THE ASSOCIATION BETWEEN CERTAIN LIVE AND CARCASS MEASUREMENTS IN GROWING AND FINISHING SWINE

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CHAPTER I

INTRODUCTION

The increased emphasis placed on muscling in meat animals in recent years has brought about a greater need for more accurate means of evaluating live animals with respect to fat and muscle development. Through their buying practices, consumers have expressed a strong preference for meatier, heavier muscled retail cuts of meat with a minimum of trimmable fat. Animals of similar ages and market weights have been shown to differ greatly in the lean-to-fat ratio in their carcasses. These differences are observed not only within breeds but also within family lines as well as within sire progeny. Since most carcass traits are moderately to highly heritable, more effective tools than are now available for meat animal appraisal are needed to estimate more accurately the body composition of animals for breeding purposes, as well as for slaughter.

Progress in the area of swine nutrition and management has been measured largely in terms of weight increase—total pounds. It appears quite likely that lean tissue of acceptable eating quality can be produced more economically than at present.

There is great need for an easily obtainable means of monitoring the type of tissue being produced during the growing and finishing period. Such a method would allow producers to better utilize the available feed resources for the production of lean tissue. To date there has not been available to researchers a convenient means of monitoring the type of tissue being produced by the animal during the growing and finishing period.

The objectives of this study are listed below.

1. To estimate the repeatability of the Permian K^{40} Counter on five different weights of Yorkshire barrows; 100, 150, 200, 250 and 300 pounds.
2. To observe any trends in the association between certain live measurements obtained from three different techniques (potassium^{40}, ultrasound and ruler probe) and various carcass measurements, at five different weights of Yorkshire barrows during the growing and finishing period.
3. To monitor growth with respect to various live and carcass measurements of Yorkshire barrows at five different weights.

CHAPTER II

REVIEW OF LITERATURE

General

Subjective appraisal of the lean and fat characteristics of live animals for slaughter or selection for breeding purposes has been, and still is, the most widely accepted method of animal selection.

Citations in the literature suggest that generally subjective appraisal has not been an accurate predictor of carcass merit, Holland and Hazel (1958), Wilson et al. (1964), Hetzer et al. (1950). From these and other findings, tools are needed to supplement subjective appraisal in the evaluation of meat animals.

Potassium^{40}

From the search for an accurate, nondestructive technique for evaluating live meat animals, has evolved the concept of potassium^{40} measurement. Potassium has been found to be most abundant in the organeles of the living cell, Manery (1954). Potassium is mainly associated with the intracellular, nonfat phase in the body and the quantity of potassium in muscle tissue is relatively constant, Conway (1957), Robinson (1960), Anderson (1959) and Smith *et al*. (1965).

Principle of the K^{40} Technique

The potassium^{40} technique makes use of two basic principles: (1) much of the potassium in the body of a live animal is found in the muscle. Results of chemical analysis of two cadavers by Forbes and Lewis (1956) indicated that about 60% of all body potassium is contained in the muscle. This value is similar to that found by Pfau (1965) who reported that the skeletal muscle of swine contains 69% of body potassium. Kirton *et al*. (1961) reported that 50% of the body potassium was found in the separable lean of sheep. Also, Lohman *et al*. (1965) and Lohman and Norton (1968) with the use of K^{40} measurements reported that 63% of the body potassium appeared in the lamb carcass, and 53.4% of the total potassium in steers was found in the "standard" trimmed lean.

(2) Skeletal muscle potassium contains a fixed proportion of naturally occurring radioactive atoms (called K^{40}, hence the name) which give off very small amounts of gamma radiation, which under certain conditions in nature, can be measured. Potassium^{40} is the principle radioactive isotope, naturally present in all organisms, Kulwich *et al*. (1960). Potassium^{40}, has an isotopic abundance of 0.0119%, a half life of about 1.25×10^{-9} years, and emits 10 beta particles for every gamma-ray, Suttle and Libby (1955).

Vinogradov (1957) reported that potassium from different sources does not vary by more than ± 0.5% in its K^{40} content. The data of Vinogradov (1957) indicates that, in the case of humans, there is about seven times as much radioactivity emitted by K^{40} as there is by the next most prevalent naturally radioactive isotope, carbon-14.

In view of these principles, if K^{40} can be measured accurately, it follows that the amount of K^{40} present in a substance should become useful as a predictor of total potassium. Total body potassium then, may in turn, become useful as a predictor of total lean (muscle) in the animal since much of the potassium in an animal is found in the muscle.

Green _et al._ (1961) found the potassium concentration of the whole body of calves and pigs to be in the area of 0.21 to 0.24%, respectively. The potassium content of body fat was found to vary from 0.01 to 0.03%; blood from 0.07 to 0.09% and ham or (thigh) of 0.29 to 0.30%. Kirton _et al_ (1963) found that empty bodies of pigs contained 0.20% potassium, and the carcasses contained 0.21%. When placed on a fat-free basis the values increased from 0.30 to 0.34%, respectively. Similar values were observed by Mullins _et al_. (1969) who determined the potassium level of the composite right side of the pig to be 0.202%. When expressed on a fat-free basis, this value increased to 0.338% potassium. Spray and Widdowson (1950) reported that the fat-free bodies of adult pigs contained about 0.28%

potassium. In the case of lambs, Lohman et al. (1965) found the whole body to contain 0.21% potassium and the carcass 0.25%.

The theoretical basis for the use of K^{40} in determinind lean body mass of animals assumes the constancy in the cellular content of potassium. However, this constancy of potassium has been questioned by Laworie and Pomeroy (1963). They studied the potassium and sodium content of five muscles (longissimus dorsi, psoas major, rectus femoris, triceps and extensor carpi radialis) from pigs slaughtered at 150, 200 or 250 pounds. A significant ($P<.10$) difference in potassium concentration was reported between muscles and between weight groups. They also stated that since the potassium concentration may differ by at least 30% between muscles, it is concluded that assessment of total muscle mass may be inaccurate if based on the integration of gamma-ray emission from K^{40}.

The constancy of potassium has also been questioned by Gillett et al. (1965, 1967, 1968). These extensive studies were conducted to determine the potassium concentration of various muscles from three different species; swine, cattle and sheep.

Gillett et al. (1965) determined the potassium content of six muscles from each of six Hampshire and six Yorkshire barrows. The muscles used were the longissimus dorsi, semimembranosus, semitendinosus, psoas major biceps femoris and rectus femoris. When the muscles were compared on a wet basis (gm. K/kg. muscle) the rectus femoris contained the most potassium and the psoas major the lowest with a percent difference of 11.9% between the mean values of these two muscles. When the potassium content was expressed on a fat-free, moisture-free basis (gm. K/kg. moisture-free muscle) the percent difference between means of the rectus femoris (highest) and psoas major (lowest) amounted to 10.5%. When potassium content was expressed on a protein basis (gm. K/kg. protein) a 13.4% difference occurred between the means of the rectus femoris (highest) and psoas major (lowest). Significant differences between breeds were also found, with the Hampshires having an average value of 19.29 gm. of potassium per kg. protein, compared to 17.51 gm. for the Yorkshires.

Similar results in the variability of potassium content of selected steer and lamb muscles were also observed by Gillett et al. (1967, 1968). Significant differences were found in the potassium and sodium concentration among seven muscles from 16 steers and among four muscles from 25 lambs on a wet, fat-free, moisture-free and protein basis. Observed variation in the potassium concentration of muscles when means were compared, were of the order of 12.91% for beef muscle and 12.77% in lamb muscle. They also stated that the sizable muscle to muscle variability in the potassium content of pork, lamb and beef (regardless of the basis of comparison) indicates the lack of constancy of the potassium protein relationship. The lack of constancy in the relationship could be a major source of error in assessing body composition from potassium or K^{40} content.

Lohman *et al.* (1968) in a detailed study determined the potassium content of eight beef cuts from 98 steers. These steers were from four breed types slaughtered at one of four live weight groups (306, 385, 465 and 544 kg.). They reported that live weight groups significantly effected potassium in certain cuts. On a fat-free dry matter basis the weighted mean potassium concentration was 14.32 gm./kg. The lowest concentration was found to be in the rib (13.72), and the highest in the round (15.27). The coefficients of variation ranged from 6.4% for the weighted mean to 11.9% for the wholesale rib. It was also observed that as live weight increased potassium concentration of the "standard" trimmed lean decreased. These workers also compared breed-types and found that Angus had significantly ($P<.05$) more "standard" trimmed lean potassium than Angus-Holstein cross-breds on a fat-free, fat-free dry matter and on a nitrogen basis.

Other workers, however, have not found such variability between muscles or breeds. Briskey *et al.* (1959a) studied the potassium content of pork ham muscles which ranged from watery and pale to dry and dark in appearance. These workers reported that there were no consistent differences in potassium concentrations (expressed on a fat-free dry weight basis). Briskey *et al.* (1959b) reported that the difference in potassium concentration (on a fat-free dry tissue basis) in pork muscle from 16 gilts associated with varying levels of forced exercise prior to slaughter were not significant.

Ward et al. (1967) studied the relationship of potassium measured as K^{40} to the moisture and fat content of ground beef. Using only five animals and eight wholesale cuts, they found a significant difference between cows in potassium concentration on a fat-free basis but not between wholesale cuts within cows. Coefficients of variation for potassium content (expressed on a fat-free and on a fat-free dry matter basis) were 9.0 and 14.7%, respectively.

Mullins et al. (1969) studied the potassium concentration in 32 Duroc pigs weighing 90.0 kg. They reported that on a fat-free, moisture-free basis, the soft tissue of the ham, loin and shoulder contained practically the same percent potassium, 1.759, 1.739 and 1.751, respectively. They also reported that on a wholesale cut basis no significant differences were evident. According to this work, the greatest source of variability in the relationship between potassium level in the carcass and carcass composition may be the result of the variation in percent of fat, bone and skin rather than variation among select muscles as indicated by Gillett et al. (1968).

Some Sources of Variation in Live Animal K^{40} Scintillation Counting

There may be many sources of variation associated with the measurement of the gamma radiation emitted by K^{40} from the live animal and the carcass.

Since gamma-rays are constantly present in the atmosphere, one of the major sources of variation which must be accounted for, is the environmental radiation or background. Twardock _et al._ (1966) reported that in the K^{40} energy channel, background count averages were about 17,500 counts per minute, or two times greater than the count rate of a 450-kg. steer and seven times greater than that of a 40-kg. sheep. Therefore, measurements of animal K^{40} count rates depend upon a very stable background count rate during the time the animal is being counted. Another source of error is self-absorption which can be defined as the absorption of gamma radiation by the sample from which they originated. Twardock _et al._ (1966) found that as sample size increases, the greater is the likelihood that a gamma-ray will lose part or all of its energy before leaving the sample and interacting with the detector. Therefore, the count rate from a given quantity of radioactive material varies inversely with the size of the animal or standard in which that material is located. It is the opinion of these workers that sample-to-detector geometry could be an important consideration. A smaller sample is more effectively surrounded by the detector than is a larger sample, so that a greater proportion of the gamma-rays leaving it will interact with the detector.

Background depression is the physical phenomenon of the sample absorbing some of the background radiation, with the result that less background radiation reaches the detectors. An estimate of background depression may be accounted for by the counting of a non-gamma emitting "phantom" of similar size to that of the sample to be measured. Gamma-rays emitted from caesium-137, Zr^{95} and Mn^{54} have energies that are high enough to cause some "spill" or overlap into the K^{40} measurement channel, causing counts to be recorded that are not actually caused by K^{40} disintegrations (Twardock et al. 1966).

More has been reported on the sources of variation associated with the animal than those inherent to the instrumentation. If the amount of potassium is about 0.20% of body weight and the carcass contains approximately 60% of total potassium, the counter must be able to detect small differences in K^{40}. When multiplied to yield total lean, the errors are increased. If the differences in total lean are small, however, the counter must be capable of detecting extremely smaller differences in K^{40} gamma-emission. Therefore, all outside contamination should be removed, so that only K^{40} gamma-emission from the lean will be detected by the instrument. Washing the animals with water and detergent may remove sources of contamination. Kirton et al. (1961) reported that washing the lambs once reduced the potassium content by 0.94 gm. of potassium per kg. live weight, or on the average 38 gm. of potassium was removed from each animal by washing. They also stated that the second washing did not reduce the gamma activity below the level accomplished by the first washing. According to Twardock _et al_. (1966) the first washing reduced the K^{40} channel count rates by 4.8% (P<.01) but the second washing reduced the count rates only by an additional 1.1%.

It is thought that radioactivity in the gastrointestinal content may be a source of error that can bias the estimate by K^{40}. This can be reduced and partly standardized by feeding only a low potassium ration prior to K^{40} measurement or by shrinking the animal, therefore, removing most of the contents from the gastrointestinal tract. Twardock _et al_. (1966) reported that among several feeds measured, oats had the lowest radioactivity; and for several bulls fed only oats for a 14-day period, an average reduction of 9% ± 4% (S.D.) in K^{40} count rate was observed during the first seven days after which there was no further decrease. Lohman _et al_. (1966) fed two steers a high-roughage diet for a week followed by a diet (oats) low in potassium. After seven days on the oat diet the K^{40} count was lower by about 10% in both steers. Kirton _et al_. (1961) attempted to standardize the contents of the digestive tract of the pigs by using the same ration for all pigs and removing them from feed 24 hours before slaughter. They found that the weight of the gastrointestinal content comprised only 1.7% of the body weight.

The Use of K^{40} Estimates as Predictors of Lean Yield

The use of potassium in the body as a predictor of lean body mass was reported as early as 1955, when Cheek and West determined the total body potassium and the lean body mass of 30 rats of various weights and ages. They reported that total body potassium exhibited a simple linear relationship to lean body mass. Woodward et al. (1956) demonstrated that the potassium content of human beings as determined by measurement of K^{40} gamma activity by means of the Los Alamos "human counter", was related to the body water content and, therefore to the lean body weight of the subjects. Muldowney et al. (1957) reported that total exchangable potassium was closely correlated (r=0.90) with lean body mass in a study carried out with 16 normal human males and 14 normal females ranging in age from 18 to 81 years. Allen et al. (1960) reported total body potassium content to be proportioned to the body mass minus bone, mineral, fat and water in humans.

Indications that there is a possible relationship between potassium content and lean body mass obtained from these preliminary studies with small animals and humans, led researchers to studies with live animals, carcasses and cuts of meat.

Zobrisky et al. (1959b) were among the first to study the utility of the naturally occurring isotopic potassium (K^{40}) as a quantitative measure of the muscle mass of large animals. They studied the relationship between K^{40} content and the muscle mass in hogs, pork carcasses and pork wholesale cuts. Their results indicated that K^{40} content may possibly have use as a rapid, nondestructive index for determining protein to fat ratios in livestock and meat.

Kulwich et al. (1958) were among the first to report correlations between potassium^{40} concentration and lean mass of a wholesale cut. In this preliminary study using limited numbers, they reported a correlation of 0.983 between gamma-rays counted per second per pound, and percent of fat-free lean of four hams. The values for measured potassium^{40} gamma-rays per second per pound varied inversely with the percent fat of the hams, with a correlation coefficient of -0.966. Later, Kulwich et al. (1960) determined the relationship between beta radioactivity of the ash in relation to the composition of ham. They reported a correlation of -0.99 between the beta radioactivity and the percent ether extract, of the separable lean from 24 hams of pigs averaging 180 pounds. In a more in depth study Kulwich et al. (1961a) determined that caesium-137 was not a suitable material for predicting the lean content of meat products, since the correlation in this instance was only 0.47, whereas, the correlation between K^{40} counts per minute and pounds of separable lean from the ham was found to be 0.96. The experimental units for this study were one ham each from ten Yorkshire barrows, eight Yorkshire gilts, seven Duroc barrows and nine Duroc gilts. However, no attempt was made to determine the effects of breed or sex in this study.

Similar results were also obtained from beef rounds by Kulwich et al. (1961b). In this study the amount of K^{40}

gamma-ray activity of an intact round from each of six bulls, six steers and four heifers was measured and correlated with the percent separable lean and fat of the rounds. They reported correlations of -0.865 and 0.798 between disintegrations per minute from K^{40} counts per pound of intact round, and percent separable fat and percent separable lean of the rounds, respectively.

Kirton _et al._ (1961) studied the use of naturally occurring K^{40} to determine the body composition of 10 live sheep averaging 40-kg. in live weight. In this study potassium content was estimated by K^{40} gamma-ray measurements on 10 live unwashed and washed lambs and of their carcasses. They found that the correlation (r=0.51) between estimated potassium content of the live unwashed lamb and percent carcass lean was not significant. However, the correlations of estimated potassium content of the live unwashed lamb with percent carcass fat (r= -0.79) and percent carcass bone (r=0.86) were both highly significant. The correlations were lower for the washed sheep and very small for the carcasses. This inconsistency in the magnitude of the reported correlations could possibly be due to the small number of animals used.

When the percent protein in the edible tissue was related to the potassium content of the live unwashed animal, the live washed animal and the carcass, the correlations were 0.80, 0.83 and 0.41, respectively. Later, Kirton and Pearson (1963) using only 10 lambs compared the flame photometry method of determining potassium with that of the potassium^{40} approach. They reported the flame photometry was more accurate than K^{40} for predicting body composition. They found correlations of 0.81, -0.92 and 0.81 between potassium content, determined by flame photometry and percent separable lean, fat and bone, respectively.

From an extensive study of the chemical analyses of 24 swine carcasses Kirton et al. (1963) suggested a greater predictive value for potassium. They reported significant correlations between percent potassium of the empty body and percent water, ether extract and protein of 0.86, -0.87 and 0.77, respectively, in the carcass.

In summary Kirton et al. (1961, 1963) and Kirton and Pearson (1963) state that although significant correlations were found between the gamma activity of the live animal and their carcass composition, the flame photometric method for determining potassium was shown to be more accurate than K^{40} for predicting composition. They also reported that the potassium^{40} method does not give an accurate estimation of the composition of individual animals, and may therefore, be limited in its usefulness.

Judge et al. (1963) evaluated 38 lamb carcasses by the use of potassium^{40} and by other measurements. They reported significant correlations of 0.74, -0.79 and 0.71 between K^{40} carcass measurements, and percent edible portion, excess fat and bone of the carcass, respectively. They also reported significant correlations of 0.65, 0.83 and 0.62

between the edible portion of the carcass and *longissimus dorsi* area expressed in square inches, per hundred pounds of carcass weight and per hundred pounds of live weight, respectively. Further, fat thickness was found to be highly correlated with percent edible portion and excess fat of the carcass -0.78 and 0.83, respectively. The authors stated that the foregoing data suggest that potassium^{40} determination on lamb carcasses could be used to predict the percent edible portion or excess fat of the carcass. However, the *longissimus dorsi* and fat measurements were found to be equal to or better in predictive value than K^{40} measurements on lamb carcasses.

Martin *et al.* (1963) studied the relationship between live animal potassium determination by K^{40} and other measurements of body composition in 35 market hogs. They reported correlations of 0.33, -0.33, 0.14 and 0.05 between gm. of potassium and *longissimus dorsi* area, backfat thickness, percent loin and percent ham, respectively. When potassium was expressed as gm. of potassium per kg. live weight correlations became, 0.29, -0.79, 0.64 and -0.35, respectively.

The extensive studies conducted by the Illinois workers, Smith *et al.* (1965), Lohman *et al.* (1965) and Breidenstein *et al.* (1965a, b) have suggested a rather high predictive value of potassium^{40} measurements. Smith *et al.* (1965) reported that live weight alone accounted for 86.7% of the total variation in fat-free lean in 46 steers, and the live body K^{40} count accounted for 42.5% of the variation. Together, live weight and live count accounted for 90.6% of the total variation in fat-free lean.

Lohman et al. (1965) studied the use of K^{40} measurement as a predictor of carcass lean in 27 lambs averaging 73.6 pounds. They reported that carcass weight accounted for 53.3% of the variation in carcass lean muscle mass, and loin eye area accounted for 56.6%. They also found that whole body potassium (K^{40}) was associated with 76.6% of the variation in carcass lean muscle mass, and carcass potassium (K^{40}) was found to account for 90.3% of the variation. Thus indicating that K^{40} measurements on the live animal or carcass were more precise in predicting carcass lean than loin eye area or carcass weight.

Breidenstein et al. (1965a) summarized the comparisons of K^{40} measurements with other methods for determining lean muscle mass in 25 sheep averaging 33.4 kg. In this study constants were fitted for sex, age, live weight and carcass weight, and these constants (basic model) were found to account for 59.5% of the variation in carcass lean muscle mass. The reported variances accounted for by various independent variables added to the basic model were as follows: specific gravity 66.7, loin eye area, a single measurement of fat thickness at the 12th rib and kidney and pelvic fat 79.4, total lean of the major cuts 76.2 and potassium content (K^{40}) of the carcass 87.0%. Later, Breidenstein et al. (1965b) reported a similar study comparing the precision of several methods of estimating carcass lean muscle mass of 29 market hogs. Constants were fitted for breed, sex, age, live weight and carcass weight. These constants (basic model) accounted for 44.7% of the variance in the total carcass lean muscle mass of swine carcasses. Following are the reported total variances accounted for when various criteria were added to the basic model: K^{40} count on live animal 87.7%; K^{40} count on one side of carcass, 91.2%; specific gravity on one side, 83.0%; carcass length, backfat and loin eye area, 81.2%; weight of ham and loin 87.5%; and the weight of four lean cuts 94.1%.

Later, Mullins _et al._ (1969) studied in depth the comparison of potassium and the other chemical constituents as indices of pork carcass composition. The experimental units for this study were 32 pigs averaging 98 kg. They reported that significant positive relationships were observed between potassium content of live pigs (K^{40} expressed as gm. and percent) and percent ham (0.66 and 0.59); percent ham and loin (0.57 and 0.54); percent four lean cuts (0.64 and 0.60), respectively. They also reported significant correlations between potassium content determined by flame photometry (expressed as gm. and percent) and percent trimmed ham (0.58 and 0.72); percent ham and loin (0.68 and 0.78); percent four lean cuts (0.57 and 0.75), respectively. They stated that although most of the correlation coefficients presented were highly significant, only a small portion of the variation in the chemical constituents and yield of wholesale cuts were accounted for by the correlation coefficients.

Bennink *et al.* (1968) determined the correlation coefficients of percent fat and potassium content as determined on 36 meat samples. They reported correlations of -0.903 and -0.620 between percent fat and gm. of potassium per kg. of fresh tissue determined by K^{40} and atomic absorption spectrometry, respectively.

Ultrasound Measurements

The term "ultrasonic" refers to sound waves or vibrations at a frequency above the audible frequency range of the human ear. Ultrasonic energy is mechanical vibration energy that can be focused into a narrow, almost parallel beam which is transmitted and reflected in much the same way as a beam of light. These sound waves emitted by the transducer pass into the tissue under study, and when a change in density is encountered some of the energy is reflected, and converted into an electrical impulse, and fed to a detecting device for amplification and recording (Stouffer 1963).

This principle was first used to detect cracks or flaws in solid materials. Since the change in density will cause a reflection of the sound waves, the idea of measuring depth of fat and muscle in live animals was considered.

Howey and Bliss (1952) stated that when properly applied, ultrasonic energy may be used to obtain echoes from tissue interfaces. These echoes can be made to generate a cross section "picture" of the specimen.

Ultrasound Estimates of Fatness and Meatiness in Swine

Price et al. (1960a) conducted a thorough study to determine the usefulness of an ultrasonic probing technique for measuring thickness of fat and lean tissue. With the use of a Speary Reflectoscope they reported that fatness could be accurately measured with ultrasonic equipment, as shown by a close relationship with backfat thickness on the intact carcass, and backfat thickness measured on a cross section of the rough loin, at the site of the ultrasonic reading. They reported a correlation coefficient between ultrasonic estimates of backfat and carcass backfat measurements of 0.88 on 84 market hogs. Ultrasonically determined backfat thickness was correlated with the percent lean cuts of the carcass, to the extent of -0.78 and with lean cuts of live weight, to the extent of -0.71. They found that ultrasonic measurements of lean did not show sufficiently high relationships with lean cuts to be directly useful for prediction purposes.

Later, Price et al. (1960b) reported the means of the ultrasonic plots of loin eye area, and carcass measurements of loin eye area to be 3.85 and 3.65 square inches, respectively, on 41 hogs. The correlation coefficients for these variables were found to be 0.74. It was found that upon plotting the points at corresponding angles, an incomplete perimeter for the estimated eye muscle resulted. This made it necessary to draw in subjectively the two ends of the longissimus dorsi.

Two different instrument frequency settings were used by Hazel and Kline (1959) in a study using ultrasonics as a measure of fatness in 56 market weight pigs. Ultrasonic measurements at frequencies of 1.5 and 2.5 megacycles per second were highly correlated with carcass backfat measurements. Correlations of 0.75 and 0.76 at frequencies of 1.5 and 2.5 megacycles per second, respectively. were obtained between average backfat measurements of the carcass and ultrasonic measurements. Ultrasonic measurements at a frequency of 2.5 megacycles per second on the back and loin were found to be more highly correlated with percent lean cuts (r= -0.90) than those for corresponding sites taken at 1.5 megacycles per second(r= -0.76).

From an extensive study conducted by Stouffer et al. (1961), it was found that ultrasonic fat measurements are more highly associated with backfat thickness and rib eye area in hogs than in cattle. With 42 market hogs the correlation coefficient between ultrasonic fat measurements and carcass fat thickness was found to be 0.92 while with 327 cattle the correlations ranged from 0.32 to 0.54. They reported a correlation coefficient between ultrasonically estimated rib eye area in hogs of 0.70, while in cattle corresponding correlations ranged from 0.22 to 0.85. Repeatability studies for predicting rib eye area and fat thickness were also reported. Rib eye area values obtained by different technicians from the same picture gave correlation coefficients of 0.67 for the first day and 0.81 for the second day. Fat thickness measurements were more highly correlated between technicians (0.81 and 0.87) than were rib eye areas. The correlations between observations taken on the two different days were significant in all cases but somewhat different between the first technician 0.71 and the second technician 0.90. The correlations between days for fat values were higher for the first technician 0.90 than for the second technician 0.75. This indicates that significant repeatability for this technique can be expected for a technician, but differences in accuracy could exist between technicians.

The estimation of loin eye area by high frequency sound was studied by Zobrisky et al. (1960) on 69 market hogs. The hogs were measured at the 10-11th rib on both sides of the midline. The correlation between the tracings of the 10th rib loin eye area of the right and of the left sides was 0.95. The correlation between the high frequency sound estimates of loin eye area from the right and left sides was 0.91. Tenth rib loin eye tracings and high frequency sound estimates of the 10th rib loin eye area for the right and left sides were also correlated (0.84 and 0.81), respectively.

Alsmeyer et al. (1963) reported correlation coefficients of 0.72, 0.80 and 0.71 between ultrasonic fat measurements and carcass fat measurements taken at the midline of the shoulder, loin and ham, respectively on 139 market hogs. The pooled correlation between the means of average ultrasonic fat measurements and backfat thickness was 0.95 among 12 breed-year groups. It was found that ultrasonic evaluations and year-breed groups accounted for 42, 69, 76 and 82% of the variations in ham fat, ham lean, backfat thickness and bone in the ham, respectively.

Du Mont and Destandau (1964) reported results of a study in which four objective measurements of fat thickness in 24 live pigs were compared. The four techniques used were radiographic, ultrasonic, lean meter and ruler probe. They found that X-ray (r=0.994) and ultrasonics (r=0.986) were extremely accurate, while the ruler probe (r=0.856) and lean meter (r=0.480) were the least accurate of the four methods in evaluating fat thickness.

The use of the ultrasonic technique as a means of measuring the fattening rate in swine was studied by Urban and Hazel (1965). In this study 25 gilts and 50 barrows were ultrasonically measured at various ages during the growing and finishing period. These live measurements were then correlated to various carcass measurements at slaughter. The correlations between ultrasonic fat measurements and loin eye area at slaughter were: at 8 weeks 0.17; 12 weeks 0.10; 16 weeks -0.07; 20 weeks -0.11 and at slaughter -0.18. For carcass backfat measurement the correlations were: at 8 weeks -0.01; 12 weeks 0.18; 16 weeks 0.21;

20 weeks 0.34 and at slaughter 0.44. For lean cuts as a percentage of carcass weight the correlations were at 8 weeks 0.07; 12 weeks -0.10; 16 weeks -0.23; 20 weeks -0.40 and at slaughter -0.54.

Watkins et al. (1967) observed that as the operator gained experience in operating the ultrasonic equipment, he was able to more accurately predict fat thickness and muscle area in cattle. Correlations of 0.90 and 0.56 were obtained between the estimated and actual values for subcutaneous fat thickness and rib eye area, respectively, on 120 cattle. There was also a tendency to overestimate the fat in thin animals and underestimate it in the fatter animals. There was a tendency to underestimate the rib eye area in the thinner animals, while the reverse was true in fatter cattle.

Johnson et al. (1968) conducted an extensive study to test the accuracy of estimating backfat thickness and loin eye area with the use of the ultrasonics technique. They reported correlation coefficients between the ultrasonic estimates and carcass measurements of backfat thickness and loin eye area for 40 Yorkshire hogs to be 0.87 and 0.52, respectively. Ultrasonic estimates of trimmable fat, and the measured trimmable fat, had correlation coefficients of 0.69 when expressed as pounds and 0.60 when expressed as a percent of live weight. Correlations for the backfat thickness and loin eye area on a group of 80 market hogs were found to be 0.84 and 0.83 for the two backfat estimates and 0.77 and 0.79 for the two loin eye estimates. Repeatabilities for backfat and loin eye area had correlation coefficients of 0.91 and 0.85, respectively.

Isler and Swiger (1968) studied the ultrasonic prediction of lean cut percentage in 379 pigs averaging 92.7 kg. They reported that correlations obtained between five ultrasonic measures of backfat and percent lean cuts ranged from -0.45 to -0.63, and a ham fat measure was correlated (r= -0.54) with percent lean cuts.

In evaluating the use of the ultrasonic technique it should be remembered that this instrument has been used primarily to estimate backfat thickness and *longissimus dorsi* area. The literature indicates that the method is more accurate in predicting these two traits than in predicting percent of lean cuts or other measures of leanness. This suggests that the greatest usefulness of the ultrasound technique for predicting carcass fat and lean may possibly be in combination with other measurements.

Probing Techniques

The idea of determining the depth of subcutaneous fat on a live animal by probing techniques was first tested by Hazel and Kline (1952). A narrow ruler was used as a mechanical probe to determine the thickness of fat along the back of market weight pigs. The correlation between probe measurements on 96 market hogs and actual carcass measurements was 0.81. Similar results were obtained by Hetzer et al. (1956) (r = 0.72) using 140 market hogs and Pearson et al. (1957) (r = 0.70) with 99 market hogs.

Various live probing techniques generally have been equal or superior to carcass backfat measurements as indicators of carcass leanness, (Hazel and Kline, 1952; Hazel and Kline, 1959; Hetzer et al., 1956; Holland and Hazel, 1958; Pearson et al., 1957; Price et al., 1960; Omtvedt et al., 1967). Some investigations have indicated the opposite trend to be true, (Hazel and Kline, 1953; Zobrisky et al., 1959).

The correlations between live probes and percent lean cuts reported by the workers quoted above generally have been in the range of -0.60 to -0.80. On occasion they have reached -0.89, Hazel and Kline (1959) and have been as low as -0.28, Hetzer et al. (1956). The causes for such wide variations are not readily apparent.

In general, the literature indicates that live probe fat measurements on swine are reliable indices of carcass merit which might be expected to explain 40 to 60% of the variation in percent lean cuts.

Carcass Evaluation

The early studies on carcass evaluation were conducted by McMeekan (1940 and 1941), Warner et al. (1934) and Hankins and Ellis (1934). These studies led the way for the use of backfat measurement, loin eye area and length as estimates of carcass composition.

Recent results showing the relationships of backfat thickness, loin eye area, percent ham, and percent ham and loin, with percent lean cuts are presented in Table I. These data indicate that, as a measure of leanness, backfat thickness is usually superior to loin eye area. Generally, backfat thickness accounted for 50 to 60% of the variation in lean cuts, while loin eye area accounted for only 30 to 40% of the variation.

The relationship with percent ham and percent ham and loin with percent lean cuts was shown to be appreciably higher than those given by backfat thickness and loin eye area. This is to be expected because of their part-whole relation with lean cuts.

The ham-loin index was first used by Plager at the National Barrow Show in 1962. Arganosa and Omtvedt (1969) reported correlations of 0.74 and 0.84 between ham-loin index and lean cuts expressed as pounds and percent of slaughter weight, respectively.

Little work has been reported which compares the various carcass measurement to the actual lean content of the carcass. Bowman et al. (1962) reported the correlation between backfat thickness and the percent separable lean of the carcass to be 0.36 on 21 market hogs, and a correlation of 0.57 was found between loin eye area and percent separable lean of the carcass.

Effects of Slaughter Weight on Carcass Merit

Some early experiments at the Illinois Agriculture

TABLE I

CORRELATION COEFFICIENTS AMONG FIVE CARCASS TRAITS USED TO EVALUATE PORK CARCASSES

	Percent Lean Cuts of:		
	Live Wt.	Carcass Wt.	Loin Eye Area
Backfat Thickness	-.73 (d) -.66 (f) -.26 (g) -.65 (n) -.48 (m) -.36 (h)	-.72 (a) -.78 (b) -.59 (c) -.80 (d) -.80 (e) -.42 (g) -.49 (h)	-.37 (a) -.08 (g) -.50 (e) -.43 (b) -.30 (c) -.28 (f) -.13 (m) -.43 (n)
Loin Eye Area	0.53 (g) 0.56 (h) 0.71 (d)	0.39 (g) 0.47 (h) 0.62 (d) 0.51 (a) 0.68 (b) 0.50 (m)	
% Ham	0.73 (i) 0.75 (k) 0.89 (l)	0.89 (b) 0.89 (c) 0.96 (j) 0.72 (k)	0.64 (b) 0.47 (c) 0.30 (k)
% Ham and Loin	0.87 (m)	0.95 (b) 0.90 (c)	0.72 (b) 0.59 (c) 0.43 (m)

Listed below is the source and number of pigs

(a) Brown <u>et al</u>., 1951 - 66
(b) Whiteman & Whatley, 1953 - 101
(c) Whiteman & Whatley, 1953 - 102
(d) Price <u>et al</u>., 1960a - 84
(e) Pearson <u>et al</u>., 1959 - 150
(f) De Pape & Whatley, 1954 - 111
(g) Omtvedt <u>et al</u>., 1967 - 76
(h) Arganosa & Omtvedt, 1969 - 650
(i) Zobrisky <u>et al</u>., 1959a - 207
(j) Hazel & Kline, 1959 - 56
(k) Pearson <u>et al</u>., 1958 - 195
(l) Smith <u>et al</u>., 1957 - 300
(m) Skelly <u>et al</u>., 1969 - 114
(n) King <u>et al</u>., 1962 - 80

Experiment Station by Bull and Longwell (1929) and Mitchell and Hamilton (1929) reported carcass differences in the percentage (on a carcass weight basis) of lean, fat, skin and bone of three groups of hogs weighing 175, 225 and 275 pounds. They reported the following percentages for the "intermediate type" hogs at 175 and 225 pounds, respectively; lean 44.4 and 45.2; fat 35.1 and 38.0; skin 6.3 and 4.7; bone 13.3 and 11.2. They found the percent protein of the carcass for the three weights to be 175 pounds, 11.5%, 225 pounds 11.6% and 275 pounds 11.0% protein.

Hogan et al. (1925) reported the results of studies with lard-type and bacon-type hogs. In this study only one hog to each type was slaughtered at each weight of 100, 150, 200, 250 and 300 pounds. Included among the observations were weights and physical composition of the shoulders, hams, bacon and loins. As live weight increased from 100 to 300 pounds the weight of trimmed hams, from the bacon-type hogs for example, increased from 7.2 to 22.9 pounds, and the percentage of separable lean of the ham decreased from 75.0 to 60.9.

Hankins and Ellis (1945) reported data on the physical and chemical characteristics of 64 carcasses from hogs of "intermediate type" slaughtered at 175, 200, 225 and 250 pounds. They found that as live weight increased from 175 to 250 pounds the amount of separable fat of the carcass increased from 37 to 45% and separable lean decreased from 41 to 32%. Further, the moisture content declined from

41.8 to 34.7% with increasing weight. Similar results have been reported by Loeffel _et al._ (1943) and Hogan _et al._ (1925).

Hankins and Ellis (1934) reported that according to chemical analyses carcasses from pigs weighing 93 to 250 pounds ranged from 30 to 57% in fat content of the carcass.

Loeffel _et al._ (1943) reported that there is an almost complete interchange between the percentages of fat and lean, between carcasses from 15C-pound hogs and those from 400 pound hogs. The carcasses from the 150 pound pigs contained 32.4% fat and 51.5% lean, while carcasses of the 400 pound hogs contained 55% fat and 34% lean. It was also noted that the percentage of fat almost doubled between the weights 150 and 400 pounds. They stated that fattening is an additive process, and as it proceeds it causes the other components such as lean, bone and skin to show corresponding percentage declines. The actual weight of both lean and bone was still increasing at the 400 pound live weight, but not as rapid as was fat deposition.

Recent data from several stations, where modern meat type hogs were used in carcass composition studies are summarized in Table II. This table presents the influence of slaughter weights on backfat thickness, loin eye area and percentage of lean cuts for hogs ranging in weights from 100 to 300 pounds. These data indicate that there are distinct fattening patterns associated with live weights. Several of the papers reported, that as live weight in-

TABLE II

THE INFLUENCE OF SLAUGHTER WEIGHT ON BACKFAT THICKNESS, LOIN EYE AREA AND PERCENTAGE LEAN CUTS

Trait	Slaughter Weight Groups (pounds)											
	100	150	160	175	180	200	210	215	225	240	250	300	
B.F.[a]	0.90	1.30				1.60					1.80	2.10	(a)
		1.13			1.27		1.48			1.52			(b)
			1.14						1.52				(c)
		0.99		1.02		1.15			1.24				(d)
						1.20			1.45				(e)
	0.90	1.20		1.40		1.50			1.50		1.70	1.80	(f)
L.E.A.[b]	2.92	3.47				4.21					5.18	4.76	(a)
		3.43			3.85		4.07			4.45			(b)
			3.61						4.39				(c)
		3.36		3.98		4.41			4.24				(d)
						4.12			4.33				(e)
	2.80	3.20		3.40		4.20			4.10		4.80	5.10	(f)
% L.C.[c]	57.8	52.8				48.5					46.8	43.7	(a)
		38.0			37.8		36.6			35.8			(b)
			39.2						38.5				(c)
		39.8		40.6		41.3			40.0				(d)
						38.8			38.2				(e)
	40.2	38.0		35.8		36.9			35.0		35.1	34.8	(f)

TABLE II CONTINUED

[a]Carcass backfat thickness, in.

[b]Loin eye area, sq. in.

[c]Percentage lean cuts, live weight

(a) Zobrisky, *et al*. 1958 (carcass weight basis)
(b) Wallace *et al*. 1960
(c) Fields *et al*. 1961
(d) Bradley, 1963a
(e) Bradley, 1963b
(f) Zobrisky *et al*. 1963

creased backfat thickness also increased. A similar trend is true for loin eye area with a range of 2.8 sq. in. for 100 pound hogs to 5.2 sq. in. for 250 pound hogs, Zobrisky *et al*. (1958). The opposite trend was true for the percentage of lean cuts which decreased as live weight increased. While there are some differences among the studies reported, backfat thickness and loin eye area were found to increase, generally, as live weight increases while percentage of lean cuts were found to decrease, generally, as live weight increases.

CHAPTER III

MATERIALS AND METHODS

General

Sixty Yorkshire barrows representing five weight groups (100, 150, 200, 250 and 300 pounds) were evaluated using three different techniques; potassium^{40}, ultrasound and ruler probe. The purpose was to observe any trends which develop in the association between the live estimates and carcass measurements obtained during this period of the pig's life cycle. These barrows averaged 62 pounds at the beginning of the study which was conducted in the fall of 1967 and the spring and summer of 1968. Six replications containing 10 pigs each were randomly allotted by slaughter weight groups of 100, 150, 200, 250 and 300 pounds, as is shown in Table III. From each replication two pigs were allotted to each weight to make a total of 12 pigs for each of the five slaughter weight groups. The design shown in Table III was also used in an attempt to monitor the growth of the pigs during the growing and finishing period.

Each pig was taken off feed and "evaluated" at each weight and placed back on feed until it reached the predetermined slaughter weight as described in Table IV.

TABLE III

DESIGN FOR SLAUGHTER WEIGHT AND CARCASS EVALUATION

	Slaughter Weight Groups (pounds)				
Replication	100	150	200	250	300
I	2[a]	2	2	2	2
II	2	2	2	2	2
III	2	2	2	2	2
IV	2	2	2	2	2
V	2	2	2	2	2
VI	2	2	2	2	2
Total	12[b]	12	12	12	12

[a]Number of animals per replication per weight group

[b]Total number of animals per weight group

TABLE IV

DESIGN FOR LIVE EVALUATION

	Slaughter Weight Groups (pounds)				
Replication	100	150	200	250	300
I	10[a]	8	6	4	2
II	10	8	6	4	2
III	10	8	6	4	2
IV	10	8	6	4	2
V	10	8	6	4	2
VI	10	8	6	4	2
Total	60[b]	48	36	24	12

[a]Number of animals evaluated per weight per replication

[b]Total number of animals evaluated per weight group

Six replications of 10 pigs each gave a total of 60 pigs evaluated at 100 pounds, 48 at 150 pounds, 36 at 200 pounds, 24 at 250 pounds and 12 at 300 pounds. This design was used to evaluate the repeatability of the K^{40} counter at these various weights. During the course of the study, one pig from each of the weight groups was lost due to the "Pork Stress Syndrome" and two additional from the 300 pound weight group were taken off test because of their inability to grow at what was considered to be a normal rate.

Fifty-three pigs finished the experiment, 11 in each of the weight groups through 250 pounds and nine in the 300 pound group. All pigs were self-fed a milo-soybean meal ration containing 16% protein, the ingredients for which are presented in Table V.

Potassium^{40} Measurement

The Permian K^{40} Counter is a mobile whole body radio activity monitoring system designed primarily for animal science research and animal evaluation. The counter is housed in a sheltered area at the Oklahoma State University Live Animal Evaluation Center, which is air conditioned for temperature control. The complete counter system is self-contained on a standard heavy-duty trailer which is forty feet long and eight feet wide. It was designed to measure the gamma-ray activity from approximately 1,000 pound animals. Samples up to 106 inches long, 36 inches wide and 60 inches in height can also be measured.

TABLE V

SIXTEEN PERCENT MILO-SOYBEAN MEAL RATION

Ingredients	Pounds
Milo - ground	1469.6
Soybean Meal (50%)	369.4
Alfalfa Meal (17%)	100.0
Calcium Carbonate	10.0
Dicalcium Phosphate	37.0
Trace Mineral Salt	10.0
Aurofac 40	0.4
Fortafeed 2-49-90	0.8
Vitamin B_{12}	2.4
Zinc Sulfate	0.4
Total	2000.0

The monitoring room of the counter is five and one half feet wide, six feet high and eight feet long. The entrance to the monitoring room is 36 inches wide and 60 inches high with motordriven sliding doors. The chamber which contains the 16 detector units is made from pre-1945 steel which was sand-blasted, cleaned and tested for contamination of radionuclides before assembly in 1965.

A description of the operational procedures of the Permian K^{40} Counter is illustrated in Figure 1. The gamma-rays emitted by K^{40} enter a "detector" (a) and upon entry produce very minute bursts of light (scintillations). These scintillations are fed into a light sensing mechanism, the photomultiplier tube, (b) which converts the light energy into electrical energy. These electrical signals are amplified (c) and counted electronically. The numerical values displayed on the scaler-counter are the K^{40} gamma-ray counts per minute (d) that were measured by the counter. The efficiency of the counter during the course of this study was 21.75% determined by a standard source of potassium chloride.

The technical specifications for the scintillator of the Permian K^{40} Counter as reported by Reid 1966 are listed below.

<u>Scintillator</u>:

Number of detector units	16
Scintillator material	Nuclear electronics 102 scintillator plastic
Total detector volume	660 liters

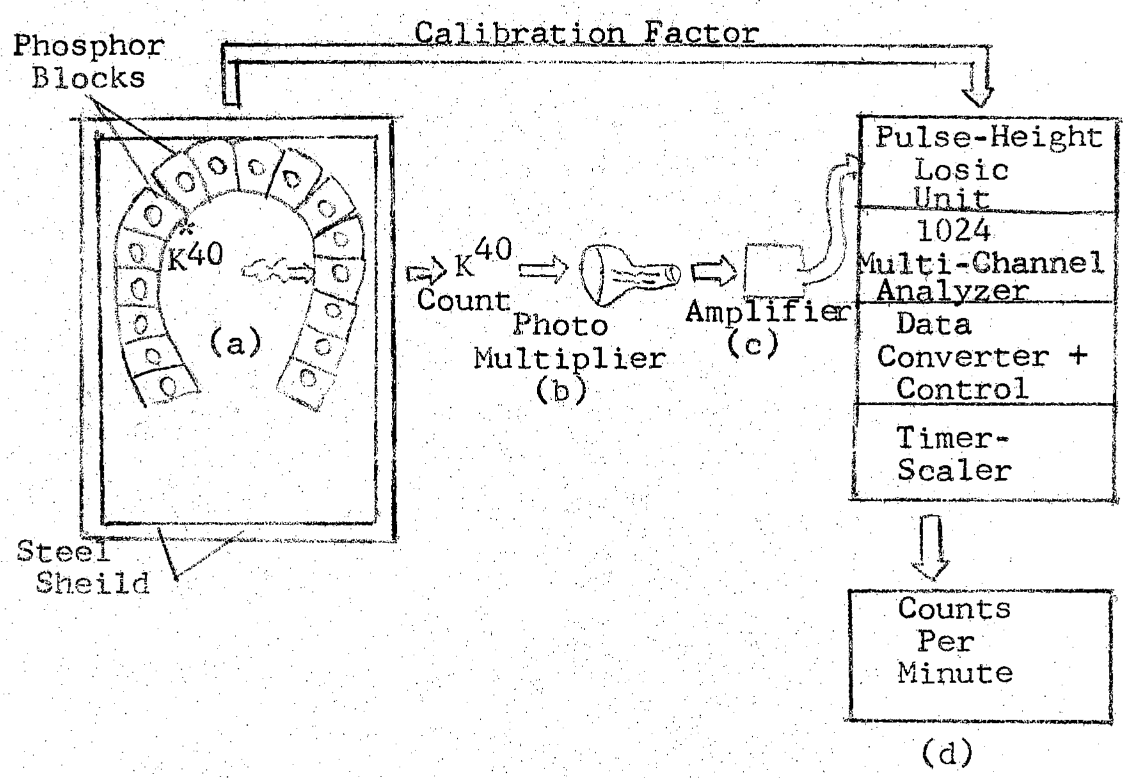

Figure 1. A Schematic Illustration of the Operational Procedures of the Permian K^{40} Counter

Minimum thickness of the scintillator	15 cm
Type of phototubes	RCA 4525
Diameter of phototubes	13.3 cm
Total number of phototubes	32

As animals reached the predetermined slaughter weight, they were counted and slaughtered on the same day. In preparation for counting, feed and water were withheld from the pigs 36 hours prior to counting. The pigs were thoroughly washed to remove possible potassium containing foreign material. They were then placed in the counter in a suitable restraining crate allowing for comparable positioning of different animals in the counter among readings. Two different size crates were used. A small crate was used for the 100-pound pigs and a larger one was used for the other four weight groups. The net K^{40} count for each animal was obtained in the following manner: two 10-minute background counts (to determine environmental radiation) were obtained for each animal by measuring the background K^{40} activity of the counter and the restraining crate, one prior to and one immediately following the 10-minute counting period for the animal. The average of the two background measurements were substracted from total count, i.e. animal count + environmental gamma radiation, to obtain net K^{40} count for each animal at each counting period. This total count was converted to counts per minute, which were used in the analysis of the data. This counting procedure was repeated for each animal with an interval between the first and second counting of not less than one hour nor more than four hours.

Ten, twenty and thirty-minute counting periods were studied to determine the possible influence of length of counting time on repeatability of K^{40} measurement on the same pig during the same day. Ten-minute background counts were also used for the 20 and 30-minute counting periods in the same manner previously discussed for the 10-minute counting period for each animal. At the time of slaughter, the unsplit carcasses were mounted on a carcass rack in such a way as to simulate the standing position of the pig in the counter, Figure 2. This was done in order to study possible effects and interrelationships of "dress-off" items on net K^{40} count. The counting procedure used for the carcass was the same as that for the live animal, i.e., obtaining a 10-minute net count, and then converting to counts per minute.

Ultrasound

Before the pigs were placed into the K^{40} counter, they were ultrasonically evaluated with a Branson Sonoray Live Animal Tester, Model 12, using a 1/2 inch, 2 mc transducer to determine the accuracy of ultrasonics in estimating back-fat thickness, loin eye area, and the value of these estimates in predicting leanness in hogs at different slaughter weights.

Each pig was weighed and placed in a restraining crate

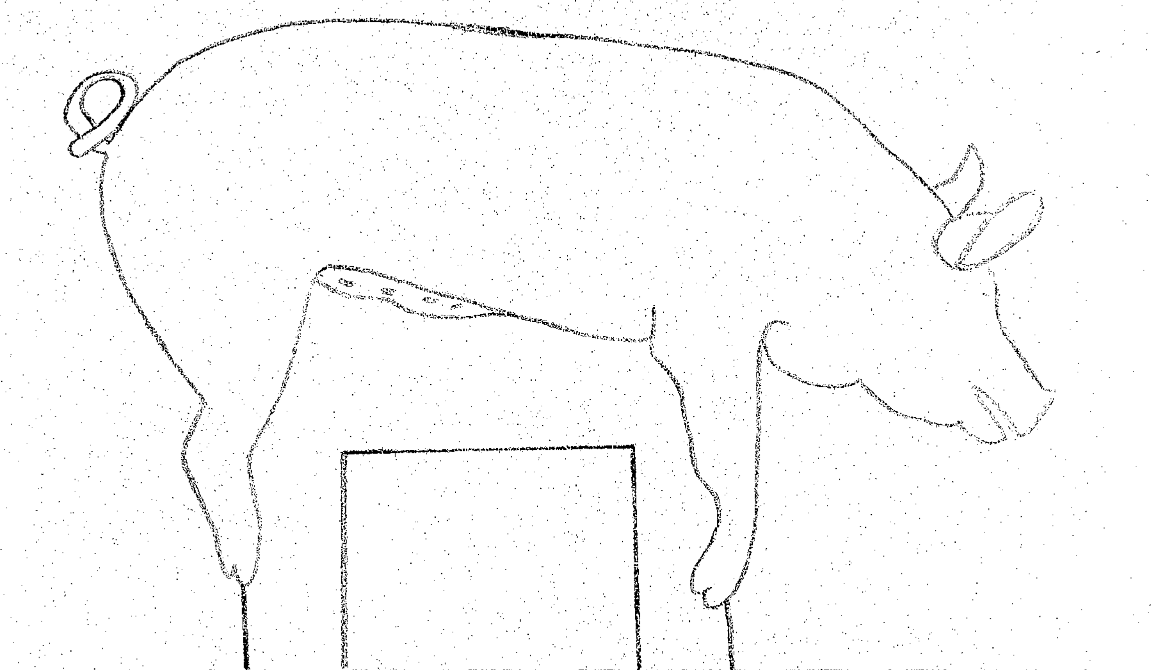

Figure 2. Example of the Mounted Unsplit Carcass, Used to Simulate the Live Animal

to prevent excessive movement. The hair over the 1st and 10th ribs and the last lumbar vertebra was clipped close to the skin. The area over the 10th rib was measured at 1/2 inch intervals for a distance of five inches. The contour of the pig's back at the 10th rib was determined using a Morilla Flexicurve and drawn on graph paper as illustrated in Figure 3. Paraffin oil was applied to the skin in each clipped area to insure air-free contact between the skin and the transducer.

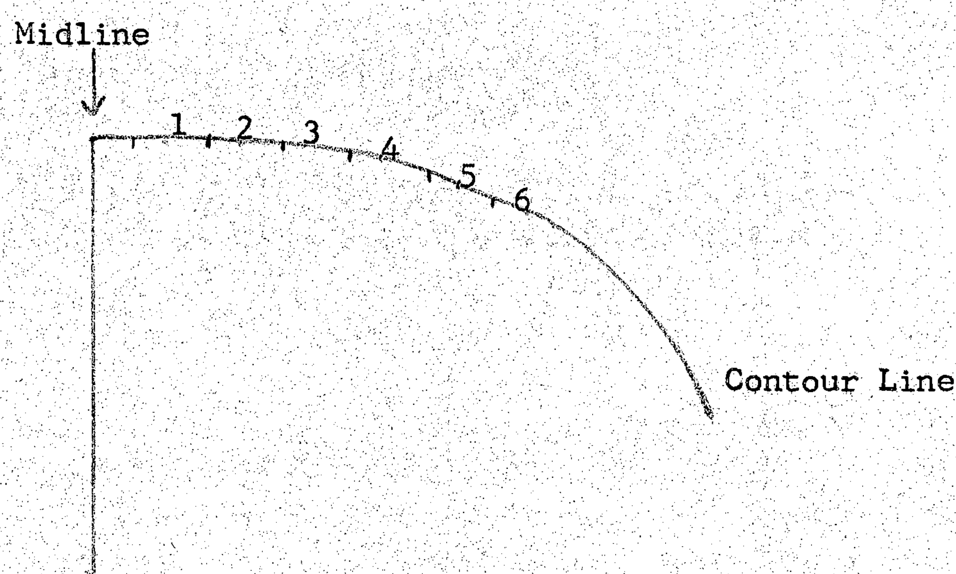

Figure 3. Schematic Illustration of the Recording of the Contour of the Pig's Back from the Flexicurve

Fat depth readings were made at the 1st and 10th ribs and the last lumbar vertebra on the midline of the back. Twelve fat and lean depth readings were made at the 10th rib in the fashion described in Figure 4.

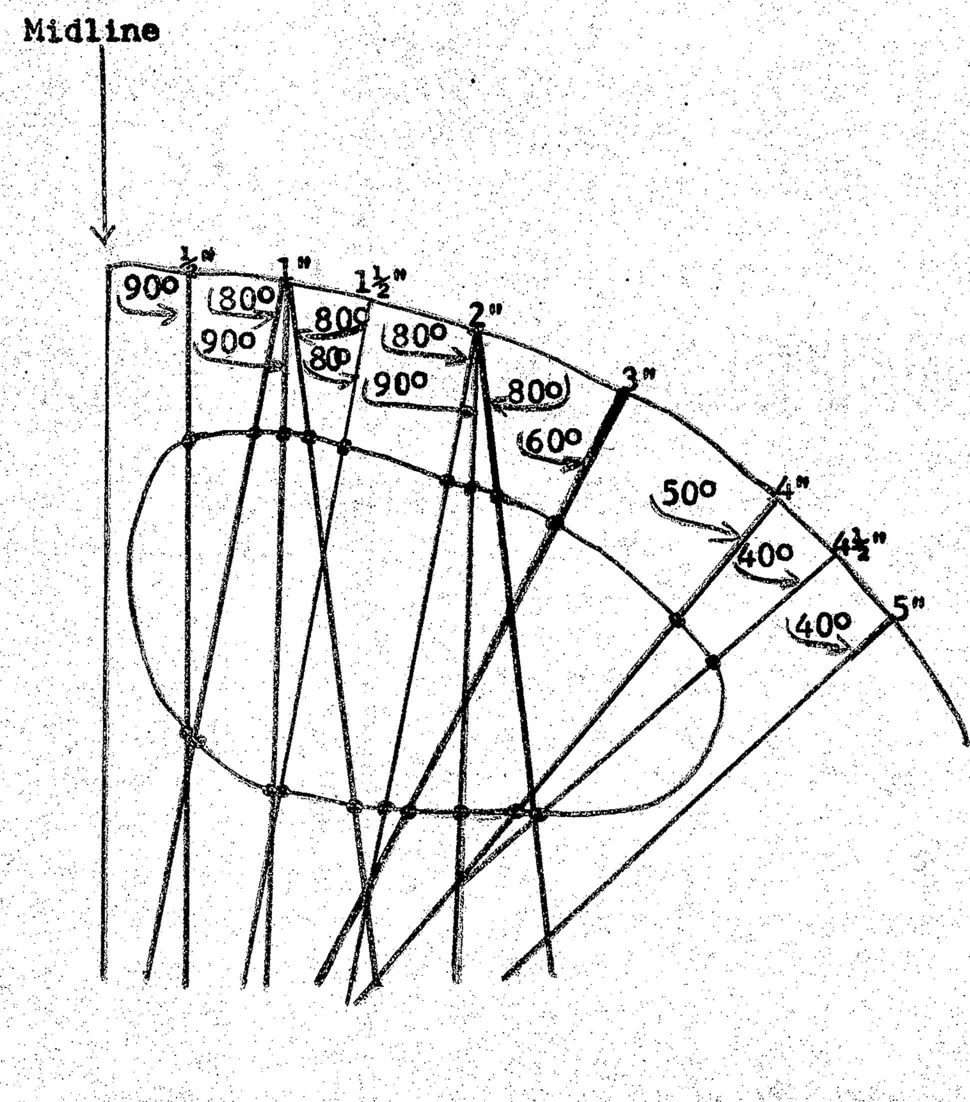

Figure 4. Example of the Location and Angles at which the 12 Fat and Lean Depth Readings Were Taken, and the Estimated Loin Eye Boundry

The fat and lean readings taken at the 10th rib were plotted with the proper angle on the contour line. The estimated muscle area was sketched and the area measured with a compensating polar planimeter. The three fat readings made on the midline (one over the 1st rib, one over the 10th rib and one over the last lumbar vertebra) were averaged for an estimate of backfat thickness.

Ruler Probe

Immediately following ultrasonic measurements, probe backfat measurements were taken on all pigs. The pigs were probed with a metal ruler graduated in tenths of an inch at the 1st rib, 10th rib and last lumbar vertebra at a position 1 1/2 inches off the midline on both the right and left sides. Average probe backfat thickness estimate was obtained by averaging the six probe measurements.

Carcass Separation

As pigs reached their predetermined slaughter weight, they were evaluated and slaughtered at the University Meat Laboratory on the same day. At slaughter the leaf fat and kidneys were removed. The unsplit carcass (head on) was mounted on a rack to simulate the standing position of the live pig (Figure 2).

After it had been evaluated by K^{40}, the carcass was split and backfat measurements were taken on the midline opposite the 1st and 10th rib and the last lumbar vertebra on both sides of the carcass. Fat depth measurements were taken over both shoulders and both hams. The shoulder fat probe was taken at a point 60% of the distance from the point of the shoulder at the midline to the junction of the radius and meta carpal, and the ham fat probe was taken 50% of the distance from the base of the tail to the junction of the tibia and meta tarsal.

Each right side was then separated into the wholesale cuts as follows; the shoulder was removed perpendicular to the axis of the body at the junction of the third and fourth thoracic vertebrae, and the jowl and neck bones were removed from the shoulder. The ham was removed perpendicular to the axis of the hind leg at the third sacral vertebra. The loin was removed from the belly along a line ventral to the tenderloin muscle at the posterior end of the loin and immediately below the body of the third thoracic vertebra at the anterior end. Weights of the trimmed ham, loin and shoulder were obtained to determine lean cut yields on a carcass weight and slaughter weight basis. The ham, loin and shoulder were trimmed very closely to obtain the most accurate measure of lean cuts. Each wholesale cut was then separated into fat (including skin), lean and bone.

The percent ham and percent ham and loin were calculated on a slaughter weight and carcass weight basis. The ham-loin index was computed using the following formula: H-L Index = 10 (% ham of slaughter wt. - 10) + 10 (loin eye area in sq. in.).

The loin eye area was measured with a compensating polar planimeter from a tracing of the cross section of the untrimmed right loin immediately behind the 10th rib, perpendicular to the back bone. To reduce moisture loss from evaporation, all separation was conducted in a cool room and exposed tissues were covered with a damp cloth as much as possible.

The sampling procedure for the separable lean was according to Munson et al. (1966) with slight modification. The total separable lean mass from the right side of each carcass was ground once through a 3/8 inch meat grinding plate and thoroughly mixed. The lean mass was then ground and mixed in a combination meat mixer-grinder through a 1/8 inch plate. Two sets of four grab samples from each animal were randomly taken and placed in airtight sample bottles for storage and subsequent proximate chemical analyses. The samples were emulsified and two determinations were obtained from each bottle giving a total of four determinations per animal. The chemical analyses which included moisture, ether extract (fat), protein and ash were determined according to the procedures outlined by Leverton and O'Dell (1959). Potassium content was determined by atomic absorption spectrophotometry. Percent fat-free lean in the carcass (and live animal) was determined by substracting the ether extract from total separable lean. Total fat included trimmable fat plus ether extracted fat of the separable lean.

Statistical Analyses

Means, standard errors, correlation coefficients and orthogonal comparisons among weight group totals were determined according to the methods outlined by Steel and Torrie (1960). The error mean squares used for the orthogonal comparisons (linear and quadratic) were determined by calculating the average of the variances for the weight groups.

Analysis of variance for the sampling procedure of the separable lean was determined according to procedures outlined by Munson *et al*. (1966).

CHAPTER IV

RESULTS AND DISCUSSION

The results of this study are discussed in two parts; (1) the association of slaughter weight with growth and (2) the association between live measures and carcass measures of leanness for pigs slaughtered at five different weights.

The Association of Slaughter Weight with Growth

Live Estimates

Table VI presents the means and standard errors of the live measures taken on pigs slaughtered at various weights. Average daily gains for these pigs were calculated for the interval between the initial weight and the predetermined slaughter weight. The average daily gain was relatively uniform from 150 to 300 pounds with a range of 1.82 to 1.72 pounds, respectively. The highest rate of gain was for the 100 pound weight group which had an average daily gain of 2.01 pounds. This could be due to the pigs being quite shrunk-out when placed on test, which would tend to effect the 100 pound weight group more than the other groups. Also, pigs in the other four weight groups were taken off feed and evaluated at each weight until they reached their pre-

TABLE VI

MEANS AND STANDARD ERRORS OF LIVE MEASUREMENTS FROM PIGS SLAUGHTERED AT VARIOUS WEIGHTS

	Slaughter Weight Groups (pounds)				
	100	150	200	250	300
Number of animals	11	11	11	11	9
Slaughter wt., lb.[a]	103.0 ±1.21	151.0 ±0.54	199.0 ±1.23	249.0 ±1.30	296.0 ±1.30
Rate of gain, lb.	2.01 ±.088	1.82 ±.058	1.79 ±.056	1.72 ±.053	1.72 ±.061
K^{40} CPM, live[b]	3533.5 ±64.7	4506.3 ±116.2	4908.1 ±89.0	5295.6 ±95.9	5646.3 ±205.1
Probe, in.	0.60 ±.026	0.96 ±.062	1.21 ±.055	1.47 ±.057	1.73 ±.051
Ultrasound estimates					
Backfat thickness, in.	0.79 ±.043	1.05 ±.032	1.23 ±.054	1.46 ±.062	1.65 ±.050
Loin eye area, sq. in.	2.58 ±.137	3.76 ±.090	4.47 ±.130	5.29 ±.114	5.44 ±.206

[a]Thirty-six hours off feed and water

[b]Average K^{40} counts per minute (CPM) from the live animal

determined slaughter weight, which would tend to reduce gain.

The mean K^{40} counts per minute (CPM) ranged from 3533.5 for the 100 pound pigs to 5646.3 for the 300 pound pigs. The increase in K^{40} counts per minute for the five weight groups showed a curvilinear response. Tests for both linearity and quadratic effects were significant ($P<.05$). Linearity was used to test the amount of variation accounted for by lineartiy, while the quadratic was used to test for the non-linear response.

All pigs were evaluated at each of the weight groups until they reached their predetermined slaughter weight. Therefore, the live estimates taken from the pigs slaughtered at each weight were compared to estimates obtained from all pigs at these weights. Figures 5, 6 and 7 includes the response curves for the pigs estimated and slaughtered at each weight and the response curves for all pigs estimated at these various weights (including those not slaughtered). When comparing the means and their standard errors for the live estimates, from the pigs that were estimated and then slaughtered—to all the pigs estimated at each weight; it was found that the standard errors overlapped at all points. This would indicate that there was essentially no difference between the live estimates from the pigs slaughtered and all those estimated at each weight, therefore, the pigs randomly selected to be slaughtered for each weight group were a representative sample of the pigs available.

As illustrated in Figure 5, live K^{40} counts per minute increased as slaughter weight increased, and the most rapid increase was in the lighter weight (100 to 150 pounds). This increase in K^{40} counts per minute could be expected since the heavier weight pigs definitely had more total lean than the lighter weights. The solid line represents only the pigs that were slaughtered at each weight, while the dotted line represents all pigs that were estimated at these weights (including those not slaughtered).

Estimates of backfat thickness by the ruler probe and ultrasound techniques increased as slaughter weight increased. The test for linearity for these two estimates of backfat thickness was significant ($P<.05$) but the quadratic test was not significant. The average backfat thickness estimated with the ruler probe ranged from 0.60 to 1.73 in. while with the ultrasound technique the estimates ranged from 0.79 to 1.65 in.

Figure 6 illustrates ruler probe backfat estimates for pigs estimated and slaughtered at each weight and all pigs estimated at these various weights. There was essentially no difference between ruler probe backfat estimates for the pigs estimated and then slaughtered—and the backfat estimates by ruler probe for all pigs estimated at these weights (including those not slaughtered). This would indicate that the pigs randomly selected for each weight were a relatively good sample from all the pigs estimated at these weights.

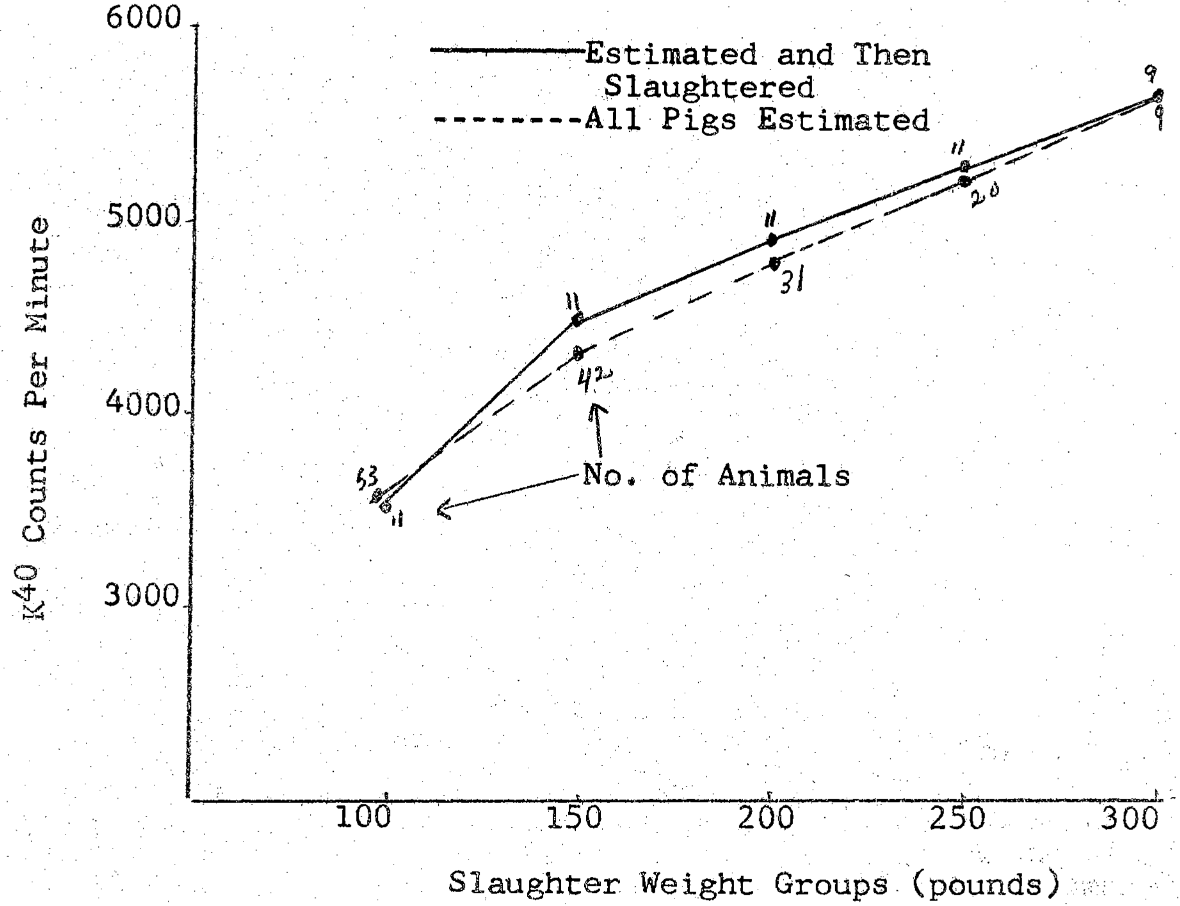

Figure 5: Average Live K^{40} Counts Per Minute for Pigs Estimated and Slaughtered at Each Weight Compared to All Pigs Estimated at These Weights

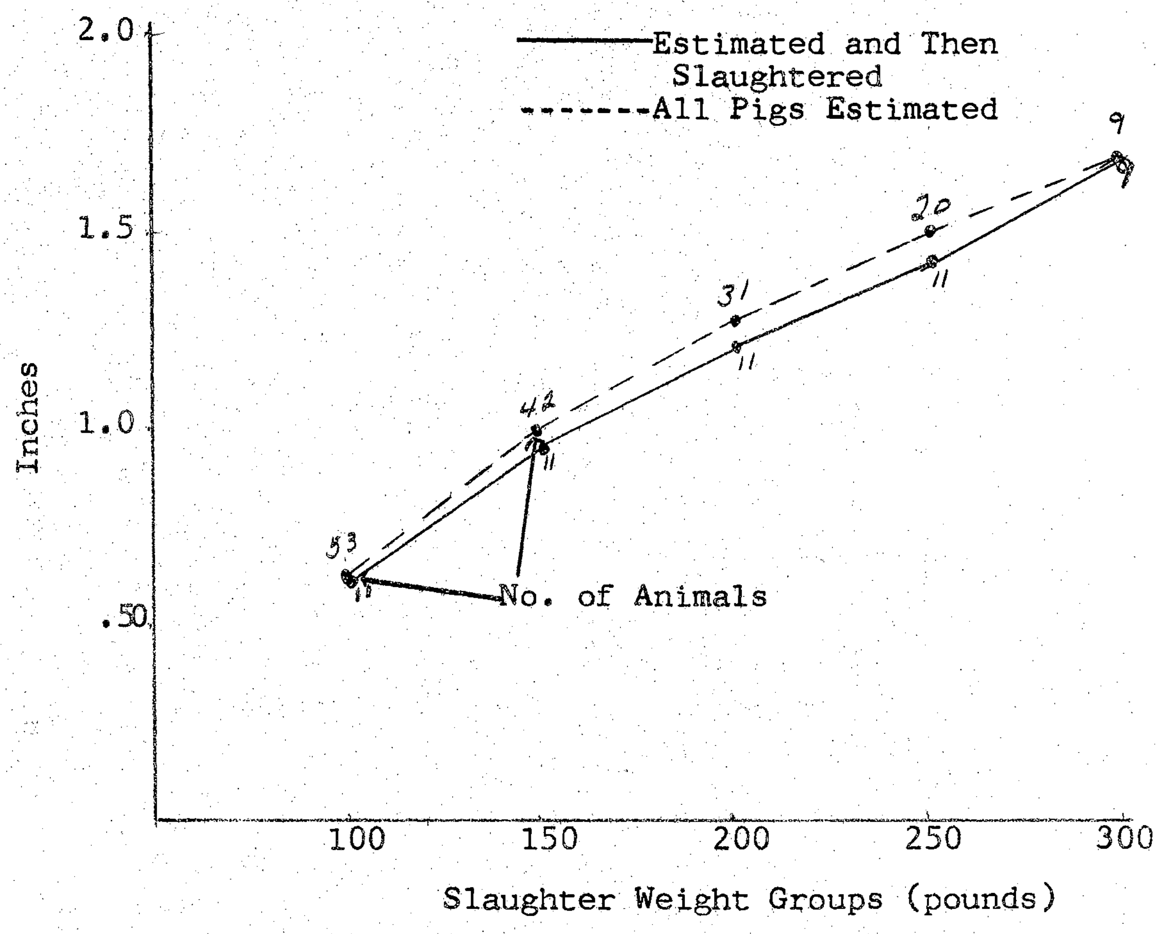

Figure 6. Ruler Probe Backfat Estimates for Pigs Estimated and Slaughtered at Each Weight Compared to All Pigs Estimated at These Weights

The average loin eye area estimated by the use of the ultrasound technique also increased as slaughter weight increased with a range of 2.58 sq. in. in the 100 pound weight group to 5.44 sq. in. in the 300 pound weight group. The test for linear and quadratic effects were both significant ($P<.05$).

Figure 7 shows the response curves for the mean ultrasound backfat thickness and loin eye area. As with the other live estimates previously discussed, there was essentially no difference between the pigs estimated and then slaughtered at each weight, and all pigs estimated at these various weights for both ultrasound backfat and loin eye area estimates. Estimate of loin eye area increased rapidly in the lighter weights, but the rate of increase declined in the heavier weights. The largest increase (1.18 sq. in.) was from 100 to 150 pounds while the smallest (0.15 sq. in.) was from 250 to 300 pounds.

The response observed for these estimates of backfat thickness and loin eye area are to be expected since carcass backfat thickness and carcass loin eye area also increase as slaughter weight increases, as was shown by (Zobrisky *et al.*, 1958; Wallace *et al.*, 1960; Fields *et al.*, 1961 and Bradley *et al.*, 1963).

Carcass Measurements

The means and standard errors of the carcass measurements obtained from pigs at the various weights studied are

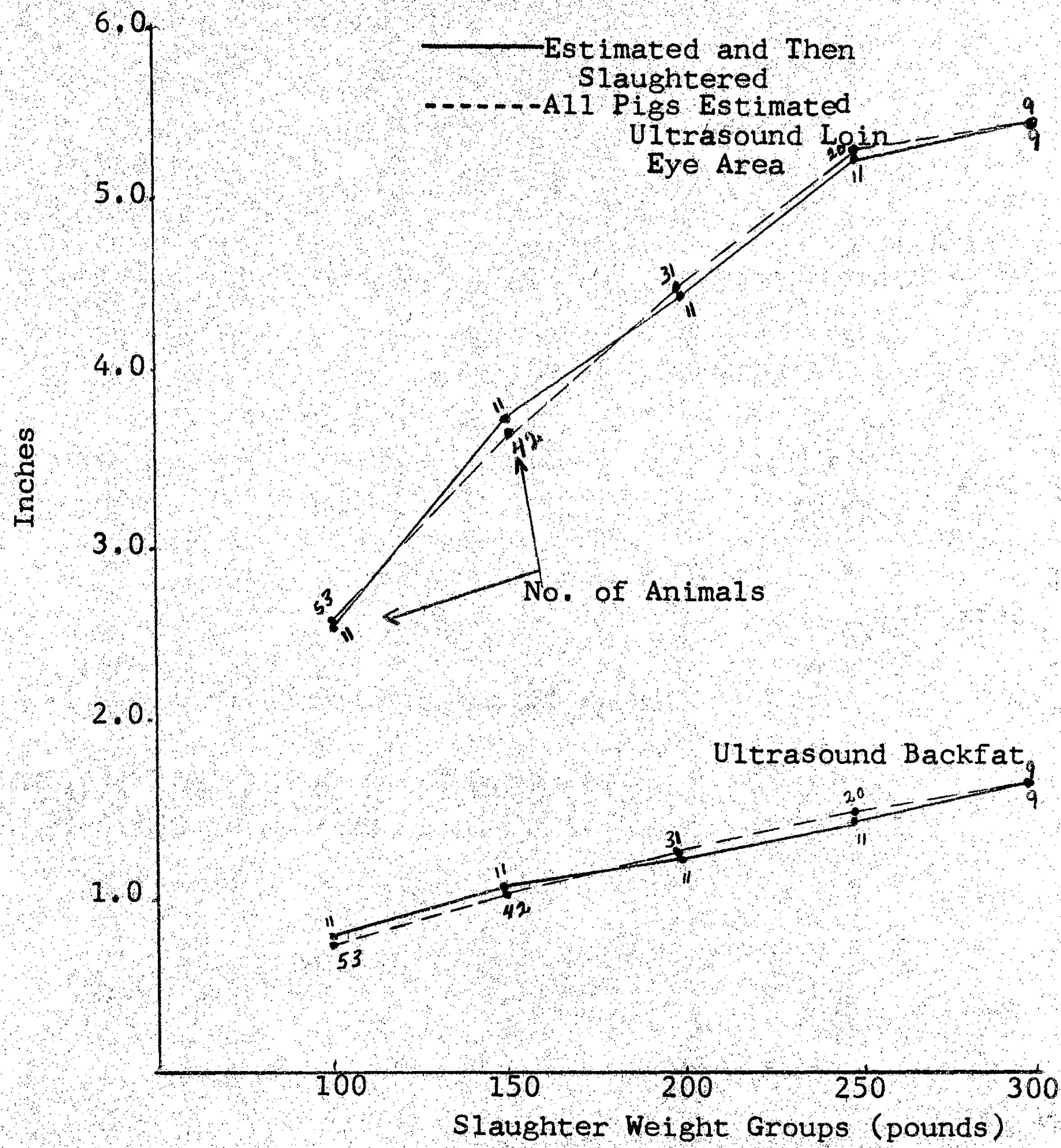

Figure 7. Ultrasound Backfat and Loin Eye Area Estimates for Pigs Estimated and Slaughtered at Each Weight Compared to All Pigs Estimated At These Weights

presented in Table VII. These carcass measurements followed basically the same trend as did the live estimates presented in Table VI. The average carcass K^{40} counts per minute increased from 3389.3 in the 100 pound group to 5706.4 in the 300 pound group. The increase in carcass K^{40} counts per minute showed a curvilinear response. The test for both linearity and quadratic effects were significant ($P<.05$). Figure 8 better illustrates the response of average carcass K^{40} counts per minute. As was observed for the live animal, carcass K^{40} counts per minute increased as slaughter weight increased, with the most rapid increase occurring in the lighter weights. However, the rate of increase declined in the heavier weights.

The fat thickness measurements taken on the carcass (backfat, ham fat and shoulder fat thickness) increased as live weight increased, with a significant ($P<.05$) amount of the variation in these responses being accounted for by linearity. The mean carcass backfat thickness ranged from 0.70 to 1.61 in., and ham fat thickness and shoulder fat thickness ranged from 0.41 to 1.02 in. and 0.45 to 1.05 in., respectively. It is interesting to note that the means of the fat thickness measurements from the ham and shoulder were very similar within the five weight groups. The average carcass loin eye area also increased as slaughter weight increased with a range of 2.49 to 5.52 sq. in. and the tests for linear and quadratic effects were significant ($P<.05$). This response in carcass loin eye area was simi-

TABLE VII

MEANS AND STANDARD ERRORS OF CARCASS MEASUREMENTS FROM PIGS SLAUGHTERED AT VARIOUS WEIGHTS

	Slaughter Weight Groups (pounds)				
	100	150	200	250	300
Number of animals	11	11	11	11	9
Slaughter wt., lb.	103.0	151.0	199.0	249.0	296.0
	±1.21	±0.54	±1.23	±1.30	±1.30
Carcass wt., lb.	70.0	108.0	146.0	187.0	223.0
	±1.18	±1.15	±1.21	±1.33	±1.87
K^{40} CPM, carcass[a]	3389.3	4336.9	5011.7	5558.8	5706.44
	±119.7	±113.07	±174.76	±105.4	±209.9
Backfat, in.	0.70	0.98	1.18	1.31	1.61
	±.018	±.039	±.045	±.054	±.067
Ham fat thickness, in.	0.41	0.53	0.76	0.81	1.02
	±.030	±.028	±.042	±.035	±.047
Shoulder fat thickness, in.	0.45	0.54	0.77	0.84	1.05
	±.022	±.025	±.046	±.035	±.058
Loin eye area, sq. in.	2.49	3.81	4.44	4.99	5.52
	±.093	±.130	±.151	±.166	±.123

[a]Average K^{40} counts per minute (CPM) from the carcass

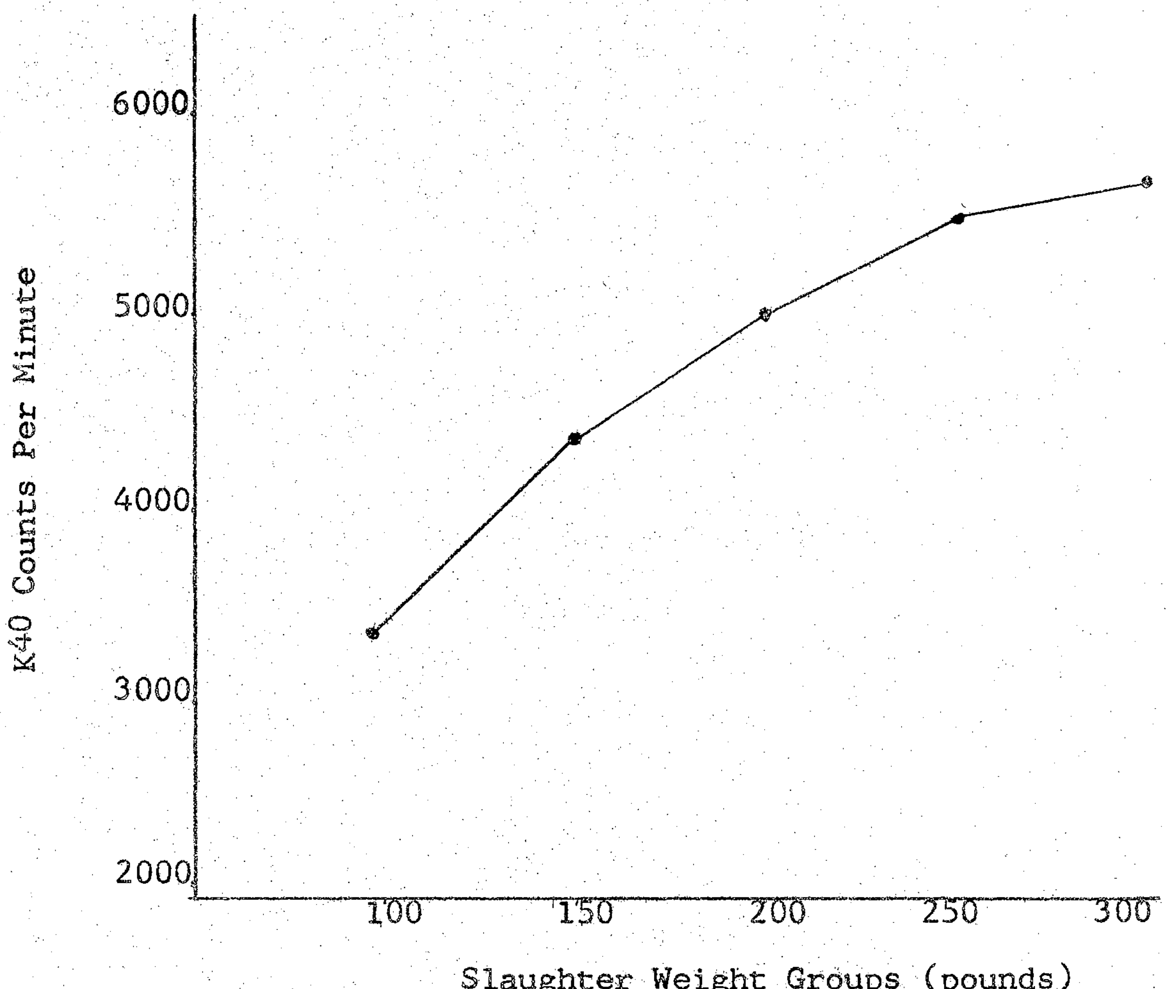

Figure 8. Carcass K^{40} Counts Per Minute for Pigs at Different Weights

lar to that observed when loin eye area was estimated with ultrasound (Figure 6).

The largest increase in backfat thickness was from 250 to 300 pounds while the largest increase in loin eye area was from 100 to 150 pounds. This indicates that loin eye area increases faster in the lighter weights while backfat thickness begins to increase more rapidly in the heavier weights. Zobrisky _et al_. (1963) found the largest increase in loin eye area to be between 150 and 200 pounds, while Bradley _et al_. (1963) found the largest increase in loin eye area to be between 150 and 175 pounds.

Figure 9 illustrates the growth pattern for the mean carcass loin eye area and backfat thickness. A very rapid increase was observed in loin eye area, for the first 50 pound increase in slaughter weight (1.32 sq. in.), with a relatively constant increase for the other three 50 pound intervals; (0.63, 0.55 and 0.53 sq. in., respectively). This indicates that the loin eye area was continuing to increase in area at 300 pounds but at a decreasing rate. The observations for backfat thickness showed an inverse relationship with loin eye area. The amount of increase for the first three 50 pound intervals were 0.18, 0.20 and 0.23 in., respectively, while the largest increase was between 250 and 300 pounds (0.30 in.).

Carcass Composition — Percentage Yields

A summary of the yield of lean cuts, ham and ham and

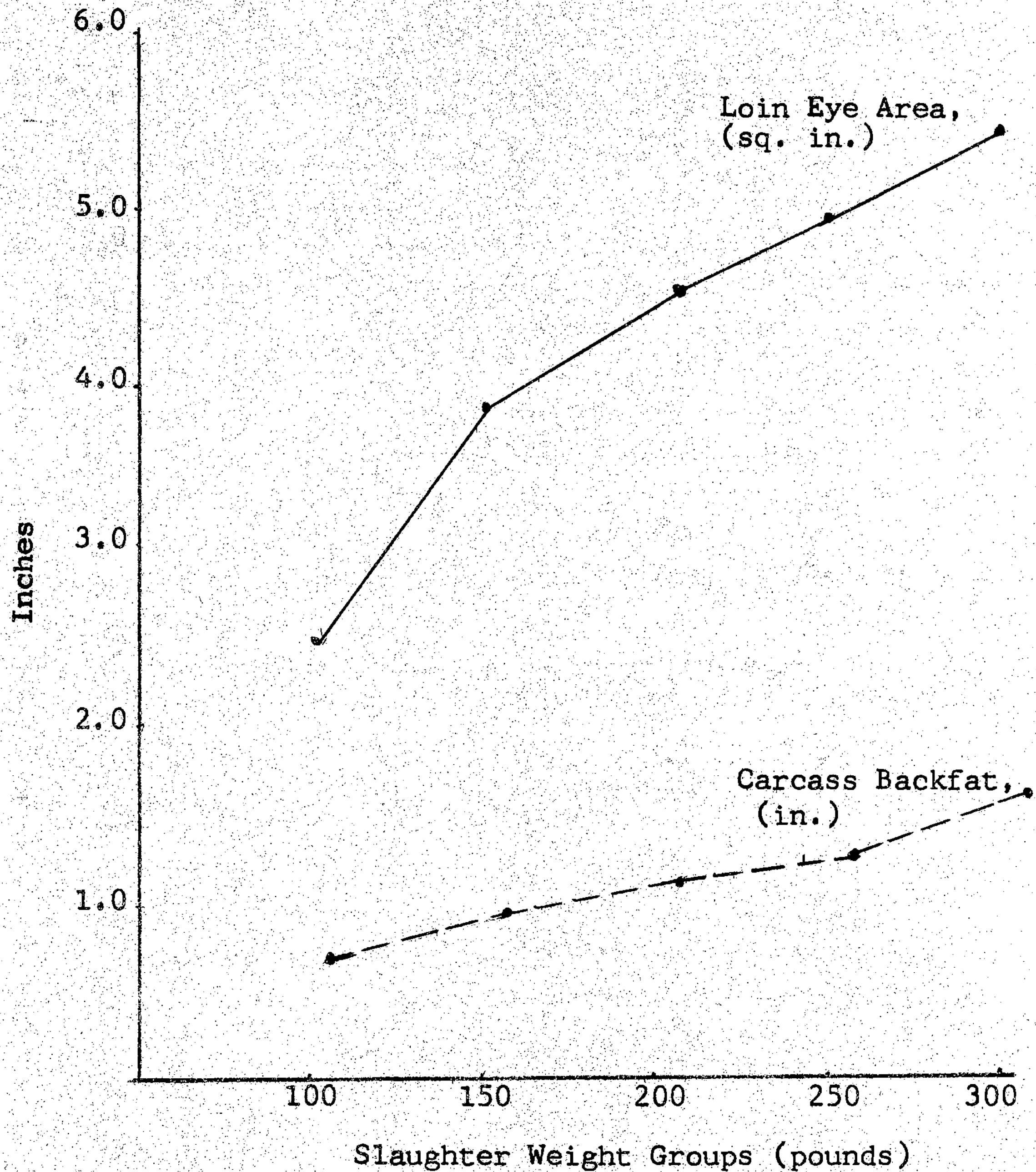

Figure 9. Carcass Loin Eye Area and Backfat Thickness from Pigs of Different Weights

loin, expressed as percent of shrunk live weight and carcass weight are presented in Table VIII. The mean ham-loin index for each weight group is also presented.

Total pounds of lean cuts, ham, and ham and loin increased as slaughter weight increased, and all showed a significant ($P<.05$) linear test. This indicates that linearity accounted for a significant amount of the variation in these responses. The average total pounds of lean cuts ranged from 42.7 to 118.9; and pounds of ham, and ham and loin ranged from 16.4 to 44.6 and 29.2 to 81.0, respectively. This would be expected because of the increase in average live weight from 103 to 296 pounds. When these values were expressed as a percentage of slaughter weight, the test for linearity was significant ($P<.10$). When the values were expressed as a percentage of carcass weight, linearity was significant ($P<.05$). These percentages, generally, decreased as slaughter weight increased. The decrease in percentage of wholesale cuts is explained by the increasing amount of fat in the carcass, therefore leaving a smaller percentage of the animal or carcass as wholesale cuts. These results are in agreement with Varney _et al_. (1962) and Zobrisky _et al_. (1958 and 1963). A significant linear test was also observed when ham-loin index was considered. The mean ham-loin index of these pigs increased as slaughter weight increased. Since ham-loin index was calculated from the percent ham of slaughter weight and the square inches of loin eye area, the increase in ham-loin index would have

TABLE VIII

MEANS AND STANDARD ERRORS OF CARCASS YIELDS AS A PERCENTAGE OF SHRUNK LIVE WEIGHT AND CARCASS WEIGHT OF PIGS AT VARIOUS SLAUGHTER WEIGHTS

	Slaughter Weight Groups (pounds)				
	100	150	200	250	300
Total lean cuts, lb.	42.7	63.4	81.1	102.1	118.9
	±.88	±1.06	±1.50	±1.63	±1.70
% Slaughter wt.	41.6	42.0	40.8	41.1	40.2
	±.61	±.70	±.74	±.59	±.44
% Carcass wt.	61.6	58.8	55.6	54.4	53.3
	±.67	±.72	±.90	±.81	±.72
Total ham, lb.	16.4	23.8	30.5	38.7	44.6
	±.34	±.55	±.60	±.78	±1.27
% Slaughter wt.	16.0	15.9	15.4	15.6	15.1
	±.25	±.40	±.29	±.32	±.37
% Carcass wt.	23.4	22.3	21.0	20.8	20.1
	±.37	±.48	±.39	±.40	±.54
Total ham + loin, lb.	29.2	43.8	54.9	69.2	81.0
	±.53	±.57	±1.08	±1.23	±1.22
% Slaughter wt.	28.3	29.0	27.7	28.1	27.4
	±.38	±.45	±.53	±.45	±.29
% Carcass wt.	41.6	40.6	37.7	37.4	36.4
	±.49	±.55	±.63	±.58	±.41
Ham-loin index	85.1	96.9	98.4	105.5	106.3
	±3.26	±4.76	±3.87	±4.42	±4.73

to be attributed to the increase in loin eye area, rather than percentage of ham, which decreased.

Means and standard errors for fat-free lean, fat, and bone, expressed as pounds and percent of slaughter weight and carcass weight, are presented in Table IX. Chemically determined fat-free lean was used as the measure of leanness for pigs in this study. This should be a relatively good measure of the actual leanness since it eliminates the effects of inter and intramuscular fat. This method of lean determination tends to put all animals on an equal basis, and the fat-free lean observed would be the actual lean produced by the animal. This also applies to the actual fatness of these pigs, inasmuch as fat includes the separable fat plus the ether extractable portion of the separable lean. Fat-free lean, fat and bone, expressed in pounds, increased as slaughter weight increased with fat increasing more rapidly in the heavier weights. Tests for linearity were significant ($P<.05$) for the responses of the three components, and the quadratic test was significant ($P<.10$) for the response of fat-free lean. The average total pounds of fat-free lean ranged from 40.6 to 109.0, while the mean pounds of fat and bone ranged from 19.77 to 96.22 and 8.85 to 20.73, respectively.

Figure 10 illustrates the effect of slaughter weight on pounds of fat-free lean, fat and bone. Pounds of fat-free lean increased rather rapidly from 100 to 300 pounds while bone increased only slightly. Pounds of fat steadily

TABLE IX

MEANS AND STANDARD ERRORS OF CARCASS COMPONENTS FROM PIGS SLAUGHTERED AT 100, 150, 200, 250 AND 300 POUNDS

	Slaughter Weight Groups (pounds)				
	100	150	200	250	300
Fat-free lean					
Total, lb.	40.6 ±1.08	60.8 ±1.51	78.7 ±2.23	96.9 ±1.60	109.0 ±2.92
% Slaughter wt.	39.4 ±.81	40.2 ±1.00	39.6 ±1.16	39.0 ±.58	36.9 ±.85
% Carcass wt.	57.8 ±.89	56.3 ±1.13	54.0 ±1.54	51.8 ±.67	48.8 ±1.25
Fat[a]					
Total, lb.	19.7 ±.66	34.9 ±1.23	50.9 ±1.81	72.7 ±1.67	96.2 ±2.13
% Slaughter wt.	19.3 ±.63	23.1 ±.80	25.6 ±.82	29.2 ±.65	32.4 ±.71
% Carcass wt.	28.4 ±1.02	32.4 ±1.14	34.9 ±1.11	38.9 ±.92	43.1 ±.92
Bone					
Total, lb.	8.85 ±.47	11.73 ±.35	14.58 ±.44	18.73 ±.62	20.73 ±.65
% Slaughter wt.	8.59 ±.38	7.75 ±.23	7.34 ±.22	7.52 ±.25	7.00 ±.21
% Carcass wt.	12.60 ±.52	10.80 ±.32	10.00 ±.29	10.02 ±.36	9.28 ±.25

[a]Trimmable fat + percent fat in separable lean

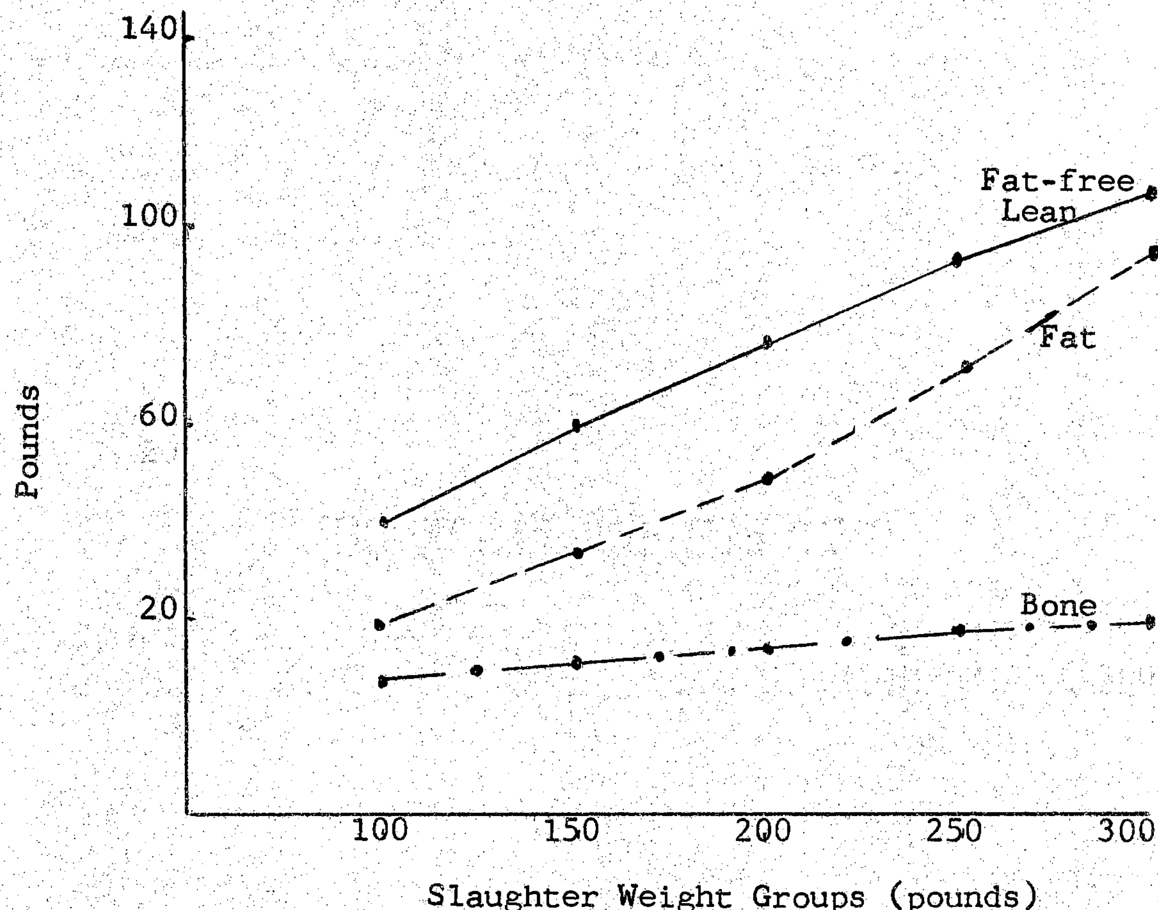

Figure 10. Pounds of Fat-free Lean, Fat and Bone from Pigs of Different Weights

increased through 200 pounds and markedly increased from 200 to 300 pounds.

The average difference between weight groups in pounds of fat-free lean, fat and bone is presented in Table X. The stage of the most rapid muscular development (20.0 pounds increase) was found to be from 100 to 150 pounds and the least (12.1 pounds increase) was from 250 to 300 pounds. The reverse was observed for fat deposition with 23.54 pounds of fat being deposited from 250 to 300 pounds while only 15.09 pounds were deposited from 100 to 150 pounds. The largest bone growth (4.15 pounds increase) occurred in the 200 to 250 pound interval.

In comparing the increase in pounds of fat-free lean for the respective weight groups with the increase in live K^{40} counts per minute, the response curves were rather similar from 200 to 300 pounds. In both cases the largest increase was from 100 to 150 pounds. However, live K^{40} count appeared to increase more rapidly at this interval than did fat-free lean.

TABLE X

AVERAGE INCREASE IN POUNDS OF FAT-FREE LEAN, FAT AND BONE FOR EACH 50 POUND INCREASE IN SLAUGHTER WEIGHT

	Slaughter Weight Group (pounds)			
	100-150	150-200	200-250	250-300
Lean	20.20	17.90	18.20	12.10
Fat	15.09	16.04	21.78	23.54
Bone	2.88	2.85	4.15	2.00

Fat-free lean and bone decreased as slaughter weight increased when expressed as a percentage of slaughter weight or carcass weight while fat increased. Linearity in this case also tested significant ($P<.05$). Figure 11 illustrates the trends in carcass composition with regard to fat-free lean, fat and bone, as a percentage of carcass weight for the respective weight groups. Percent fat-free lean declined rapidly from 100 to 300 pounds while fat steadily increased through 200 pounds and markedly increased from 200 to 300 pounds. Percent bone decreased slightly with an increase in slaughter weight.

The point of equal fat and lean was not reached in this experiment, but they were approaching equality in the 300 pound weight group. Loeffel et al. (1943) found the point of equal fat and lean was reached at approximately 220 pounds. This is probably due to the differences in the types of pigs used in the experiments. The pigs used by Loeffel et al. (1943) were fatter than those used in this study, which would cause the point of equal fat and lean to occur earlier. The observed trends for fat-free lean, fat and bone were similar to those previously established by other workers (Loeffel et al., 1943; Bradley et al., 1963; Berg and Richmond, 1969). These data indicate that there are distinct patterns associated with the deposition of fat and the growth of lean. As slaughter weight increases the rate at which fat is deposited increases but the rate of growth of lean decreases.

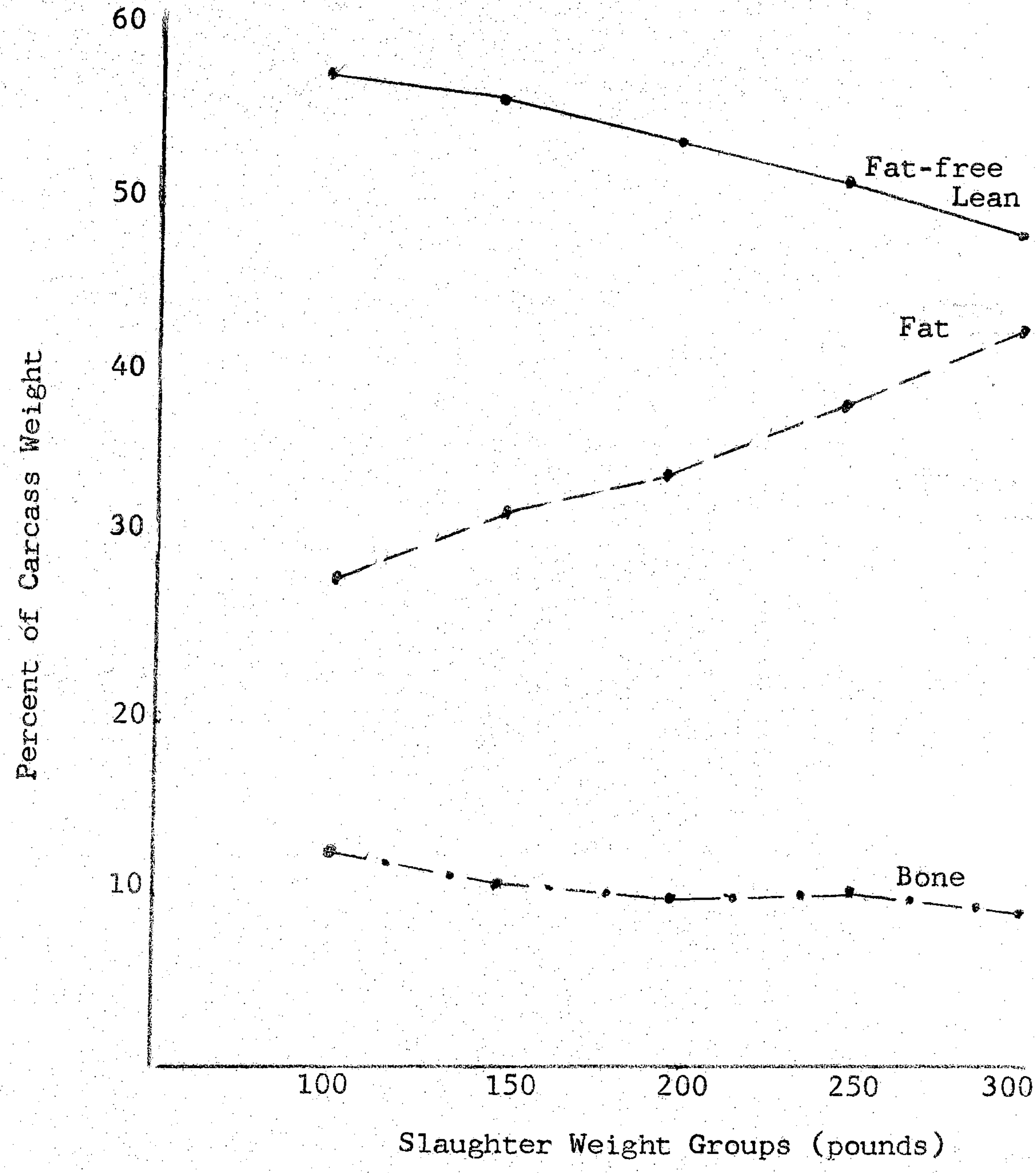

Figure 11. Percentage of Fat-free Lean, Fat and Bone of the Carcass from Pigs of Different Weights

Carcass Composition — Chemical Analyses

The chemical composition of the separable lean for all weight groups is presented in Table XI.

TABLE XI

MEANS AND STANDARD ERRORS FOR CHEMICAL COMPONENTS OF THE SEPARABLE LEAN FROM PIGS SLAUGHTERED AT 100, 150, 200, 250 AND 300 POUNDS

Percentage of Separable Lean	Slaughter Weight Groups (pounds)				
	100	150	200	250	300
Moisture	65.6 ±.739	63.5 ±.714	60.9 ±.478	57.9 ±.365	57.1 ±.587
Fat	15.9 ±.920	18.1 ±.956	21.1 ±.656	24.6 ±.399	25.7 ±1.037
Protein	17.9 ±.291	18.0 ±.256	17.4 ±.243	16.5 ±.147	16.7 ±.188
Ash	1.05 ±.033	1.04 ±.033	0.96 ±.022	0.95 ±.029	0.92 ±.031
Potassium[a]	0.336 ±.007	0.333 ±.008	0.306 ±.007	0.288 ±.009	0.278 ±.003

[a]Determined by atomic absorption spectrophotometry

As was expected the percent moisture decreased as slaughter weight increased, while the opposite trend was observed for percent fat. Inasmuch as external fat of the wholesale cuts was trimmed as uniformly as possible for all weights, the increase in percentage of fat is largely due to the increase in intermuscular fat in the heavier weights. The percent protein declined as slaughter weight increased, and followed a similar trend to that for fat-free lean. A downward trend was also noticed for the mean percentages of ash and potassium with a range of 1.05 to 0.92 and 0.336 to 0.278, respectively. Significant linear tests were observed for all responses in regard to the chemical components.

The percent variation accounted for in percent ether extract for the sampling procedure of the separable lean is presented in Table XII.

TABLE XII

THE PERCENT VARIATION ACCOUNTED FOR IN PERCENT ETHER EXTRACT FOR THE SAMPLING PROCEDURE OF THE SEPARABLE LEAN

Percent Variation Accounted For by	Slaughter Weight Groups (pounds)				
	100[1]	150[1]	200[1]	250[1]	300[2]
Animal	96.31	94.95	80.96	80.11	92.98
Bottle	2.11	4.42	16.35	17.09	5.42
Determination	1.57	0.63	2.96	3.49	1.61

[1]Degrees of freedom — animal 10, bottle 11, determination 22

[2]Degrees of freedom — animal 8, bottle 9, determination 22

The sampling procedure was as follows: Two sets of four grab samples from each animal were randomly placed into two bottles and two determinations were taken from each bottle to give a total of four determinations per animal. As was expected the animals accounted for the largest amount of variation in percent ether extract, while determination accounted for the least amount of variation. According to the variation accounted for by bottles, the sampling procedure was quite adequate for the 100 and 150 pound weight groups but there may be some question as to its adequacy in the heavier weight, especially in the 200 and 250 pound weight groups. Bottles accounted for 16.35 and 17.09% of the variation, respectively. Since the variation accounted for by bottles should have been rather uniform for all weight groups, these differences in variation accounted for by bottles, points out that bottle differences is only an estimate of sampling variation. This suggests that a better (or more extensive) sampling procedure may be necessary in the heavier weight groups to assure an adequate sample.

The Association Between Live Measures and Carcass Measures of Leanness

Correlation coefficients were obtained between various live measures and carcass measures of leanness for the five different weight groups. It should be pointed out that these coefficients were calculated using only 11 animals in weight groups through 250 pounds and nine animals in the 300 pound group. Realizing the degree to which extreme values could effect correlation coefficients calculated from small numbers of observations, only general trends will be discussed and conclusions will be drawn in a general manner.

Permian K^{40} Counter — Animal Studies

In order for any method or tool to be of value in a research effort, it must first of all be repeatable. The term repeatable means that two independent counts taken on the same animal on the same day are in close agreement. Studies were made to determine the degree to which the Permian K^{40} Counter would repeat itself on five different weights of pigs. To accomplish this, it became necessary to calculate the degree of association between variables under investigation. For example, coefficients were calculated to express the association between two K^{40} counts on the same animal at different times on the same day which became an important criteria for measuring the dependability of this procedure.

The repeatability of the Permian K^{40} Counter located at the Oklahoma State University Live Animal Evaluation Center was determined for five different weights of pigs. The correlation coefficients between first and second live K^{40} counts per minute for three different lengths of counting time (10, 20 and 30 minutes) are presented in Table XIII. The correlation coefficients between the two counts taken at the 10-minute counting periods ranged from 0.61 to 0.94. These correlations were all significant ($P<.05$). These positive correlation coefficients indicate that there

TABLE XIII

CORRELATION COEFFICIENTS BETWEEN FIRST AND SECOND LIVE K^{40} COUNTS PER MINUTE

Slaughter Weight Groups (pounds)	Length of Counting Time (minutes) 10 N	10 r	20 N	20 r	30 N	30 r
100	(49)	0.72*	(23)	0.57*	(24)	0.66*
150	(40)	0.61*	(18)	0.44*	(18)	0.53*
200	(32)	0.77*	(15)	0.85*	(15)	0.86*
250	(22)	0.76*	(10)	0.90*	(10)	0.90*
300	(9)	0.94*				

N = number of animals

r = correlation coefficients

* ($P<.05$)

were fair to good agreement between the two readings, thus the instrument was found to be repeating itself reasonably well. The lowest correlation for the 10-minute counting periods between first and second K^{40} counts was found in the 150 pound weight group (r=0.61). Repeatabilities tended to increase as slaughter weight increased up to a correlation of 0.94 for the 300 pound weight group.

The correlations associated with the 20 and 30-minute counting periods followed the same general trend with a range of 0.44 to 0.90 for the 20-minute period and 0.53 to

0.90 for the 30-minute period. These data indicate that increasing the counting periods to 20 and 30 minutes did not increase the agreement between first and second live counts per minute. Therefore, counts per minute for the 10-minute counting period were used in the analysis of the data when correlations were determined between count and measures of leanness. The repeatability for the lighter weights should have been as high as that observed for the heavier weights in order to put confidence in the instrument for predicting leanness in light weight pigs and in monitoring tissue changes. However, it should be pointed out that the correlation in the 300 pound weight group was obtained on only nine observations. Also these readings were obtained over a rather long period of time, approximately one year.

Table XIV presents the correlation coefficients for live K^{40} counts (first, second and average) with lean cuts and fat-free lean (pounds and percent) for each weight group. The correlations obtained for the 100 pound weight group between count and pounds of lean cuts ranged from -0.37 to 0.07 and between count and percent lean cuts ranged from -0.08 to 0.41. When count and pounds of fat-free lean and count and percent fat-free lean were considered, the range of correlations was -0.05 to 0.00 and 0.24 to 0.26, respectively. These correlations proved to be low and nonsignificant, meaning that there was little agreement between count and lean cuts expressed as pounds or as percent.

TABLE XIV

CORRELATION COEFFICIENTS BETWEEN LIVE K^{40} COUNTS PER MINUTE AND MEASURES OF LEANNESS

		Slaughter Weight Groups (pounds)[1]									
Measures of Leanness	K^{40} Counts	100 Lb.	100 %[a]	150 Lb.	150 %	200 Lb.	200 %	250 Lb.	250 %	300 Lb.	300 %
Lean Cuts	First	-0.37	-0.08	0.47	0.43	0.38	0.35	0.91*	0.83*	0.48	0.52
	Second	0.07	0.41	0.25	0.18	0.52	0.49	0.78*	0.81*	0.72*	0.71*
	Average	-0.20	0.16	0.39	0.33	0.48	0.45	0.88*	0.86*	0.61	0.63
Fat-Free Lean	First	-0.04	0.24	0.07	0.05	0.62*	0.58	0.92*	0.84*	0.82*	0.71*
	Second	0.00	0.26	-0.14	-0.18	0.56	0.52	0.72*	0.74*	0.83*	0.79*
	Average	-0.05	0.24	-0.04	-0.07	0.62*	0.58	0.85*	0.83*	0.84*	0.82*

[1]Eleven animals in all weight groups except 300 pound (with 9)

[a]Percent of slaughter weight (36 hour shrink)

*r=0.60 significant (P<.05) through 250 pounds and r=0.67 (P<.05) for 300 pounds

Basically, the same trends were observed for the 150 pound weight group where the ranges of correlations between count and lean cuts and count and fat-free lean were 0.18 and 0.47 and -0.18 to 0.07, respectively. The negative correlations obtained in the 100 and 150 pound weight groups showed an inverse relationship; as count went up, lean cuts and fat-free lean went down. Thus, in this case the method proved to be unreliable.

The correlations obtained between count and measures of leanness for the 200 pound weight group were higher than in the case of the lighter weight groups discussed above. The correlations between count and lean cuts and count and fat-free lean ranged from 0.35 to 0.52 and 0.52 to 0.62, respectively. Although there were some significant correlations in this group, there still was a rather low agreement between count and lean cuts or count and fat-free lean for this weight group. The correlation coefficients between live K^{40} count and lean cuts were lower than those reported by Mullins _et_ _al_. (1969). They reported correlation coefficients between percent lean cuts and grams and percent potassium determined by K^{40} of 0.64 and 0.60, respectively.

The correlations for the 250 pound weight group were substantially higher than those for the three lighter weight groups discussed above. These correlations were all significant ($P<.05$). The range in correlations for this group was 0.78 to 0.91 between count and lean cuts and 0.72

to 0.92 between count and fat-free lean. These relationships indicate that the live K^{40} counts per minute were highly associated with pounds and percent lean cuts as well as pounds and percent fat-free lean. In this case the counter proved to be more reliable as a predictor of leanness. Similarly, live K^{40} counts per minute were found to be significantly associated with pounds and percent fat-free lean in the 300 pound weight group with a range of 0.71 to 0.84 significant ($P<.05$), also indicating some agreement between counts and measures of leanness. Correlations obtained between count and lean cuts were not as high for this group, as those for count and fat-free lean with only two (0.72 and 0.71) being significant ($P<.05$).

There was a trend toward higher correlations between K^{40} count and both pounds and percent fat-free lean with an increase in slaughter weight. When K^{40} count and pounds or percent lean cuts were correlated, a similar trend was noticed through the 250 pound weight group. Correlations between count and lean cuts for the 300 pound weight group, however, were lower than in the 250 pound group.

Table XV presents the correlation coefficients between live K^{40} counts per minute and grams of potassium and pounds of protein in the separable lean. These data indicate the same general trend as was observed when count was correlated with lean cuts and fat-free lean. Lower correlations were obtained in the lighter weights and higher correlations in the heavier weights. The correlations for the 100 pound

TABLE XV

CORRELATION COEFFICIENTS BETWEEN LIVE K^{40} COUNTS PER MINUTE AND GRAMS OF POTASSIUM AND POUNDS OF PROTEIN IN THE SEPARABLE LEAN

Measures of Leanness	K^{40} Counts, Live	Slaughter Weight Groups (pounds)[1] 100 r	150 r	200 r	250 r	300 r
	First	-0.26	0.39	0.64*	0.72*	0.85*
Potassium, gm.	Second	-0.24	0.24	0.58	0.61*	0.85*
	Average	-0.29	0.42	0.66*	0.76*	0.90*
	First	0.13	0.33	0.74*	0.89*	0.87*
Protein, lb.	Second	0.08	-0.01	0.61*	0.75*	0.96*
	Average	0.09	0.17	0.71*	0.85*	0.93*

[1]Eleven animals in all weight groups except 300 pound (with 9)

*r=0.60 significant (P<.05) through 250 pounds and r=0.67 (P<.05) for 300 pounds

weight group ranged from -0.24 to -0.29 and 0.08 to 0.13 between live K^{40} count and grams of potassium and pounds of protein, respectively. The negative correlations obtained in the 100 pound weight group showed an inverse relationship; as count went up grams of potassium went down. Thus, in this case the method proved to be unreliable. These values increased as live weight increased up to the 300 pound weight group where the coefficients ranged from 0.85 to 0.90 and 0.87 to 0.96, respectively. The ranges in correlation coefficients for the 200 pound weight group between live K^{40} count and grams of potassium (r=0.58 to 0.66) and protein (r=0.61 to 0.74) were in close agreement with those reported by Mullins _et al_. (1969). They reported correlations between percent potassium determined by live K^{40} measurements and percent potassium determined by flame photometry of 0.64, and percent potassium (K^{40}) with percent protein of 0.59. The rather high correlations observed in the heavier weights between count and pounds of potassium indicate that the Permian K^{40} Counter was doing a better job of measuring the actual gamma-ray emissions from the animals at these weights.

Permian K^{40} Counter — Carcass Studies

Table XVI presents the correlation coefficients between the first and second carcass K^{40} counts for the respective weight groups. As with the live animal, the counting period was for 10 minutes. Correlations between count-

TABLE XVI

CORRELATION COEFFICIENTS BETWEEN FIRST AND SECOND CARCASS K^{40} COUNTS PER MINUTE[1]

Slaughter Weight Group (pounds)	Carcass Weight (lb.)	Number of Carcasses	Correlation Coefficients
100	70	11	0.91*
150	108	11	0.88*
200	146	11	0.92*
250	187	11	0.89*
300	223	9	0.96*

*(P<.05)

[1]10-minute counting period

ings in all weight groups were found to be significant (P<.05) and ranged from 0.88 to 0.96. These results indicate that the two carcass K^{40} counts made on the same day were in good agreement. Correlations between the two counts are expected to be higher for the carcasses than for the live animals because the carcasses were held firmly in place and at a fixed distance from the detectors also, the counts were not influenced by offal such as hair, gastro-intestinal tract and contents.

The data presented in Table XVII indicates the same general trend in K^{40} counts in relation to measures of leanness as was found for the live animals namely lower corre-

TABLE XVII

CORRELATION COEFFICIENTS BETWEEN CARCASS K^{40} COUNTS PER MINUTE AND MEASURES OF LEANNESS

Measures of Leanness	K^{40} Counts, Carcass	Slaughter Weight Groups (pounds)[1] 100 r	150 r	200 r	250 r	300 r
Lean cuts, lb.	First	0.25	0.74*	0.26	0.60*	0.73*
	Second	0.19	0.50	0.31	0.70*	0.81*
	Average	0.22	0.60*	0.29	0.66*	0.78*
Fat-free lean, lb.	First	0.14	0.40	0.69*	0.60*	0.80*
	Second	0.17	0.24	0.74*	0.72*	0.85*
	Average	0.16	0.33	0.73*	0.67*	0.83*

[1]Eleven animals in all weight groups except 300 pound (with 9)

*r=0.60 significant (P<.05) through 250 pounds and r=0.67 (P<.05) for 300 pounds

tions in the lighter weights and higher correlations in the heavier weights. The correlations for the 100 pound weight group ranged from 0.14 to 0.25 between carcass K^{40} counts and pounds of lean cuts and fat-free lean. These correlations were low and nonsignificant. Four of the six correlations between carcass K^{40} count and pounds of lean cuts or fat-free lean for the 150 pound weight group were also nonsignificant. In the 200 pound weight group, correlations between carcass K^{40} count and pounds of fat-free lean were all statistically significant ($P<.05$) with a range of 0.69 to 0.74. When count was correlated with pounds of lean cuts at this weight, none of the three were significant ($r=0.26$, 0.31 and 0.29). The correlations between carcass K^{40} count and pounds of lean cuts in the 200 pound weight group were lower than the correlation of 0.62 reported by Mullins et al. (1969) between grams of potassium determined by K^{40} counts of the carcass and percent lean cuts.

In the 250 pound weight group, all correlations were significant ($P<.05$). The range in correlations for this group was from 0.60 to 0.72. There was a substantial increase in the correlations for the 300 pound group over the others previously discussed. The correlations between count and lean cuts and count and fat-free lean ranged from 0.73 to 0.85 and were all significant ($P<.05$). This suggests that there was reasonably good agreement with both K^{40} count and pound of lean cuts as well as with K^{40} count and pounds of fat-free lean.

Table XVIII presents the correlation coefficients between carcass K^{40} counts per minute and grams of potassium and pounds of protein in the separable lean. These data indicate the same general trend as was noticed when live K^{40} count was correlated with grams of potassium and pounds of protein in that lower correlations were obtained in the lighter weights and higher correlations in the heavier weights. The range in correlations for the 100 pound weight group was from 0.12 to 0.15 and 0.24 to 0.27 between carcass K^{40} counts and grams of potassium and pounds of protein, respectively. These values increased as live weight increased up to the 300 pound weight group where the coefficients varied from 0.73 to 0.76 and 0.86 to 0.93, respectively. The ranges in correlations for the 200 pound weight group between carcass K^{40} count and potassium (r=0.67 to 0.79) and count and protein (r=0.61 to 0.70) were in close agreement with those reported by Mullins _et al_. (1969). They reported correlations between percent potassium determined by K^{40} and percent potassium determined by flame photometry (r=0.77) and with grams of protein (r=0.82). From these results it appears that the K^{40} counter was doing a more precise job of measuring the actual gamma-rays emitted from the carcass in the heavier weights than in the lighter weights.

These results for the carcass study of K^{40} measurements indicate that the rather high repeatabilities observed between first and second K^{40} counts in the lighter

TABLE XVIII

CORRELATION COEFFICIENTS BETWEEN CARCASS K^{40} COUNTS PER MINUTE AND GRAMS OF POTASSIUM AND POUNDS OF PROTEIN IN THE SEPARABLE LEAN

Measures of Leanness	K^{40} Counts, Carcass	Slaughter Weight Groups (pounds)[1] 100 r	150 r	200 r	250 r	300 r
	First	0.15	0.68*	0.67*	0.75*	0.76*
Potassium, gm.	Second	0.12	0.51	0.72*	0.77*	0.73*
	Average	0.15	0.64*	0.79*	0.78*	0.75*
	First	0.27	0.55	0.61*	0.60*	0.86*
Protein, lb.	Second	0.24	0.40	0.70*	0.70*	0.93*
	Average	0.26	0.50	0.67*	0.67*	0.90*

[1]Eleven animals in all weight groups except 300 pound (with 9)

*r=0.60 significant (P<.05) through 250 pounds and r=0.67 (P<.05) for 300 pounds

weight carcasses, as compared to the low correlations between carcass K^{40} counts and measures of leanness at these same weights, illustrate that a measurement can be highly repeatable and have a low predictability of another variable.

Permian K^{40} Counter — Discussion

The trend observed, in the potassium^{40} study, was that correlation coefficients between K^{40} counts per minute and measures of leanness generally increased as slaughter weight increased. This trend was observed in both the live animal and carcass studies. It was also observed that correlations between K^{40} counts (live and carcass) and grams of potassium followed the same general trend as when K^{40} counts were correlated with lean cuts and fat-free lean; namely, higher correlations in the heavier weights and lower correlations in the lighter weights. Since potassium was rather highly correlated with fat-free lean for all of the five weight groups (Table XXI), this would indicate that the K^{40} counter was doing a better job of measuring the actual gamma-rays emitted from the animals in the heavier weights than in the lighter weights.

The low correlations observed between K^{40} counts and measures of leanness in the lighter weights may be due to the positioning of the animals or carcasses in the counter and to the ratio of sample to detector volume. The Permian K^{40} Counter was designed for larger animals (1,000 pounds). These lighter weight pigs or carcasses occupied only a small portion of the space inside the detector system, therefore, allowing a smaller chance for the gamma-rays emitted from the animals or carcasses to reach the detectors. As the animals increased in live weight they were occupying more of the space inside the detector system. Therefore, the gamma rays emitted by the animal or carcasses had a better chance of reaching the detectors and being counted. Also, the lighter weight hogs having less total lean and less total potassium, therefore, yielding fewer total counts, made up a smaller percent of the total count (background + sample) than did the larger hogs.

It should also be pointed out that these measurements were obtained over a rather long period of time, approximately one year, therefore the efficiency of the counter could have changed somewhat during this period. It was also noticed that in a few cases extreme differences occurred between the first and second counts obtained on the same animal the same day. This is not likely to be caused by some inherent factor in the animal and would suggest that the instrument was not operating properly at all times.

In general, the data obtained from the K^{40} measurements during the course of this study suggest that the Permian K^{40} Counter could be used as a predictor of leanness in 250 and 300 pound hogs and carcasses from hogs slaughtered at these weights. However, there is some question as to its predictability in lighter weight hogs and carcasses, and to its usefulness as a tool to monitor growth at these lighter weights. In an attempt to increase the association between K^{40} counts and measures of leanness for light weight animals further studies could involve methods of reducing the background counts and bringing the detector system closer to the sample. This would increase the chance for the gamma-rays emitted from the animal to reach the detector and be counted if such is the problem.

Ultrasound and Ruler Probe

The repeatability of the ultrasound technique has been studied by other workers, Stouffer et al. (1961) and Johnson et al. (1968), and was found to be rather repeatable. Repeatability studies were not included in this experiment, but studies to determine the degree of association between ultrasound estimates and measures of leanness for five different weights of pigs during the growing and finishing period were conducted.

Table XIX presents the correlation coefficients between some live estimates (obtained from ultrasound and ruler probe) and some carcass measurements for the respective weight groups. Correlation coefficients between ultrasound backfat estimates and carcass backfat thickness ranged from -0.09 in the 100 pound weight group to 0.93 in the 200 pound weight group. Correlations for 150, 250 and 300 pound weight groups were 0.54, 0.85 and 0.61, respectively.

The correlation coefficient between ultrasound backfat thickness and carcass backfat thickness ($r=0.93$) for

TABLE XIX

CORRELATION COEFFICIENTS BETWEEN SOME LIVE ESTIMATES AND SOME CARCASS MEASUREMENTS

Carcass Measurements	Live Estimate	Slaughter Weight Groups (pounds)[1] 100	150	200	250	300
Backfat thickness	Ultrasound backfat	-0.09	0.54	0.93*	0.85*	0.61
	loin eye area	-0.49	-0.70*	-0.52	-0.17	-0.57
	Ruler Probe backfat	0.69*	0.50*	0.75*	0.85*	0.79*
Loin eye area	Ultrasound backfat	0.29	-0.47	-0.58	-0.42	-0.34
	loin eye area	0.83*	0.81*	0.74*	0.76*	0.83*
	Ruler Probe backfat	-0.36	-0.12	-0.59	-0.24	-0.42

[1]Eleven animals in all weight groups except 300 pound (with 9)

*r=0.60 significant (P<.05) through 250 pounds and r=0.67 (P<.05) for 300 pounds

the 200 pound weight group was in close agreement with results reported by Price et al. (1958, 1960a), Stouffer et al. (1961) and Johnson et al. (1968). These data indicate that ultrasound backfat estimates are in reasonably close agreement with carcass backfat thickness at 200 and 250 pounds, but were rather inaccurate in predicting carcacass backfat thickness in the 100 pound weight group.

The magnitude of the correlation coefficients between ruler probe backfat estimates and carcass backfat thickness was found to be rather uniform for all weight groups. The lowest coefficient between these two variables was found in the 150 pound group (r=0.50) which was nonsignificant. Correlation coefficients for the other weight groups were 0.69, 0.75, 0.85 and 0.79 for pigs in the 100, 200, 250 and 300 pound groups, respectively. These four correlations were significant (P<.05) and indicate a rather close agreement between ruler probe backfat and carcass backfat thickness. The correlation coefficients between ruler probe, backfat estimates and carcass backfat thickness (r=0.75) for the 200 pound weight group were in close agreement with the correlations of 0.72 and0.70 reported by Hetzer et al. (1965) and Pearson et al. (1957), respectively.

In general, when all weights were considered, these data suggest that ruler probe backfat estimates were in closer agreement with carcass backfat thicknesss than were ultrasound backfat estimates. This also indicates that ruler probe backfat estimates may be more useful in monitoring backfat thickness than ultrasound backfat estimates.

A positive relationship (r=0.29) was found between ultrasound backfat estimates and carcass loin eye area in the 100 pound weight group. Negative correlations ranged from -0.47 in the 150 pound weight group to -0.58 for the 200 pound weight group and were all nonsignificant. Nonsignificant correlations were also observed between ruler probe backfat and carcass loin eye area indicating that the two estimates of backfat thickness had rather low associations with carcass loin eye area in the five weight groups of pigs considered.

Correlation coefficients between loin eye area estimated with ultrasound and carcass loin eye area were rather uniform for the five weight groups. Correlations for pigs in the 100, 150, 200, 250 and 300 pound groups were 0.83, 0.81, 0.74, 0.76 and 0.83, respectively. The correlation coefficient between ultrasound loin eye area and carcass loin eye area for the 200 pound weight group (r=0.74) was quite comparable to those reported by Zobrisky _et al_. (1960) (r=0.81, 0.84) and those reported by Johnson _et al_. (1968) (r=0.77, 0.79). These data suggest that ultrasound loin eye area estimates could possibly predict carcass loin eye area at one of the five weights about as precise as it can at another, and could possibly be used to monitor the growth of loin eye area during the growing and finishing period. The correlation coefficients between ultrasound loin eye area and carcass backfat thickness for the respective weight groups were all nonsignificant with the exception of the one -0.70 obtained for the 150 pound weight group.

Table XX presents the correlation coefficients between live estimates (ultrasound and ruler probe) and measures of leanness (lean cuts and fat-free lean). The measures of leanness are expressed as pounds and percent of slaughter weight. Positive correlations were observed between ultrasound estimates of backfat and lean cuts in the 100 pound weight group while negative correlations were found for the other weight groups. The correlation coefficients between this estimate of backfat and lean cuts expressed as pounds or percent were found to be nonsignificant with the exception of those for the 150 pound weight group (-0.82 and -0.75) which were significant ($P<.05$). The correlation coefficients between ultrasound backfat estimates and lean cuts expressed as pounds and as percent were -0.44 and -0.53, respectively, for the 200 pound weight group. These correlations are lower than those reported by Johnson et al. (1968).

Similar trends were also observed when ultrasound backfat estimates were correlated with pounds or percent fat-free lean for the five weight groups of pigs. These correlations were also nonsignificant with the exception of those for the 200 pound weight group (-0.77 and -0.80) which were significant ($P<.05$).

When ruler probe backfat was correlated with lean cuts and with fat-free lean the coefficients were, generally, low

TABLE XX

CORRELATION COEFFICIENTS BETWEEN SOME LIVE ESTIMATES AND MEASURES OF LEANNESS

Measures of Leanness		Slaughter Weight Groups (pounds)[1]									
		100		150		200		250		300	
		Lb.	%[a]	Lb.	%	Lb.	%	Lb.	%	Lb.	%
Lean cuts	Ultrasound backfat	0.51	0.22	-0.82*	-0.75*	-0.44	-0.53	-0.44	-0.57	-0.09	-0.21
	loin eye area	0.83*	0.77*	0.66*	0.74*	0.74*	0.65*	0.50	0.60*	0.43	0.52
	Ruler probe backfat	-0.57	-0.53	-0.49	-0.58	-0.77*	-0.78*	-0.39	-0.46	-0.34	-0.42
Fat-free lean	Ultrasound backfat	0.28	0.07	-0.51	-0.46	-0.77*	-0.80*	-0.29	-0.42	-0.27	-0.33
	loin eye area	0.81*	0.77*	0.66*	0.69*	0.74*	0.65*	0.41	0.50	0.72*	0.74*
	Ruler probe backfat	-0.36	-0.27	-0.01	-0.04	-0.74*	-0.71*	-0.35	-0.42	-0.53	-0.55

[1]Eleven animals in all weight groups except 300 pound (with 9)

*r=0.60 significant (P<.05) through 250 pounds and r=0.67 (P<.05) for 300 pounds

and nonsignificant with the exception of those in the 200 pound weight group which were significant (P<.05).

These data indicate that, in general, variation in backfat thickness estimated with ultrasound or ruler probe did not account for a significant portion of the variation in lean cuts or fat-free lean, expressed as pounds or percent, for the respective weight groups. This indicates that backfat estimates would not be a precise tool to monitor growth as determined by these two measures of leanness.

A substantial increase in correlation coefficients was observed when ultrasound loin eye area estimates were correlated to lean cuts and fat-free lean expressed as pounds or percent. These correlations are also presented in Table XX. Ultrasound loin eye area estimates were found to be significantly (P<.05) associated with lean cuts expressed as pounds and percent through the 200 pound weight group; however, in the 250 and 300 pound weight groups only one was significant. The ranges in correlation coefficients were (0.83 and 0.77), (0.66 and 0.74), (0.74 and 0.65), (0.50 and 0.60), (0.43 and 0.52), for pigs in the 100, 150, 200, 250 and 300 pound weight groups, respectively. The correlation coefficients between ultrasound loin eye area estimates and lean cuts (0.74 and 0.65) for the 200 pound weight group were higher than those reported by Johnson et al. (1968). When this estimate of loin eye area was correlated with pounds or percent fat-free lean, the coefficients were significant (P<.05) for each weight group with the exception of those for the 250 pound group. The correlations for the respective weight groups were (0.81 and 0.77), (0.66 and 0.69), (0.74 and 0.65), (0.41 and 0.50), (0.72 and 0.74), for pigs in the 100, 150, 200, 250 and 300 pound weight groups, respectively.

These results indicate that ultrasound loin eye area estimates were in rather close agreement with lean cuts and fat-free lean expressed as pounds or percent through the 200 pound weight group; however, they were in low agreement with these measures of leanness in the 250 pound weight group. This also indicates that ultrasound loin eye area estimates could possibly be used as a tool to monitor the growth of lean cuts or fat-free lean from 100 to 200 pounds.

Ultrasound and Ruler Probe — Discussion

The low and nonsignificant correlations observed between ultrasound backfat estimates and measures of leanness and fatness in the 100 pound weight group could possibly be due to the failure of the operator to read the instrument properly. The scale on the oscilloscope of the instrument used is one-half as large as the actual measurement. Therefore, the operator noticed that, because of the very small amount of backfat on these light weight pigs, it was very difficult to obtain the proper measurement or select the proper echo from the oscilloscope of the instrument. This did not appear to be as much of a problem when backfat thickness increased in the heavier weights. There is also a thin layer of soft connective tissue (false lean) in the fat over the shoulder, and care had to be taken in order not to record this reading for the actual fat thickness. This problem was more apparent in the heavier weights, especially in the 300 pound hogs, than in the lighter weights.

Pressure from the belts on the restraining crate which held the pigs may have had some influence on the ultrasound estimates of backfat, especially over the shoulder. When this measurement was obtained, care was taken to eliminate as much of the interference as possible.

When ruler probe backfat measurements were obtained, care was taken not to enter the loin muscle with the probe and record this as the actual fat thickness. This appeared to be more of a problem in the lighter weights because of the small amount of backfat. It was very easy to push through the fat into the muscle in these light weight hogs. Also the connective tissue in the fat over the shoulder was found to be more of a problem when probing in the heavier weight hogs than in the lighter weights.

It was also observed by comparing the carcass tracing of loin eye area and the ultrasound plots that the dorsal side of the _longissimus dorsi_ was estimated more accurately than was the ventral side. The problem in estimating the ventral side of the _longissimus dorsi_ may be due to the two muscles, _multifidus dorsi_ and _serratus thoracic digitatious_, which lie adjacent to the _longissimus dorsi_ on the ventral side and are separated from it only by a thin membrane. Therefore, it was difficult to distinguish between the readings on the oscilloscope from the ventral side of the _longissimus dorsi_ and those from the other two muscles.

Upon plotting the points, it was found that the ends of the loin eye area had to be drawn in subjectively which is another source of error. This could cause more error in the heavier weights than in the lighter weights, because of larger loin eyes, and therefore more of the area had to be drawn in subjectively. The operator noticed that correct readings for the dorsal and ventral sides of the loin eye muscle from fatter hogs were more difficult to obtain than those from the trimmer hogs. This could also be a source of error when estimating loin eye area in heavier weight hogs.

Care was also taken to keep the animal straight in the restraining crate, since the mechanism used in determining the angle of the probe for the ultrasound instrument was designed to be most accurate when the animal is properly positioned and not leaning in the crate. The heavier weight hogs (200, 250 and 300 pounds) fit the crate better than the light weight hogs. Therefore, there was less movement when measurements were obtained on the heavier weight hogs. Care had to be taken especially when the 100 pound pigs were measured, in order to keep them properly positioned and not leaning in the crate.

In general these data suggest that both ruler probe and ultrasound backfat estimates were more highly associated with carcass backfat in the heavier weight than in the lighter weight hogs. Generally, these two estimates of backfat thickness were in low agreement with measures of leanness for the five weight groups. This would indicate that these two estimates of backfat would be limited in their usefulness as tools to monitor fatness or leanness in the earlier stages of the growing and finishing period. Ultrasound loin eye area was found to estimate carcass loin eye area at one weight about as precise as at another weight. This would indicate that ultrasound loin eye area estimates could possibly be used as a tool to monitor the growth of loin eye area from 100 to 300 pound hogs.

Carcass Measurements

Since there is limited data in the literature concerning the relationships between various carcass measurements and fat-free lean, the correlations presented in Table XXI were determined. This table presents the correlation coefficients between various carcass measurements and fat-free lean expressed as pounds and percent for the five weight groups of pigs during the growing and finishing period. Pounds of lean cuts were found to be significantly related ($P<.05$) to fat-free lean through the 250 pound weight group, but nonsignificant correlations were observed for the 300 pound weight group. These coefficients between pounds of lean cuts and pounds or percent fat-free lean

TABLE XXI

CORRELATION COEFFICIENTS BETWEEN VARIOUS CARCASS MEASUREMENTS AND FAT-FREE LEAN EXPRESSED AS POUNDS AND PERCENT

Carcass	Slaughter Weight Groups (pounds)									
	100		150		200		250		300	
Measurements	Lb.[a]	%[b]	Lb.	%	Lb.	%	Lb.	%	Lb.	%
Lean cuts, lb.	0.85*	0.70*	0.62*	0.59	0.75*	0.69*	0.70*	0.88*	0.64	0.54
% Slaughter wt.										
Ham	0.26	0.48	0.63*	0.67*	0.71*	0.70*	0.65*	0.82*	0.73*	0.67*
Ham & loin	0.53	0.66*	0.19	0.24	0.68*	0.66*	0.86*	0.87*	0.72*	0.69*
Lean cuts	0.65*	0.73*	0.61*	0.62*	0.78*	0.78*	0.80*	0.91*	0.68*	0.60
Ham-loin index	0.62*	0.61*	0.72*	0.75*	0.82*	0.81*	0.67*	0.77*	0.77*	0.73*
Loin eye area, sq. in.	0.88*	0.86*	0.69*	0.68*	0.77*	0.77*	0.55	0.58	0.79*	0.79*
Backfat, in.	-0.56	-0.56	-0.50	-0.51	-0.80*	-0.85*	-0.35	-0.42	-0.26	-0.27
Potassium, gm.	0.84*	0.68*	0.73*	0.70*	0.92*	0.93*	0.90*	0.92*	0.75*	0.71*
Protein, lb.	0.94*	0.92*	0.92*	0.88*	0.97*	0.95*	0.93*	0.94*	0.94*	0.90*

[1]Eleven animals in all weight groups except 300 pound (with 9)

[a]Fat-free lean, lbs.

[b]Fat-free lean, percent slaughter weight (36 hour shrink)

*r=0.60 significant (P<.05) through 250 pounds and r=0.67 (P<.05) for 300 pounds

were (0.85 and 0.70), (0.62 and 0.59), (0.75 and 0.69), (0.70 and 0.88), (0.64 and 0.54), respectively for pigs in the 100, 150, 200, 250 and 300 pound weight groups. When lean cuts were expressed as a percentage of slaughter weight and correlated with fat-free lean, similar trends were also observed. It was observed that pounds of lean cuts generally over estimated pounds of fat-free lean. This is probably due to the amount of internal fat, especially in the shoulder, and the amount of bone present in the wholesale cuts.

Percent ham and percent ham and loin of slaughter weight appeared to be more highly associated with pounds or percent fat-free lean in the heavier weights than in the lighter weights. Correlation coefficients between carcass backfat thickness were found to be low and nonsignificant for all weight groups with the exception of those for the 200 pound weight group (-0.80 and -0.85), which were significant ($P<.05$).

Ham-loin index was found to be rather closely associated with fat-free lean for all weight groups. The correlation coefficients between ham-loin index and pound or percent fat-free lean were (0.62 and 0.61), (0.72 and 0.75), (0.82 and 0.81), (0.67 and 0.77), (0.77 and 0.73), respectively for pigs in the 100, 150, 200, 250 and 300 pound weight groups, which were all significant ($P<.05$). These results indicate a rather close agreement between ham-loin index and fat-free lean. A similar trend was also observed when carcass loin eye area was correlated with pounds and percent fat-free lean. In this case the coefficients were rather uniform for the respective weight groups; (0.88 and 0.86), (0.69 and 0.68), (0.77 and 0.77), (0.55 and 0.58), (0.79 and 0.79), respectively for pigs in the 100, 150, 200 250 and 300 pound weight groups. These results indicate a rather close agreement between carcass loin eye area and fat-free lean expressed as pounds or as a percentage of slaughter weight. This also indicates that loin eye area could possibly predict fat-free lean at one of the five weights about as precise as it can at another.

Grams of potassium and pounds of protein of the separable lean appeared to be more highly associated with fat-free lean for the respective weight groups than the other carcass measurements considered. In this case the correlation coefficients ranged from 0.68 to 0.92 and 0.88 to 0.97, respectively. However, other measurements, such as ham-loin index and carcass loin eye area, accounted for about as much of the variation in fat-free lean for each of the five weight groups as did potassium and protein and are much more readily obtained and at less expense.

Table XXII presents the correlation coefficients between various carcass measurements and lean cuts expressed as pounds or as a percentage of slaughter weight. In general, when all weights were considered, the carcass measurements studied were in reasonably good agreement with lean cuts expressed as pounds or as a percentage of slaugh-

TABLE XXII

CORRELATION COEFFICIENTS BETWEEN VARIOUS CARCASS MEASUREMENTS AND LEAN CUTS EXPRESSED AS POUNDS OR PERCENT

	Slaughter Weight Groups (pounds)									
Carcass	100		150		200		250		300	
Measurements	Lb.[a]	%[b]	Lb.	%	Lb.	%	Lb.	%	Lb.	%
% Slaughter wt.										
Ham	0.61*	0.66*	0.78*	0.85*	0.77*	0.79*	0.72*	0.85*	0.81*	0.83*
Ham & loin	0.62*	0.83*	0.53	0.78*	0.95*	0.96*	0.93*	0.95*	0.75*	0.81*
Ham-loin index	0.71*	0.72*	0.84*	0.90*	0.77*	0.81*	0.77*	0.87*	0.76*	0.79*
Loin eye area, sq. in.	0.84*	0.78*	0.68*	0.68*	0.53	0.57	0.68*	0.69*	0.48	0.53
Backfat, in.	-0.40	-0.38	-0.79*	-0.55	-0.55	-0.44	-0.43	-0.51	-0.20	-0.23
Potassium, gm.	0.68*	0.63*	0.87*	0.86*	0.62*	0.69*	0.85*	0.86*	0.65	0.67*
Protein, lb.	0.78*	0.68*	0.82*	0.78*	0.75*	0.78*	0.89*	0.88*	0.73*	0.74*

[1]Eleven animals in all weight groups except 300 pound (with 9)

[a]Lean cuts, lbs.

[b]Lean cuts, percent slaughter weight (36 hour shrink)

*r=0.60 significant (P<.05) through 250 pounds and 0.67 (P<.05) for 300 pounds ter weight. These correlations were generally significant ($P < .05$) for each of the five weight groups with the exception of carcass backfat thickness which was usually low and nonsignificant. In general, these carcass measurements were associated with about 50 to 70% of the variation in lean cuts.

CHAPTER V

SUMMARY

Sixty Yorkshire barrows representing five weight groups (100, 150, 200, 250 and 300 pounds) were evaluated using three different techniques; potassium^{40}, ultrasound and ruler probe. The purpose was to observe any trends which develop in the association between the live estimates, and carcass measurements obtained during this period of the pig's life cycle. Each pig was taken off feed and "evaluated" at each weight, irrespective of final slaughter weight and was placed back on feed until it reached the predetermined slaughter weight. The pigs were slaughtered at this weight immediately following live evaluation.

Growth patterns of body composition were studied from live and carcass measurements. Potassium^{40} counts per minute for the live animal and for the carcass increased as slaughter weight increased. However, the rate of increase declined in the heavier weights. Estimates of loin eye area and backfat thickness increased as slaughter weight increased, with estimates of loin eye area increasing more rapidly in the lighter weights, and backfat thickness increasing more rapidly in the heavier weights. Similar trends were also observed for carcass loin eye area and

backfat thickness. Average total pounds of lean cuts, ham and ham and loin increased as slaughter weight increased. However, these measures decreased as slaughter weight increased, when expressed as a percentage of slaughter or carcass weight. Similarly, the mean ham-loin index increased as slaughter weight increased.

The average total pounds of fat-free lean ranged from 40.6 to 109.0 while the mean pounds of fat and bone ranged from 19.77 to 96.2 and 8.85 to 20.7, respectively. The data indicated that about 57.8% of a 70 pound meat-type carcass was fat-free lean, while a 223 pound carcass contained about 48.8%. The stage of most rapid muscular development (20.2 pounds increase) was found to be from 100 to 150 pounds and the least (12.1 pounds increase) was from 250 to 300 pounds. The reverse was observed for fat deposition with 23.54 pounds of fat being deposited from 250 to 300 pounds while only 15.09 pounds were deposited from 100 to 150 pounds.

Correlation coefficients between first and second K^{40} counts were determined on the live animals and the carcasses to determine how well K^{40} counts taken at different times agree. Correlation coefficients between first and second (10-minute) live K^{40} counts for the weight groups; 100, 150, 200, 250 and 300 pounds were found to be 0.72, 0.61, 0.77, 0.76, 0.94, respectively. Correlations between first and second carcass K^{40} counts were found to be higher than those for the live animal. In this case the coefficients for the respective weight groups were 0.91, 0.88, 0.92, 0.89, 0.96, respectively.

Correlations between K^{40} counts on live hogs, and pounds of fat-free lean and percent fat-free lean increased as live weight increased. Similar trends held true for correlations between K^{40} counts on live hogs and lean cuts through the 250 pound weight group. Correlations between carcass K^{40} counts and lean cuts or fat-free lean followed basically the same trend as for the live animal; namely, higher correlations in the heavier weights and lower correlations in the lighter weights. Correlations between potassium^{40} measurements (live and carcass) and grams of potassium and pounds of protein also increased as live weight increased. In general, the results of this study suggest that the Permian K^{40} Counter could be used as a predictor of leanness in 250 and 300 pound hogs, and carcass from hogs slaughtered at these weights. However, there is some question as to its predictability in lighter weights.

Both ruler probe backfat and ultrasound backfat estimates were found to be more highly associated with carcass backfat thickness in the heavier weights than in the lighter weights. Ruler probe, ultrasound backfat, and carcass backfat thickness were generally in low agreement with measures of leanness for the five weight groups.

Significant ($P<.05$) correlations were found between loin eye area estimated with ultrasound and carcass loin eye area and were rather uniform for the five weight groups. Ultrasound loin eye area estimates were found to be significantly ($P<.05$) associated with lean cuts expressed as pounds and percent through the 200 pound weight group. However, the correlations decreased in the 250 and 300 pound weight groups, and were found to be nonsignificant. When this estimate of loin eye area was correlated with pounds or percent fat-free lean, the coefficients were significant ($P<.05$) for each weight group with the exception of those for the 250 pound group. A similar trend was also observed when carcass loin eye area was correlated to pounds and percent fat-free lean. In general, the carcass measurements studied were in fairly good agreement with lean cuts and fat-free lean expressed as pounds or as a percent of slaughter weight, and on the average was associated with about 50 to 70% of the variation in these two measures of leanness.

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