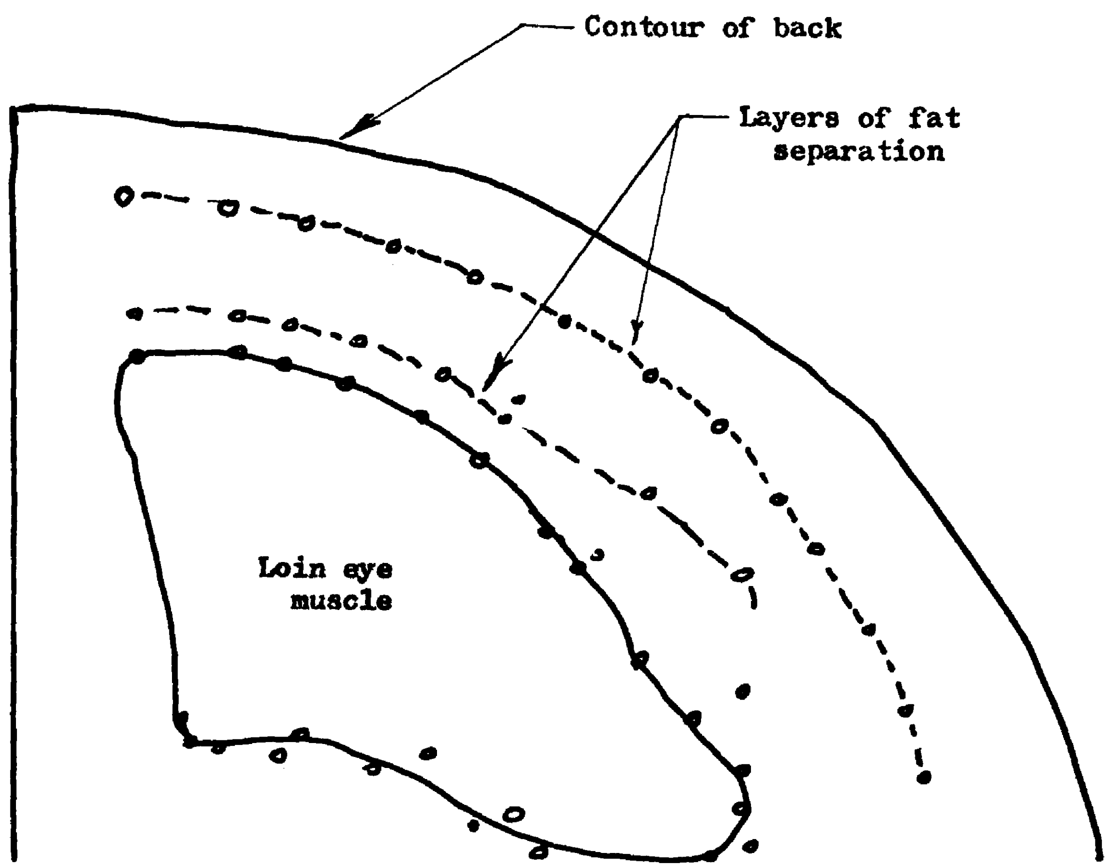

Figure III. Plot of Pork Loin Cross Section duced owing to errors in techniques or human judgement were large enough to mask the effect of any error in the assumption of velocity. The correlation coefficient for estimated loin eye area with the actual area taken from a tracing (.74) was highly significant. Approximately 55 percent of the variation in carcass measurements of loin eye area could be predicted from plots of ultrasonic data collected from live pigs.

No assurance was offered that the velocity of ultrasound through fat was not slightly different from that through lean. Also, the velocity of ultrasound through fat or lean probably varied from one animal to another (Claus, 5). Assuming the errors introduced by velocity differences within and between animals to be negligible, it was found upon plotting the points at corresponding angles of radiation that an unclosed perimeter for the estimated eye muscle resulted (Figure IV). Thus, it was necessary to subjectively "draw in" the end of the loin eye muscle. Since the sound waves reflected from tissue layers that lie perpendicular to the projected beam are the only ones causing strong peaks on the oscilloscope, it was not possible to locate the exact position of the surface of the loin eye muscle adjacent to the backbone. It was not practical to obtain duplicate or triplicate sets of readings on each animal due to the irritability of the animals and the time involved.

Since the area of the loin eye muscle may be significantly related to fat thickness, a correlation coefficient was computed for the carcass measurement of loin eye area with the sum of four fat thickness estimates at 1, 2, 3 and 4 inches from the midline of each hog as measured on the loin cross-sectional plots. A correlation value of -.20 was found. This indicated that estimates of muscle area by plotting ultrasonic reflection values were much more accurate for predicting actual area than was fat thickness.

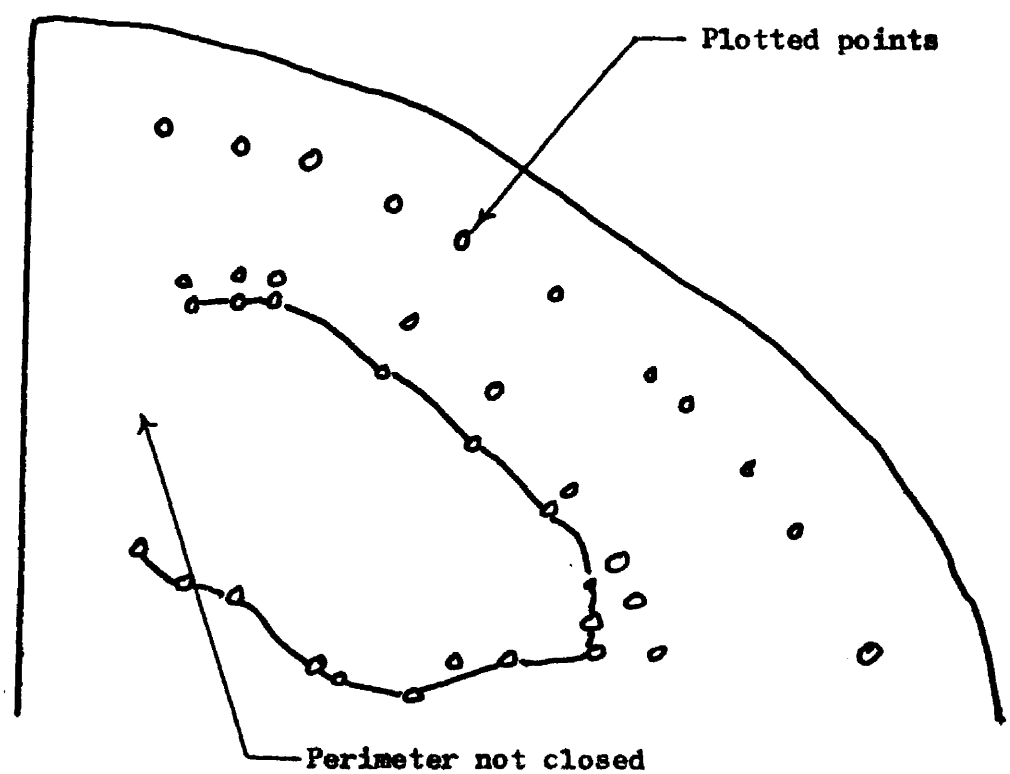

Figure IV. Illustration of Unclosed Perimeter of Plots.

SUMMARY AND CONCLUSIONS

An ultrasonic method was applied to measurement of subcutaneous fat thickness and depth of the Longissimus dorsi muscle in two groups of cattle and two groups of swine. In cattle, the relationship of ultrasonic estimates of fat thickness to carcass measurements was low. It was believed that the inaccuracy of the Reflectoscope for measuring fat depth in cattle was primarily due to the softness of flesh. Also, the depth of the rib eye muscle of cattle was not accurately estimated by the sound probe.

Fat thickness of live swine could be accurately measured with the ultrasonic equipment. The experience gained on Group A seemed to improve the overall accuracy of the sounding method as illustrated by the higher correlation values for ultrasonic estimates with carcass measurements in Group B as compared to Group A. Considering the data from both groups of swine, it was concluded that fat thickness estimates made with the ultrasonic probe were equal to mechanical probes or carcass measurements for prediction of lean cut yield. Regardless of how fat thickness was measured, it seemed to be the most accurate indicator of total leanness in swine. Deletion of the direct effect of slaughter weight in these relationships did not alter the strength of the relationships to any marked degree.

Applying regression equations to the estimation of the velocity of ultrasound in the fat of live swine, an average velocity value of 1660 meters per second was found when the live probe values were used as the basis. The velocity through fat was greatest over the shoulder (1800 m/sec.), intermediate over the center of the back (1650 m/sec.) and lowest over the loin (1525 m/sec.). The velocity in the fat of the warm carcasses was greater than that in live swine, which was believed to be due to the temperature effect on ultrasonic velocity. When the generally larger values of backfat thickness as determined at the midline of the carcasses were used for velocity estimation, the apparent velocity through fat was approximately 1850 m/sec. Considering the probable variations in velocity between and within animals, it was concluded that the velocity of ultrasound in fat tissue of live swine may range from 1500 to 1900 meters per second.

The ultrasonic device proved to have no value for measuring the depth of the loin eye in Group A. Changes in techniques resulted in low but significant correlation values for ultrasonic estimates of lean depth with mechanical carcass measurements in Group B. However, the low relationship of lean depth as measured ultrasonically or by mechanical probe to lean cut yield demonstrated the lack of any significant predictive value for a simple measurement of the depth of the loin eye.

On the other hand, loin eye area was highly related to lean cut yield in both groups of swine. Combining loin eye area and backfat thickness for the prediction of lean cut yield resulted in an improved relationship in Group B. It seemed that fatness was the most accurate index of carcass value of the factors studied, while the area of the loin eye was an additional index of yield that may prove valuable in practical applications.

Although the use of regression equations for estimating the velocity of ultrasound through lean tissue may have involved some error, the velocities in lean tissue did not appear to differ markedly from the range of velocities in fat. The velocity in lean was found to range from 1700 to 1900 m/sec.

The depth of tissue layers and angles of radiation of ultrasound were recorded for each animal in Groups III and C. Plots resembling a loin cross section were made from the data collected by means of the ultrasonic equipment. The areas of the rib eye muscle of cattle as measured on the plots did not vary in the same manner as the areas determined on carcass tracings. Therefore, the ultrasonic techniques used in this study for estimating rib eye size were not successful in cattle. The mean of the plotted muscle areas for Group C swine did not differ significantly from the mean of the areas from carcass tracings. A correlation coefficient of .74 was obtained for the ultrasonically estimated area with actual area. It was concluded that this rather slow tedious process of estimating the loin eye area of swine by means of live soundings could be used in breeding programs for selecting swine with superior loin eye areas.

Animal movements, velocity variations, unavoidable subjectivity, live animal and carcass position differences, softness of flesh, and inherent errors within the ultrasonic equipment were all factors that could have resulted in erroneous measurements with the ultrasonic device. All factors considered, it was concluded that an ultrasonic probe could be used for fat thickness measurements in swine with reliability equal to that of any of the more common techniques. The type Z transducer facilitated more accurate measurement of lean depth and area.

It was postulated that improvements in equipment design, along with adequate familiarization will allow researchers to measure quite precisely the amount of fat, and the size and shape of certain muscles of swine with little difficulty. The practicality of ultrasonic equipment for use in meat animal evaluation remains debatable. Equipment costs and reliability of the fat and muscle area measurements for estimating total body composition will determine the ultimate value of this method.

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Appendix A - Data - Group I, Cattle

Neck Strap No.	Measurements on Tracing 1 Fat Depth	2 Lean Depth	Measurements by Ultrasound 3 Fat Depth	4 Lean Depth
13	1.32	2.38	0.45	2.95
4	0.90	2.70	0.33	3.07
10	1.02	2.20	0.35	2.75
3	0.61	2.52	0.30	3.30
12	1.22	2.14	0.30	3.50
7	0.75	2.09	0.37	2.93
8	0.82	2.64	0.40	2.90
1	0.57	2.87	0.38	2.92
15	0.85	2.16	0.28	3.22
2	0.85	2.83	0.38	2.82
5	0.59	2.68	0.32	3.08
6	0.53	2.83	0.30	2.70
11	0.65	2.20	0.30	2.90
14	0.67	2.78	0.35	2.85
16	0.98	3.15	0.32	3.23
9	0.61	2.66	0.30	2.90
	12.94	40.83	5.43	48.02
Mean	0.81	2.55	0.34	3.00
S. D.	0.227	0.310	0.045	0.210

Appendix B - Data - Group II, Cattle

Neck Strap No.	Measurements on Tracing 1 Fat Depth	2 Lean Depth	Meansurements by Ultrasound 3 Fat Depth	4 Lean Depth
106	1.14	2.40	2.0	2.80
14	0.59	1.93	1.0	2.30
6	0.69	2.76	1.0	2.50
11	1.00	2.05	1.4	2.80
72	0.81	2.43	1.3	2.75
77	0.87	2.05	1.3	2.65
62	0.94	2.36	1.1	3.15
61	0.70	2.56	1.2	2.80
80	0.83	2.14	1.4	2.50
66	0.69	2.50	1.3	2.45
10	0.96	2.72	1.4	2.40
3	0.90	2.60	1.3	2.95
70	0.75	2.72	0.9	2.55
124	0.51	2.38	1.1	2.65
63	1.10	2.33	1.3	2.05
71	1.00	2.00	1.2	2.60
28	0.66	2.60	1.2	2.30
94	1.34	2.04	1.0	2.80
73	1.05	2.58	1.2	2.90
59	0.94	2.38	0.9	2.55
74	1.12	2.32	1.3	3.05
65	1.10	2.16	1.2	2.40
121	1.00	2.70	1.2	3.30
99	0.88	2.34	1.0	2.90
7	1.00	2.52	1.4	3.30
67	0.87	2.68	0.9	2.45
92	0.61	2.70	1.4	3.10
8	1.05	2.09	1.2	3.40
119	1.26	2.03	1.4	2.50
100	0.61	2.32	1.0	2.60
105	0.61	1.89	1.1	2.45
75	0.73	2.70	1.3	2.85
27	0.98	2.24	1.4	2.70
5	1.03	2.90	1.3	4.15
2	0.79	2.60	1.0	2.90
4	0.59	2.48	1.5	3.00
85	1.20	2.38	1.6	3.55
115	0.98	2.80	1.3	3.70
	33.88	91.38	47.0	106.75
Mean	0.89	2.40	1.24	2.81
S. D.	0.204	0.268	0.214	0.420

Appendix C - Data - Group III, Cattle

Steer No.		Area of Loin Eye from Tracing	Area of Ultrasonic Plots
1		10.00	13.25
2		9.76	14.45
3		9.41	14.42
4		10.57	13.05
5		11.45	12.14
6		10.88	14.03
7		9.99	16.26
8		10.98	16.69
9		10.16	13.36
10		9.79	11.50
11		9.49	13.98
12		10.13	15.63
14		10.92	13.74
15		9.50	13.45
		143.03	195.95
	Mean	10.22	14.00
	S. D.	0.618	1.397

Appendix D - Data - Group A, Swine

Hog No.	Sl. Wt.	Fat Depth - Ultrasonic				Fat Depth - Live Probe			
		Shoulder	Center	Loin	Av.	Shoulder	Center	Loin	Av.
D 4-8	205	3.90	2.00	2.10	2.67	1.60	1.05	1.10	1.25
D 10-1	212	4.10	2.40	2.30	2.93	1.95	1.45	1.15	1.52
D 8-14	205	4.60	2.30	2.50	3.13	2.05	1.35	1.25	1.55
CDH 36-10	206	3.50	2.10	2.70	2.77	1.75	1.35	1.30	1.47
CDH 36-12	210	3.40	2.10	3.30	2.93	1.85	1.10	1.25	1.40
DH 35-9	206	3.70	3.00	3.10	3.27	2.05	1.50	1.60	1.72
CDH 36-11	210	4.00	2.40	2.40	2.93	2.05	1.60	1.25	1.63
CDH 47-12	209	3.50	1.90	2.60	2.67	1.70	1.25	1.40	1.45
D 21-9	213	3.00	1.80	2.30	2.37	1.55	1.05	1.25	1.28
D 16-10	212	3.60	2.00	2.80	2.80	1.75	1.15	1.55	1.48
D 8-15	201	3.50	2.20	2.40	2.70	1.75	1.20	1.15	1.37
DH 37-13	208	4.00	2.40	2.60	3.00	2.10	1.50	1.35	1.65
D 11-7	212	3.40	2.20	2.40	2.67	1.85	1.65	1.20	1.57
Y 240	194	3.70	2.20	2.70	2.87	2.05	1.40	1.25	1.57
CDH 47-7	204	3.70	2.40	2.60	2.90	2.10	1.45	1.45	1.67
Y 231	192	2.30	1.30	2.10	1.90	1.30	0.80	1.00	1.03
D 17-5	203	3.00	2.30	2.20	2.50	1.75	1.40	1.10	1.42
D 14-2	212	4.00	2.40	3.00	3.13	1.90	1.55	1.50	1.65
D 6-9	212	4.00	2.00	2.30	2.77	1.90	1.20	1.25	1.45
CDH 31-5	216	4.00	2.50	2.90	3.13	1.95	1.45	1.50	1.63
CDH 47-10	214	3.60	2.20	2.40	2.73	1.90	1.25	1.20	1.45
CDH 47-9	212	3.80	2.40	2.70	2.97	2.05	1.50	1.40	1.65
Y 4-9	194	2.80	1.90	2.40	2.37	1.55	1.15	1.20	1.30
Y 7-12	197	3.10	1.80	2.30	2.40	1.95	1.15	1.10	1.40
Y 5-6	196	3.40	2.10	2.40	2.63	1.75	1.20	1.25	1.40
Y 6-7	200	2.90	2.00	3.00	2.63	1.60	1.05	1.10	1.25
DH 33-1	220	4.50	2.70	2.90	3.37	2.25	1.90	1.30	1.82
D 6-7	214	3.50	2.00	2.00	2.50	1.60	1.10	1.05	1.25
H 56-3	181	3.30	2.50	2.70	2.83	2.20	1.85	1.25	1.77
Y 237	189	2.70	2.10	2.30	2.37	1.85	1.25	1.20	1.43
H 51-2	184	3.20	2.00	2.40	2.53	2.05	1.40	1.20	1.55
H 56-4	180	3.00	2.10	2.20	2.43	1.90	1.75	1.15	1.60
H 61-3	190	3.60	3.00	3.00	3.20	2.55	1.60	1.65	1.93
C 228	192	3.50	2.50	2.40	2.80	1.75	1.65	1.20	1.53
D 6-2	230	4.00	2.90	3.00	3.30	2.60	1.70	1.55	1.95
D 6-6	222	2.50	1.60	2.20	2.10	1.90	1.30	1.25	1.48
HD 31-12	210	3.40	2.30	2.90	2.87	2.20	1.95	1.60	1.92
HD 45-1	211	4.50	2.70	2.80	3.33	2.70	2.00	1.55	2.08
HD 31-4	219	3.80	2.30	2.70	2.93	2.05	1.35	1.40	1.60
HD 46-8	216	4.10	2.00	2.40	2.83	2.35	1.75	1.40	1.83

Appendix D - continued

Hog No.	Sl. Wt.	Fat Depth - Ultrasonic Shoulder	Center	Loin	Av.	Fat Depth - Live Probe Shoulder	Center	Loin	Av.
HD 36-13	208	3.20	1.80	2.80	2.60	1.90	1.15	1.35	1.47
HD 38-3	204	4.20	2.40	3.20	3.27	2.25	1.90	1.70	1.95
D 20-2	226	4.60	2.50	3.40	3.50	2.45	1.80	1.70	1.98
D 1-1	200	4.00	2.30	2.30	2.87	2.00	1.30	1.25	1.52
CH 39-4	205	3.70	2.20	2.90	2.93	1.95	1.45	1.50	1.63
DH 35-5	207	4.50	2.60	2.80	3.30	2.25	1.30	1.35	1.63
CDH 47-8	208	3.90	1.80	2.40	2.70	1.80	1.10	1.25	1.38
CDH 36-7	203	4.80	3.00	3.50	3.77	2.45	1.40	1.50	1.78
D 9-4	208	2.90	2.20	2.70	2.60	1.95	1.50	1.40	1.62
D 5-7	205	3.70	2.10	2.20	2.67	1.85	1.15	1.25	1.42
CDH 36-5	204	4.10	2.10	2.60	2.93	1.95	1.45	1.30	1.57
CDH 34-4	206	4.60	2.70	2.50	3.27	2.45	1.20	1.30	1.65
D 5-1	213	4.40	2.90	2.80	3.27	2.35	1.70	1.50	1.85
D 18-12	206	3.60	2.00	2.20	2.60	1.85	1.40	1.20	1.48
D 21-3	210	3.90	2.50	2.40	2.93	2.25	1.85	1.35	1.82
D 12-6	214	5.00	2.90	2.60	3.50	2.80	1.50	1.30	1.87
HD 50-11	194	3.60	2.10	2.20	2.63	1.85	1.20	1.10	1.38
HD 50-4	180	4.40	3.00	3.10	3.50	2.25	1.55	1.30	1.70
T 222	200	2.90	1.90	2.40	2.40	1.85	1.25	1.30	1.47
D 12-7	214	4.10	2.60	2.70	3.13	2.20	1.25	1.35	1.60
Y 3-9	202	2.90	1.40	1.30	1.87	1.25	0.85	0.80	0.97
Y 7-3	186	2.40	1.60	1.80	1.93	1.50	0.90	1.10	1.17
Y 6-6	192	2.80	2.10	2.40	2.43	1.95	1.10	1.35	1.47
T 243	197	3.30	2.40	2.80	2.83	1.70	1.30	1.10	1.37
Y 13-6	190	3.00	2.00	2.00	2.33	1.70	1.10	1.05	1.28
Y 7-9	200	3.20	2.10	2.50	2.60	1.85	1.15	1.25	1.42
C 1	228	3.30	2.60	2.90	2.93	1.85	1.30	1.35	1.50
C 5	224	3.30	2.60	3.40	3.10	1.85	1.30	1.75	1.63
C 8	216	3.10	1.80	2.20	2.37	1.65	1.20	1.15	1.33
C 7	232	3.00	2.10	2.50	2.53	1.60	1.35	1.35	1.43
C 6	217	3.90	2.40	3.30	3.20	2.20	1.65	1.70	1.85
C 2	246	3.90	2.80	3.30	3.33	2.15	1.60	1.65	1.80
C 3	226	3.30	2.40	3.10	2.93	1.75	1.20	1.45	1.47
C 4	252	3.70	2.30	2.70	2.90	2.00	1.35	1.50	1.62
	15336	267.30	167.20	192.30	208.81	145.35	102.05	97.65	115.03
Mean	207.25	3.61	2.26	2.60	2.82	1.96	1.38	1.32	1.55
S.D.	13.43	0.58	0.37	0.40	0.38	0.30	0.26	0.19	0.22

Appendix D - continued

	Fat Depth - Carcass Probe				Av.		
Hog No.	Shoulder	Center	Loin	Av.	Backfat Thickness	Fat Depth Tracing	Fat Trim
D 4-8	1.70	1.20	1.20	1.37	1.63	1.22	23.13
D 10-1	2.00	1.50	1.20	1.57	1.61	1.54	24.98
D 8-14	2.00	1.30	1.30	1.53	1.74	1.46	25.05
CDH 36-10	1.70	1.40	1.40	1.50	1.68	1.32	25.95
CDH 36-12	2.00	1.30	1.80	1.70	1.62	1.42	21.81
DH 35-9	2.00	1.50	1.70	1.73	1.86	1.94	28.38
CDH 36-11	1.70	1.60	1.50	1.60	1.79	1.50	26.94
CDH 47-12	1.80	1.40	1.40	1.53	1.58	1.46	26.26
D 21-9	1.50	1.20	1.30	1.33	1.59	1.25	20.56
D 16-10	1.50	1.40	1.60	1.50	1.48	1.46	25.60
D 8-15	1.80	1.50	1.30	1.53	1.63	1.24	23.75
DH 37-13	2.10	1.70	1.40	1.73	1.87	1.73	27.86
D 11-7	1.70	1.60	1.30	1.53	1.62	1.68	25.42
Y 240	1.90	1.50	1.40	1.60	1.68	1.42	26.32
CDH 47-7	1.90	1.60	1.60	1.70	1.71	1.50	28.30
Y 231	1.20	0.80	1.10	1.03	1.16	0.96	20.07
D 17-5	2.00	1.50	1.20	1.57	1.67	1.48	23.15
D 14-2	1.90	1.70	1.60	1.73	1.90	1.71	28.04
D 6-9	1.80	1.30	1.40	1.50	1.75	1.46	23.21
CDH 31-5	2.00	1.60	1.50	1.70	1.77	1.64	27.33
CDH 47-10	2.00	1.60	1.40	1.67	1.65	1.50	25.56
CDH 47-9	2.00	1.60	1.50	1.70	1.72	1.40	26.24
Y 4-9	1.70	1.30	1.40	1.47	1.43	1.17	21.58
Y 7-12	1.50	1.10	1.20	1.27	1.57	1.28	21.58
Y 5-6	1.70	1.20	1.30	1.40	1.56	1.30	22.27
Y 6-7	1.60	1.10	1.30	1.33	1.46	1.28	20.76
DH 33-1	2.10	1.70	1.40	1.73	1.88	2.00	27.75
D 6-7	1.70	1.20	1.10	1.33	1.64	1.10	20.13
H 56-3	1.85	1.30	2.00	1.72	1.85	2.16	26.23
Y 237	1.70	1.10	1.20	1.33	1.52	1.08	22.30
H 51-2	1.70	1.20	1.30	1.40	1.67	1.38	28.82
H 56-4	2.00	1.50	1.80	1.77	1.77	1.65	28.79
H 61-3	2.00	1.60	1.80	1.80	2.21	2.24	32.20
C 228	1.60	1.60	1.50	1.57	1.50	1.67	24.10
D 6-2	2.50	1.70	1.70	1.97	2.21	2.13	30.15
D 6-6	1.80	1.50	2.00	1.77	1.61	1.57	24.94
HD 31-12	2.00	1.70	1.60	1.77	1.82	1.87	27.52
HD 45-1	2.20	2.00	1.50	1.90	2.01	1.99	30.87
HD 31-4	1.80	1.50	1.60	1.63	1.77	1.44	28.54
HD 46-8	2.20	1.80	2.30	2.10	2.01	1.81	29.77

Appendix D - continued

Hog No.	Fat Depth - Carcass Probe Shoulder	Center	Loin	Av.	Av. Backfat Thickness	Fat Depth Tracing	Fat Trim
HD 36-13	1.80	1.50	1.50	1.60	1.68	1.38	25.13
HD 38-3	2.00	1.90	1.80	1.90	2.05	1.83	32.11
D 20-2	2.30	2.00	1.80	2.03	2.31	1.83	33.07
D 1-1	1.70	1.70	1.30	1.57	1.70	1.63	27.37
CH 39-4	1.70	1.20	1.50	1.47	1.67	1.46	26.21
DH 35-5	2.30	1.50	1.50	1.77	1.87	1.50	27.57
CDH 47-8	1.50	1.20	1.20	1.30	1.69	1.28	25.56
CDH 36-7	2.00	1.60	1.70	1.77	2.04	1.79	30.50
D 9-4	1.70	1.50	1.60	1.60	1.71	1.69	27.19
D 5-7	1.50	1.30	1.10	1.30	1.47	1.26	21.99
CDH 36-5	1.80	1.50	1.50	1.60	1.89	1.56	25.64
CDH 34-4	2.10	1.40	1.40	1.63	1.92	1.63	26.47
D 5-1	2.10	1.80	1.50	1.80	1.99	1.69	27.87
D 18-12	1.60	1.20	1.10	1.30	1.56	1.26	23.36
D 21-3	2.00	1.70	1.40	1.70	1.80	1.61	24.94
D 12-6	2.20	1.60	1.40	1.73	1.86	1.70	27.65
HD 50-11	1.60	1.10	1.20	1.30	1.60	1.42	22.27
HD 50-4	1.80	1.60	1.40	1.60	2.00	1.63	29.59
T 222	1.90	1.50	1.70	1.70	1.65	1.52	27.30
D 12-7	2.00	1.50	1.50	1.67	1.63	1.48	27.44
Y 3-9	1.30	1.00	0.90	1.07	1.29	0.98	16.42
Y 7-3	1.40	1.00	1.10	1.17	1.28	1.10	17.85
Y 6-6	1.50	1.30	1.30	1.37	1.52	1.38	21.12
T 243	1.80	1.40	1.10	1.43	1.56	1.66	22.99
Y 13-6	1.50	1.00	1.10	1.20	1.46	1.20	19.78
Y 7-9	1.60	1.20	1.40	1.40	1.64	1.20	23.69
C 1	1.80	1.30	1.50	1.53	1.74	1.61	25.60
C 5	1.80	1.40	1.80	1.67	1.77	1.81	28.26
C 8	1.65	1.30	1.30	1.42	1.48	1.32	23.95
C 7	1.60	1.20	1.40	1.40	1.57	1.44	23.87
C 6	1.80	1.50	1.80	1.70	1.74	1.70	27.00
C 2	2.00	1.70	1.70	1.80	1.94	1.97	28.12
C 3	1.70	1.30	1.60	1.53	1.59	1.54	26.95
C 4	2.00	1.50	1.50	1.67	1.84	1.56	24.79
	134.90	106.30	107.70	116.31	126.71	112.98	1891.91
Mean	1.82	1.44	1.46	1.57	1.71	1.52	25.57
S.D.	0.24	0.24	0.25	0.21	0.21	0.27	3.31

Appendix D - continued

Hog No.	Lean Depth - Ultrasonic				Lean Depth - Carcass Probe			
	Shoulder	Center	Loin	Av.	Shoulder	Center	Loin	Av.
D 4-8	0.65	0.70	0.75	0.70	2.87	2.22	2.70	2.60
D 10-1	0.65	0.80	0.65	0.70	3.16	2.00	2.38	2.51
D 8-14	0.50	0.45	0.55	0.50	2.53	1.93	2.48	2.31
CDH 36-10	0.75	0.65	0.75	0.72	2.71	2.30	2.42	2.48
CDH 36-12	0.90	0.65	0.85	0.80	3.20	2.32	1.90	2.47
DH 35-9	1.05	0.60	0.55	0.73	2.92	2.16	2.04	2.37
CDH 36-11	0.70	0.50	0.60	0.60	3.18	1.86	2.56	2.53
CDH 47-12	1.05	1.15	1.20	1.13	2.92	2.18	2.22	2.44
D 21-9	0.60	0.60	0.85	0.68	2.99	2.38	3.15	2.84
D 16-10	0.70	0.50	0.40	0.53	2.87	2.02	2.22	2.37
D 8-15	0.65	0.80	0.80	0.75	2.84	1.57	2.24	2.22
DH 37-13	0.90	0.70	0.80	0.80	2.94	1.96	2.22	2.37
D 11-7	0.90	0.80	0.60	0.77	3.02	2.18	2.60	2.60
Y 240	0.65	0.60	0.55	0.60	2.08	1.49	1.83	1.80
CDH 47-7	1.15	0.70	0.90	0.92	2.67	1.94	1.98	2.20
Y 231	0.75	0.85	0.85	0.82	2.93	1.84	2.25	2.34
D 17-5	1.00	1.05	0.70	0.92	3.08	2.08	2.11	2.42
D 14-2	0.90	0.90	0.80	0.87	2.74	1.88	2.22	2.28
D 6-9	0.50	0.70	0.65	0.62	2.92	2.16	2.46	2.51
CDH 31-5	1.00	0.85	0.65	0.83	3.04	1.59	2.48	2.37
CDH 47-10	1.90	0.70	0.70	1.10	2.53	1.78	2.58	2.30
CDH 47-9	1.00	0.70	0.65	0.78	2.61	1.82	2.36	2.26
Y 4-9	0.90	1.25	1.20	1.12	2.63	1.42	2.10	2.05
Y 7-12	1.15	1.90	1.75	1.60	2.59	1.73	2.50	2.27
Y 5-6	1.00	1.75	1.60	1.45	2.71	1.99	2.28	2.33
Y 6-7	0.95	1.50	0.90	1.12	2.85	2.09	2.68	2.54
DH 33-1	1.15	0.65	0.85	0.88	2.66	2.08	2.54	2.43
D 6-7	0.75	0.90	1.10	0.92	2.32	2.11	2.92	2.45
H 56-3	1.05	1.25	1.55	1.28	2.83	1.85	1.86	2.18
Y 237	0.95	1.25	0.85	1.02	2.16	1.54	2.18	1.96
H 51-2	1.30	1.80	1.50	1.53	3.22	1.87	1.97	2.35
H 56-4	1.00	1.05	1.60	1.22	2.53	1.37	1.74	1.88
H 61-3	1.90	1.80	1.50	1.73	2.43	1.82	2.22	2.16
C 228	0.25	1.15	1.00	0.80	2.61	1.27	2.24	2.04
D 6-2	0.60	1.45	0.80	0.95	2.42	1.84	2.20	2.15
D 6-6	0.95	0.90	0.90	0.92	2.69	2.12	1.86	2.22
HD 31-12	1.20	1.65	1.15	1.33	2.64	1.81	2.36	2.27
HD 45-1	1.55	1.05	0.90	1.17	3.11	1.82	2.40	2.44
HD 31-4	1.33	1.35	1.25	1.31	3.16	1.88	2.42	2.49
HD 46-8	1.05	1.20	1.00	1.08	2.76	1.62	1.24	1.87

Appendix D - continued

Hog No.	Lean Depth - Ultrasonic Shoulder	Center	Loin	Av.	Lean Depth - Carcass Probe Shoulder	Center	Loin	Av.
HD 36-13	1.40	2.30	1.20	1.63	2.81	2.04	1.81	2.22
HD 38-3	1.10	2.30	1.00	1.47	3.04	1.76	1.86	2.22
D 20-2	0.70	0.95	1.20	0.95	2.70	2.02	2.33	2.35
D 1-1	1.20	1.15	0.55	0.97	3.18	1.53	2.44	2.38
CH 39-4	0.65	1.30	0.45	0.80	3.30	2.38	1.88	2.52
DH 35-5	0.85	0.70	1.00	0.85	3.01	1.92	1.85	2.26
CDH 47-8	0.55	1.10	0.70	0.78	3.03	1.99	2.46	2.49
CDH 36-7	1.20	1.20	1.45	1.28	2.64	1.94	2.00	2.19
D 9-4	0.65	1.00	0.85	0.83	2.36	2.00	2.34	2.23
D 5-7	1.05	1.15	1.20	1.13	2.83	2.20	2.52	2.52
CDH 36-5	0.75	0.85	0.70	0.77	3.00	1.96	2.36	2.44
CDH 34-4	1.10	1.05	1.15	1.10	3.21	2.14	2.34	2.56
D 5-1	1.30	0.85	0.60	0.92	2.70	1.78	2.28	2.25
D 18-12	0.80	0.70	1.20	0.90	3.16	2.18	2.64	2.66
D 21-3	0.35	0.65	0.60	0.53	3.35	2.08	1.71	2.38
D 12-6	0.80	0.75	1.30	0.95	3.04	2.10	2.10	2.41
HD 50-11	0.90	0.55	0.90	0.78	2.93	2.08	3.01	2.67
HD 50-4	0.50	0.70	0.55	0.58	2.92	2.02	2.42	2.45
T 222	1.25	1.25	1.40	1.30	3.34	1.92	1.96	2.41
D 12-7	1.45	0.90	0.75	1.03	3.08	1.96	2.16	2.40
Y 3-9	1.15	0.90	1.15	1.07	2.40	1.36	2.33	2.03
Y 7-3	1.20	1.00	1.30	1.17	2.14	1.32	2.64	2.03
Y 6-6	0.80	1.15	1.20	1.05	2.40	1.06	2.05	1.84
T 243	0.95	1.40	1.30	1.22	2.29	2.02	2.40	2.24
Y 13-6	0.70	1.80	1.50	1.33	2.44	2.19	2.60	2.41
Y 7-9	0.70	1.55	1.15	1.13	2.38	1.95	1.98	2.10
C 1	1.25	2.10	1.55	1.63	3.28	2.64	2.91	2.94
C 5	0.95	2.10	0.90	1.32	3.04	2.30	2.26	2.53
C 8	1.25	1.50	1.10	1.28	2.76	1.73	2.44	2.31
C 7	0.80	0.65	0.95	0.80	2.46	2.34	2.69	2.50
C 6	0.75	1.30	0.85	0.97	2.96	2.28	1.66	2.30
C 2	0.95	2.20	2.05	1.73	3.31	2.08	2.55	2.65
C 3	0.95	0.70	0.65	0.77	2.51	2.20	2.61	2.44
C 4	0.95	1.05	0.95	0.98	2.84	2.36	3.11	2.77
	69.78	80.60	72.55	74.30	207.91	143.72	169.81	173.77
Mean	0.94	1.09	0.98	1.00	2.81	1.94	2.29	2.35
S.D.	0.30	0.46	0.34	0.30	0.31	0.29	0.34	0.22

Appendix D - continued

Hog No.	Lean Depth - Tracing	Lean Cuts Carcass	Lean Cuts Live	Primal Cuts Carcass	Primal Cuts Live	Area L. D. 10th Rib	Area L. D. Last Rib
D 4-8	1.95	53.74	38.54	66.26	47.51	4.19	4.00
D 10-1	1.40	53.72	38.05	65.48	46.38	3.65	3.55
D 8-14	1.93	52.73	38.20	65.66	47.56	4.18	4.04
CDH 36-10	1.89	51.90	38.54	65.75	48.83	3.71	3.74
CDH 36-12	2.27	54.94	41.76	69.06	52.49	4.55	4.90
DH 35-9	1.79	49.67	36.53	62.08	45.66	3.57	3.64
CDH 36-11	1.84	51.85	38.67	64.87	48.38	3.51	3.38
CDH 47-12	1.85	50.67	37.94	64.31	48.16	3.58	3.98
D 21-9	2.11	57.81	43.43	68.94	51.78	5.21	5.32
D 16-10	1.79	52.15	37.67	65.99	47.67	3.81	3.59
D 8-15	1.71	52.50	37.61	65.62	47.01	3.64	3.66
DH 37-13	1.73	51.01	37.76	64.38	47.67	3.72	3.76
D 11-7	1.95	53.56	38.66	66.93	48.30	3.98	4.17
Y 240	1.14	52.14	38.40	65.96	48.58	2.99	2.71
CDH 47-7	1.61	50.43	37.54	64.03	47.66	2.92	3.33
Y 231	1.63	54.84	40.52	67.77	50.08	3.67	4.25
D 17-5	2.09	55.87	39.36	66.26	46.67	3.97	4.14
D 14-2	1.67	50.87	37.40	63.22	46.48	3.21	3.13
D 6-9	1.89	56.59	40.80	67.97	49.01	4.46	4.27
CDH 31-5	1.54	51.89	38.68	63.91	47.64	3.46	3.47
CDH 47-10	1.83	50.64	37.03	64.12	46.89	3.40	3.60
CDH 47-9	1.97	52.99	38.96	64.79	47.64	3.92	3.82
Y 4-9	1.75	54.96	39.48	67.41	48.42	3.44	3.71
Y 7-12	1.61	54.30	38.45	67.38	47.72	3.64	3.44
Y 5-6	1.71	53.90	38.78	66.52	47.86	3.61	3.55
Y 6-7	1.60	55.12	39.73	67.58	48.70	3.94	3.79
DH 33-1	1.42	49.02	35.17	62.41	44.78	2.78	2.87
D 6-7	2.20	55.31	39.16	67.92	48.08	4.37	4.47
H 56-3	1.46	48.92	35.14	62.62	44.97	2.37	2.57
Y 237	1.26	52.27	38.44	66.58	48.97	3.23	3.66
H 51-2	1.97	49.67	36.71	63.34	46.82	3.02	3.55
H 56-4	1.65	48.52	35.48	62.58	45.76	2.70	2.97
H 61-3	2.09	47.02	34.89	61.74	45.82	2.83	3.11
C 228	1.38	50.17	38.28	65.22	49.76	3.28	3.31
D 6-2	1.59	47.90	34.67	61.20	44.30	3.05	3.10
D 6-6	1.87	54.88	39.55	66.88	48.20	4.35	4.11
HD 31-12	1.63	50.28	37.45	63.73	47.47	3.41	3.79
HD 45-1	1.73	46.40	34.19	60.93	44.90	3.37	3.35
HD 31-4	2.03	48.99	35.34	62.66	45.20	4.04	4.21
HD 46-8	1.40	48.84	35.24	63.47	45.80	3.32	3.09

Appendix D - continued

Hog No.	Lean Depth - Tracing	Lean Cuts Carcass	Lean Cuts Live	Primal Cuts Carcass	Primal Cuts Live	Area L.D. 10th Rib	Area L.D. Last Rib
HD 36-13	1.46	52.04	38.53	66.36	49.13	3.27	3.77
HD 38-3	1.63	47.72	34.98	61.81	45.29	3.18	3.14
D 20-2	1.71	48.60	36.02	60.66	44.96	3.96	3.90
D 1-1	1.33	49.86	36.52	63.52	46.52	2.85	2.89
CH 39-4	1.93	51.50	38.44	65.10	48.58	3.74	3.99
DH 35-5	1.74	50.16	37.44	62.98	47.00	3.13	3.37
CHD 47-8	1.61	52.74	38.80	65.75	48.36	3.39	3.61
CDH 36-7	0.81	48.11	35.66	62.19	46.11	2.75	2.87
D 9-4	1.77	51.78	36.26	63.42	44.41	3.40	3.38
D 5-7	1.95	54.15	39.76	67.31	49.41	3.84	4.03
CDH 36-5	1.40	50.47	36.77	64.63	47.09	3.43	3.43
CDH 34-4	1.97	51.82	38.11	64.88	47.72	3.73	4.17
D 5-1	1.79	50.00	36.38	62.90	45.77	2.82	3.55
D 18-12	1.87	53.16	39.13	66.51	48.96	3.85	3.94
D 21-3	1.65	53.44	39.19	65.58	48.10	3.48	3.53
D 12-6	1.80	50.22	36.41	63.54	46.06	3.48	3.33
HD 50-11	1.80	55.05	41.18	67.77	50.69	4.17	4.21
HD 50-4	1.85	49.89	37.45	63.02	47.31	2.81	3.20
T 222	1.84	50.81	37.69	64.39	47.77	4.29	3.88
D 12-7	1.67	49.10	35.88	63.01	46.04	3.17	3.02
Y 3-9	1.52	57.26	40.30	68.56	48.25	4.16	3.84
Y 7-3	1.10	59.04	42.85	70.15	50.91	4.21	4.19
Y 6-6	0.71	53.72	37.63	66.95	46.90	2.89	3.42
T 243	1.08	55.07	41.09	67.89	50.66	4.03	4.41
Y 13-6	1.54	55.63	40.84	69.21	50.82	4.03	4.06
Y 7-9	1.79	53.07	38.17	64.77	46.59	3.34	3.70
C 1	2.09	51.54	38.77	64.20	48.29	4.21	4.37
C 5	1.83	49.67	37.11	61.77	46.15	3.36	3.86
C 8	1.82	52.26	37.38	64.82	46.36	3.33	3.76
C 7	1.42	53.72	38.40	65.35	46.72	3.75	3.97
C 6	1.76	50.22	37.03	62.94	46.40	3.33	3.80
C 2	2.01	50.59	38.25	63.87	48.29	4.53	4.81
C 3	1.71	48.97	35.94	62.81	46.10	3.67	3.51
C 4	1.34	52.34	39.05	64.79	48.33	4.58	4.60
	125.23	3842.70	2811.61	4806.94	3517.63	266.21	274.61
Mean	1.69	51.93	37.99	64.96	47.54	3.60	3.71
S.D.	0.29	2.63	1.87	2.18	1.71	0.53	0.51

Appendix E - Data - Group B, Swine

Hog No.	Sl. Wt.	Fat Depth - Ultrasonic: Live Av.	Live Center	Carc. Av.	Carc. Center	Fat Depth: Live Probe Av.	Carc. Probe Av.	Tracing Center
DH 61-7	181.0	2.67	2.1	2.70	2.1	1.37	1.30	1.12
D 33-9	195.0	2.60	2.2	2.80	2.4	1.50	1.37	1.36
DH 60-9	191.0	2.60	2.2	2.83	2.4	1.37	1.37	1.38
DH 61-5	180.0	2.27	1.8	2.37	2.1	1.20	1.30	1.12
DH 61-8	192.0	2.47	2.0	2.50	2.0	1.35	1.33	1.54
H 80-3	185.0	2.07	1.8	2.57	2.3	1.23	1.27	1.18
DH 58-1	189.0	2.47	1.9	2.63	2.1	1.32	1.30	1.22
Y 249	192.5	2.41	2.0	2.57	2.3	1.22	1.20	1.12
B 10-11	208.0	2.40	1.6	2.53	1.9	1.18	1.20	1.00
H 7-1	220.5	2.83	2.2	3.00	2.2	1.58	1.37	1.26
H 6-1	232.0	3.00	2.5	3.00	2.4	1.65	1.53	1.56
BH 53-1	207.0	2.80	1.9	3.03	2.3	1.67	1.67	1.26
BH 55-5	205.5	2.93	2.0	3.17	2.4	1.57	1.47	1.42
C 6-3	219.5	3.23	2.4	3.50	2.8	1.80	1.70	1.75
BH 53-5	221.0	2.70	1.9	2.93	2.3	1.70	1.57	1.22
H 2-1	219.5	2.96	2.2	3.16	2.3	1.65	1.60	1.30
C 3-10	187.0	2.43	1.8	2.50	2.0	1.42	1.47	1.30
H 2-3	192.0	2.60	2.0	2.63	2.2	1.35	1.37	1.28
H 5-10	194.0	2.63	2.2	2.90	2.5	1.42	1.33	1.32
Y 10-1	194.0	2.17	1.8	2.10	1.8	1.12	1.13	1.12
Y 264	201.0	2.10	1.8	2.23	2.1	1.17	1.13	1.14
B 10-10	186.0	2.20	1.8	2.30	2.0	1.08	1.23	1.04
H 5-2	191.0	2.63	2.1	2.90	2.5	1.47	1.40	1.46
D 27-9	184.0	2.13	1.7	2.37	2.1	1.03	1.13	1.14
Y 252	214.0	2.90	2.7	3.10	2.5	1.53	1.47	1.53
Y 255	190.0	2.10	1.6	2.20	1.8	1.08	1.07	0.98
H 86-3	185.0	3.00	2.2	3.23	2.5	1.58	1.63	1.34
D 29-2	204.5	2.30	1.9	2.60	2.2	1.37	1.33	1.26
P 283	194.0	2.90	2.1	2.97	2.5	1.27	1.37	1.36
P 279	192.0	2.67	2.1	2.87	2.2	1.38	1.33	1.10
P 258	201.5	3.10	2.3	2.93	2.6	1.43	1.50	1.30
D 27-7	205.0	2.93	2.2	3.30	2.7	1.43	1.57	1.34
D 32-8	205.5	2.87	2.2	3.13	2.7	1.58	1.50	1.46
D 27-3	201.5	3.20	2.4	3.43	2.9	1.65	1.70	1.46
B 10-2	196.5	2.23	1.4	2.33	1.8	1.25	1.20	0.98
Y 14-9	193.0	2.13	1.7	2.40	2.0	1.13	1.33	1.16
H 87-2	197.5	3.37	3.0	3.33	2.6	1.75	1.63	1.56
B 7-12	194.0	2.23	1.8	2.20	1.8	1.05	1.10	0.94
H 8-8	192.0	2.13	1.7	2.30	1.8	1.17	1.17	1.04
H 55-4	190.0	2.60	1.9	2.90	2.5	1.48	1.50	1.26
B 2-6	162.0	1.77	1.1	1.57	1.1	0.73	1.00	0.69
B 8-1	188.0	2.37	1.7	2.60	2.2	1.25	1.13	0.98
BH 8-5	197.0	2.30	1.9	2.23	1.9	1.15	1.13	1.06
BH 53-6	188.0	2.67	2.0	2.87	2.3	1.35	1.33	1.18
D 32-4	193.0	2.83	2.5	2.90	2.7	1.53	1.43	1.56

Appendix E - continued

Hog No.	Sl. Wt.	Fat Depth - Ultrasonic: Live Av.	Live Center	Carc. Av.	Carc. Center	Fat Depth: Live Probe Av.	Carc. Probe Av.	Tracing Center
BH 57-8	197.0	2.43	1.9	2.53	2.1	1.25	1.20	1.12
B 8-10	198.0	1.73	1.3	1.90	1.4	0.85	1.00	0.90
Y 14-5	190.0	1.67	1.3	1.60	1.5	0.80	0.87	0.83
D 31-8	191.0	2.40	2.0	2.53	1.9	1.30	1.30	1.26
H 80-8	188.0	3.07	2.5	3.37	2.9	1.72	1.70	1.65
BH 56-7	188.5	2.57	1.8	2.70	2.1	1.40	1.33	1.28
H 80-5	195.0	3.40	2.8	3.77	3.3	1.78	1.83	1.79
YC 4-5	245.0	3.10	2.3	2.93	2.3	1.67	1.60	1.57
YC 3-7	219.0	2.77	1.9	2.77	2.1	1.63	1.53	1.34
YC 3-6	197.0	2.60	2.1	2.53	2.2	1.43	1.37	1.22
YC 1-5	198.0	2.97	2.5	2.93	2.5	1.62	1.53	1.54
YC 7-6	189.0	2.67	2.0	2.73	2.1	1.45	1.37	1.18
YC 6-7	206.0	3.00	2.3	3.30	2.6	1.77	1.57	1.52
YC 6-6	201.0	2.73	1.9	3.07	2.3	1.60	1.53	1.24
YC 1-6	205.0	3.17	2.3	3.17	2.4	1.58	1.47	1.32
YC 2-6	201.0	3.00	2.3	3.10	2.4	1.52	1.53	1.32
YC 5-5	207.0	3.00	2.2	3.10	2.5	1.67	1.50	1.54
D 34-12	196.0	2.73	2.0	2.87	2.1	1.55	1.47	1.22
D 34-7	188.0	2.57	2.0	2.90	2.4	1.43	1.47	1.42
H 87-6	186.0	2.77	2.4	3.00	2.7	1.63	1.47	1.46
D 39-3	195.0	3.37	2.5	3.60	2.9	1.77	1.87	1.69
YC 2-5	189.0	3.27	2.5	3.47	2.9	1.83	1.67	1.57
D 33-5	189.0	2.63	2.0	2.67	2.1	1.42	1.33	1.16
H 83-5	192.0	2.80	2.6	2.87	2.6	1.45	1.33	1.38
D 34-11	192.0	2.73	2.3	2.87	2.3	1.47	1.40	1.34
CDH 65-1	183.0	2.63	1.9	2.63	1.9	1.20	1.27	0.96
DH 61-11	190.0	2.23	1.7	2.27	1.8	1.02	1.10	0.88
D 77-2	184.0	2.53	1.9	2.70	2.1	1.22	1.23	1.18
CD 64-1	197.0	2.37	1.9	2.70	2.2	1.32	1.27	1.08
CH 59-9	181.0	2.60	2.0	2.53	2.0	1.23	1.23	1.04
DH 58-9	216.0	2.33	2.2	2.80	2.3	1.30	1.30	1.24
H 80-7	192.0	2.90	2.4	3.40	2.9	1.48	1.40	1.52
H 81-4	185.0	2.63	2.1	3.03	2.4	1.35	1.27	1.44
DH 61-1	218.0	3.00	2.2	2.60	2.0	1.67	1.57	1.57
H 86-8	189.0	3.07	2.2	3.40	2.8	1.55	1.47	1.52
DH 58-3	193.0	2.27	1.8	2.50	2.0	1.13	1.10	1.06
H 83-6	193.0	2.90	2.2	2.83	2.4	1.30	1.30	1.38
C 267	202.0	1.93	1.4	2.13	1.7	1.05	1.00	1.02
H 270	196.0	2.00	1.6	2.23	1.9	1.00	1.07	0.87
	16,513.0	220.44	171.5	232.64	189.8	116.97	114.98	106.77
Mean	196.6	2.62	2.04	2.78	2.26	1.39	1.37	1.27
S. D.	12.32	0.39	0.34	0.43	0.37	0.24	0.20	0.23

Appendix E - continued

Hog No.	Av. Backfat Thickness	Lean Depth - Center Ult. Live	Ult. Carc.	Carc. Probe	Tracing Meas.	Lean Cuts Carcass	Lean Cuts Live
DH 61-7	1.58	0.90	1.50	1.81	1.75	50.15	37.13
D 33-9	1.60	1.17	1.80	1.91	1.85	53.42	40.00
DH 60-9	1.57	1.07	1.30	1.79	1.57	50.10	37.90
DH 61-5	1.39	1.10	1.40	1.93	1.79	52.74	38.53
DH 61-8	1.52	1.43	1.43	1.85	1.63	50.84	37.86
H 80-3	1.50	1.40	1.33	2.18	1.93	52.75	40.49
DH 58-1	1.57	1.47	1.50	2.28	2.03	55.00	40.74
Y 249	1.50	1.33	1.63	2.38	2.07	58.37	44.73
B 10-11	1.45	1.47	1.57	2.27	2.22	59.87	43.89
H 7-1	1.48	1.37	1.97	2.05	1.97	51.51	37.96
H 6-1	1.66	1.27	1.90	2.28	1.87	50.03	36.98
BH 53-1	1.72	1.37	1.93	1.41	2.07	53.59	40.00
BH 55-5	1.73	1.13	1.70	2.07	1.73	51.41	38.15
C 6-3	1.89	1.10	1.87	2.00	1.77	50.65	37.27
BH 53-5	1.73	1.47	1.83	2.40	2.20	54.22	40.36
H 2-1	1.69	1.47	1.73	2.05	1.93	51.99	38.13
C 3-10	1.27	1.50	1.43	2.10	1.93	56.89	43.05
H 2-3	1.46	1.28	1.47	1.95	1.97	58.00	43.80
H 5-10	1.56	1.27	1.57	2.19	2.06	52.15	38.71
Y 10-1	1.26	1.30	1.40	2.03	1.84	58.24	42.63
Y 264	1.41	1.00	1.10	1.76	1.56	55.15	40.47
B 10-10	1.32	1.40	1.63	2.11	2.12	56.60	41.69
H 5-2	1.54	1.40	1.87	1.83	1.97	53.83	39.74
D 27-9	1.25	1.63	1.40	1.76	1.75	55.75	39.54
Y 252	1.80	1.20	1.77	2.08	1.83	52.46	39.84
Y 255	1.34	1.17	1.20	1.92	1.61	54.68	40.29
H 86-3	1.98	1.37	1.77	1.73	1.87	50.55	37.43
D 29-2	1.52	1.27	1.77	1.95	1.81	54.78	40.32
P 283	1.47	1.50	1.67	2.11	1.97	56.57	44.61
P 279	1.50	1.30	1.67	2.13	2.05	54.73	41.61
P 258	1.59	1.23	1.53	2.20	2.09	54.39	39.01
D 27-7	1.68	1.37	1.80	2.14	2.20	52.72	38.83
D 32-8	1.67	1.47	1.60	1.93	1.79	54.52	39.93
D 27-3	1.83	1.30	1.90	1.84	1.95	51.63	36.90
B 10-2	1.50	1.43	1.60	2.03	1.87	55.22	41.73
Y 14-9	1.39	1.23	1.33	1.81	1.87	58.04	42.85
H 87-2	1.99	1.10	1.73	2.04	1.65	48.31	36.20
B 7-12	1.45	1.30	1.60	2.15	2.18	56.92	42.40
H 8-8	1.24	1.43	1.70	1.68	1.73	56.64	39.97
H 55-4	1.66	1.37	1.27	1.59	1.59	54.72	38.74
B 2-6	1.04	1.23	1.13	1.76	1.85	61.14	46.23
B 8-1	1.48	1.23	1.37	1.99	1.81	58.97	42.66
BH 8-5	1.29	1.37	1.77	2.23	2.18	57.59	41.22
BH 53-6	1.57	1.33	1.53	1.97	1.85	52.70	39.39
D 32-4	1.54	1.17	1.60	1.98	1.81	52.89	38.91

Appendix E - continued

Hog No.	Av. Backfat Thickness	Lean Depth - Center Ult. Live	Ult. Carc.	Carc. Probe	Tracing Meas.	Lean Cuts Carcass	Lean Cuts Live
BH 57-8	1.45	1.17	1.50	2.15	1.95	57.31	41.17
B 8-10	1.26	1.37	1.73	2.13	2.07	59.33	42.70
Y 14-5	0.98	1.07	1.30	1.76	1.71	60.15	42.10
D 31-8	1.52	0.93	0.97	1.89	1.57	51.79	37.83
H 80-8	1.83	1.07	1.53	1.92	1.69	52.04	37.92
BH 56-7	1.60	1.30	1.50	1.91	1.87	57.72	42.25
H 80-5	2.08	1.47	1.40	1.82	1.48	46.35	33.87
YC 4-5	1.69	1.53	1.63	1.94	1.85	51.26	38.28
YC 3-7	1.66	1.37	1.60	1.97	1.99	52.05	38.26
YC 3-6	1.60	1.40	1.57	1.87	1.91	54.95	40.02
YC 1-5	1.76	1.27	1.67	1.87	2.09	53.26	39.54
YC 7-6	1.65	1.23	1.50	2.15	1.87	50.82	37.78
YC 6-7	1.86	1.33	1.53	1.92	1.81	49.42	36.94
YC 6-6	1.65	1.57	1.53	2.07	1.85	53.49	39.25
YC 1-6	1.80	1.33	1.30	1.91	1.67	49.40	35.90
YC 2-6	1.63	1.23	1.40	1.77	1.75	52.12	38.51
YC 5-5	1.79	1.37	1.57	2.11	1.77	51.22	38.60
D 34-12	1.66	1.33	1.60	1.87	1.77	50.90	37.52
D 34-7	1.62	1.23	1.60	1.97	1.63	51.93	37.15
H 87-6	1.79	1.40	2.00	1.97	1.89	48.96	35.54
D 39-3	1.87	1.27	1.63	1.71	1.57	48.77	34.64
YC 2-5	1.93	1.37	1.63	1.91	1.65	48.86	36.19
D 33-5	1.52	1.43	1.70	2.03	1.89	53.59	38.28
H 83-5	1.86	1.33	1.53	1.99	1.97	49.68	36.35
D 34-11	1.62	1.33	1.73	2.12	1.83	51.54	38.38
CDH 65-1	1.60	1.27	1.77	2.07	2.07	54.85	40.16
DH 61-11	1.27	1.33	1.70	2.27	2.09	57.15	42.26
D 77-2	1.33	1.37	1.50	2.19	1.63	54.32	40.00
CD 64-1	1.38	1.37	1.57	2.23	1.81	53.52	39.39
CH 59-9	1.49	1.33	1.63	2.05	2.01	54.78	40.55
DH 58-9	1.69	1.27	1.83	2.21	2.16	56.74	42.68
H 80-7	1.73	1.40	1.83	2.34	1.99	51.35	38.52
H 81-4	1.70	1.20	1.70	2.09	1.81	51.76	38.19
DH 61-1	1.81	1.27	1.37	2.24	1.97	51.10	38.21
H 86-8	1.80	1.47	1.47	2.11	1.67	48.58	36.11
DH 58-3	1.36	1.20	1.43	2.17	1.90	55.51	40.70
H 83-6	1.79	0.97	1.60	2.07	1.97	52.96	38.96
D 267	1.35	1.33	1.53	2.25	2.06	57.69	42.70
H 270	1.40	1.47	1.47	2.27	2.37	58.27	42.96
	132.56	109.57	132.62	168.94	157.75	4508.91	3325.18
Mean	1.58	1.30	1.58	2.01	1.88	53.68	39.58
S. D.	0.21	0.14	0.20	0.19	0.18	3.17	2.43

Appendix E - continued

Hog No.	Primal Cuts Carcass	Primal Cuts Live	Area L.D. 10th Rib	Area L.D. Last Rib	Specific Gravity Ham	Shape Index
DH 61-7	64.92	48.07	2.63	3.12	1.045	15.57
D 33-9	66.71	49.95	3.88	3.86	1.048	16.08
DH 60-9	63.67	48.17	3.46	3.57	1.047	15.40
DH 61-5	67.34	49.19	3.43	3.93	1.051	15.54
DH 61-8	64.30	47.89	3.47	3.36	1.042	15.57
H 80-3	67.60	51.89	4.34	4.18	1.053	14.75
DH 58-1	68.64	50.85	3.65	4.24	1.055	14.60
Y 249	70.27	53.84	4.45	4.71	1.057	14.74
B 10-11	71.41	52.36	4.74	5.00	1.065	13.50
H 7-1	65.54	48.30	3.35	4.15	1.051	15.90
H 6-1	64.20	47.46	3.84	4.01	1.046	15.44
BH 53-1	68.02	50.77	3.91	4.52	1.060	14.77
BH 55-5	65.41	48.54	3.66	3.72	1.053	14.56
C 6-3	63.37	46.63	3.21	3.54	1.052	16.60
BH 53-5	66.32	49.37	4.53	4.78	1.063	14.48
H 2-1	65.59	48.11	3.78	4.05	1.049	14.49
C 3-10	69.26	52.41	4.07	4.36	1.058	15.33
H 2-3	69.24	52.29	4.91	4.43	1.057	14.71
H 5-10	66.32	49.23	4.07	4.08	1.045	14.19
Y 10-1	70.60	51.68	3.96	4.29	1.058	14.97
Y 264	66.95	49.13	3.82	3.89	1.061	15.12
B 10-10	68.87	50.72	4.06	4.35	1.062	14.60
H 5-2	67.23	49.63	3.60	4.02	1.039	14.40
D 27-9	67.24	47.69	3.81	3.73	1.048	14.76
Y 252	66.37	50.40	3.99	3.80	1.050	15.25
Y 255	68.00	50.10	3.69	3.77	1.052	16.07
H 86-3	63.69	47.16	3.58	3.64	1.045	14.08
D 29-2	68.44	50.37	3.56	3.59	1.054	16.22
P 283	68.72	54.20	5.24	4.31	1.050	15.98
P 279	68.05	51.74	4.84	4.50	1.046	13.56
P 258	66.92	47.99	4.27	4.50	1.046	13.53
D 27-7	65.26	48.07	4.30	4.57	1.051	14.15
D 32-8	68.60	50.24	3.63	3.68	1.049	15.08
D 27-3	64.55	46.13	3.23	3.56	1.044	14.73
B 10-2	68.38	51.68	4.72	4.11	1.057	14.24
Y 14-9	69.72	51.48	3.50	3.65	1.064	15.22
H 87-2	63.18	47.34	3.03	3.32	1.042	15.71
B 7-12	69.38	51.68	4.14	4.80	1.062	14.70
H 8-8	70.74	49.92	3.70	3.76	1.056	15.20
H 55-4	67.96	48.10	2.97	3.10	1.052	14.67
B 2-6	72.33	54.69	4.03	3.95	1.070	15.10
B 8-1	71.03	51.38	3.49	3.68	1.061	15.27
BH 8-5	71.49	51.17	4.24	4.52	1.056	14.35
BH 53-6	67.01	50.08	3.38	3.72	1.052	14.50
D 32-4	67.11	49.38	3.76	3.60	1.042	14.96

Appendix E - continued

Hog No.	Primal Cuts Carcass	Primal Cuts Live	Area L.D. 10th Rib	Area L.D. Last Rib	Specific Gravity Ham	Shape Index
BH 57-8	70.25	50.46	3.97	4.23	1.059	14.55
B 8-10	71.19	51.24	4.98	4.59	1.063	13.83
Y 14-5	71.47	50.03	3.53	3.52	1.064	14.68
D 31-8	65.34	47.72	3.35	3.46	1.048	15.40
H 80-8	67.15	48.94	3.24	3.40	1.050	15.12
BH 56-7	68.59	50.21	4.01	4.95	1.056	14.03
H 80-5	60.95	44.54	--	2.93	1.046	---
YC 4-5	65.79	49.14	4.50	4.47	1.048	14.58
YC 3-7	65.34	48.04	3.97	4.30	1.053	14.55
YC 3-6	67.70	49.31	4.23	4.40	1.058	14.38
YC 1-5	65.58	48.69	3.90	4.32	1.052	14.81
YC 7-6	64.06	47.62	3.55	3.76	1.053	14.20
YC 6-7	63.25	47.28	3.31	3.72	1.046	15.23
YC 6-6	66.17	48.56	3.57	3.81	1.057	14.52
YC 1-6	63.22	45.95	3.42	3.31	1.051	14.74
YC 2-6	64.78	47.86	3.28	3.63	1.051	15.37
YC 5-5	64.68	48.74	3.50	3.64	1.047	16.07
D 34-12	64.67	47.68	3.81	3.65	1.044	15.56
D 34-7	65.24	46.68	3.06	3.20	1.050	15.11
H 87-6	62.81	45.59	2.98	3.58	1.044	15.52
D 39-3	61.26	43.51	2.62	2.54	1.041	16.62
YC 2-5	62.25	46.11	2.91	3.30	1.046	14.08
D 33-5	67.74	48.39	4.14	3.89	1.050	14.85
H 83-5	64.06	46.88	3.49	3.73	1.051	15.69
D 34-11	65.10	48.49	3.77	3.61	1.053	14.52
CDH 65-1	68.66	50.27	4.33	4.25	1.057	13.34
DH 61-11	69.96	51.74	4.58	4.93	1.058	13.63
D 77-2	68.19	50.22	3.75	3.52	1.058	15.00
CD 64-1	66.96	49.29	3.71	4.05	1.049	14.36
CH 59-9	67.69	50.11	4.05	4.65	1.058	14.26
DH 58-9	69.05	51.94	5.04	5.40	1.052	14.34
H 80-7	65.76	49.32	4.12	3.90	1.048	14.39
H 81-4	65.86	48.59	2.83	3.38	1.048	14.02
DH 61-1	64.36	48.12	3.37	4.02	1.046	15.38
H 86-8	63.10	46.90	2.87	3.19	1.040	15.64
DH 58-3	68.80	50.44	3.56	4.00	1.055	14.97
H 83-6	67.39	49.58	3.59	4.05	1.048	14.84
C 267	70.94	52.50	5.25	5.71	1.058	15.09
H 270	71.42	52.65	5.05	5.08	1.055	14.31
	5622.73	4146.80	317.11	334.09	88.377	1234.22
Mean	66.94	49.37	3.82	3.98	1.052	14.87
S. D.	2.62	2.12	0.59	0.56	0.006	0.70

Appendix F - Data - Group C, Swine

Pig No.	1 Eye Muscle Area from Cross-sectional Plots	2 Eye Muscle Area from Tracings	3 Sum of Four Fat Thickness Measures
58-10	2.85	2.77	4.3
58-11	3.37	2.75	3.7
1-3	4.77	4.33	3.4
1-13	4.14	4.23	4.8
2-11	3.55	3.23	5.5
43-8	5.14	4.14	4.7
45-11	3.57	4.22	5.3
39-5	4.68	4.18	4.6
43-10	4.65	4.13	3.4
323	5.80	4.90	2.4
320	4.40	4.49	4.0
2-6	3.76	3.82	5.1
32-7	3.62	3.36	5.1
57-3	3.30	3.37	5.6
57-5	2.85	3.09	5.6
0	4.80	4.55	4.9
32-8	3.19	3.00	5.1
33-8	4.21	3.84	5.4
45-15	4.63	3.95	4.8
36-9	3.93	3.37	5.1
1-15	3.48	3.07	3.1
2-15	3.62	3.48	5.9
54.2	3.50	3.51	3.2
39-9	4.37	3.89	5.2
311	3.60	4.60	4.4
58-8	3.75	2.90	3.2
2-12	3.35	3.22	6.1
2-16	3.65	3.28	5.2
50-9	3.22	3.33	2.7
1-1	4.32	3.91	4.2
54-4	3.83	4.08	3.3
42-8	3.45	2.79	5.0
1-14	3.74	2.79	4.9
39-8	3.96	3.52	5.9
39-1	4.57	4.55	4.5
1-5	3.10	3.84	4.3
48-5	3.44	3.05	5.6
41-8	3.32	3.30	3.4
2-8	3.52	3.43	4.7
35-1	3.48	4.01	5.3
36-5	3.45	3.33	5.2
	157.93	149.60	188.1
Mean	3.85	3.65	4.59
S. D.	0.64	0.58	0.93