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Date March 6, 1987

INFLUENCE OF FEEDER PIG BODY TYPE ON PERFORMANCE AND FAT DEPOSITION

A Thesis
Presented for the
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ABSTRACT

Two hundred twenty feeder pigs (80 U.S. No. 1, 80 U.S. No. 2 and 60 U.S. No. 3 feeder pigs) were purchased through a Tennessee graded feeder pig sale. Feeder pigs were then delivered to the University of Tennessee Plateau Experiment Station feeder pig facility where the pigs were subjectively evaluated by trained evaluators on a scale of 1 to 5 for: frame height, frame length, overall frame, propensity to fatten, body width, belly depth and bone. Objective feeder pig traits included: initial weight, length from poll to tail, body girth posterior to front leg as well as ultrasonic measurements of fat depth at the first rib, last rib and last lumbar vertebrae and an estimate of tenth rib longissimus muscle depth. A photographic slide of each pig was taken and the following life scale measurements were obtained from the developed slide: hock length, body depth, height from floor to belly, height of midpoint between shoulder and tail and length from point of shoulder to tail. A scatter plot of poll to tail length versus initial weight was generated to allot similar pigs to three slaughter endpoints of 91, 104 or 118 kg (SG I, SG II and SG III, respectively).

Prediction equations were developed to estimate average daily gain and lean gain per day on feed by the subjective and objective measurements. The variable sex accounted for

a large degree of variation for both average daily gain and lean gain per day on feed. In addition the mean separations tables show that barrows gained faster than gilts ($P<.05$). Body types, either assessed subjectively of objectively, were poor predictors of average daily gain and lean gain per day on feed.

A statistical approach of canonical variate analysis was then used to attempt to transform the subjective and objective variables into a smaller composite variables to predict slaughter grade and percent lean cuts. Pooled slaughter groups were only slightly successful in predicting slaughter grade and percent lean cuts. There was and improvement in the prediction of slaughter grade and percent lean cuts as hogs reached heavier weights and expressed their genetic potential. Only a small percentage of the variation in slaughter grade and percent lean cuts was explained. The predictions were superior to the predicions of carcass merit by feeder pig grades.

Finally, an attempt was made to characterize fat deposition patterns of slaughter hogs. None of the subjective measurements affected the fat deposition pattern ($P>.05$). Objective measures bone deminsion ($p<.04$) and body depth ($P<.09$) both, influenced fat deposition patterns. The relationship of bone and fat deposition was not expected and is difficult to explain.

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CHAPTER I

REVIEW OF LITERATURE

1. FACTORS AFFECTING CARCASS COMPOSITION

SEX

Feeder pig grades are determined by evaluation of the logical slaughter potential of the pig and its thriftiness. Under these standards, the logical slaughter potential is determined by the visual evaluation of both the muscular and skeletal systems. The development of lean and fat as the animal grows has an important effect upon carcass grade. Futhermore, thriftiness is the apparent ability of the animal to rapidly and efficiently gain weight. Thriftiness takes into account size for age and general indicators of health. Because most feeder pigs are sold between the weights of 30 and 120 pounds and sex exerts little influence on carcass composition at these weights, sex is not a factor in determining the feeder pig grade as in the feeder calf industry (USDA, 1970).

Sex affects carcass composition of slaughter hogs. According to Pace (1986) in a study with 220 feeder pigs fed to slaughter weights of 91, 104 or 118 kg, gilts had superior carcass grades as compared to barrows ($P<.05$). Gilt carcass grades were particularly superior at 118 kg with the average carcass grade for barrows and gilts, 3.30

and 1.92, respectively. In addition, gilt carcasses were leaner than barrow carcasses at all fat measurement points, had larger loineye areas (LEA) and were longer ($P<.05$). At 118 kg, the average backfat for the barrow and gilt carcasses was 42.21 and 36.75 mm, respectively. Zobrisky et al. (1958) also reported that male castrates were more highly finished than gilts at each of six slaughter weights (50, 100, 150, 200, 250 and 300 pounds). Buck (1963) found similar results in a study with 250 pigs. Gilts yielded a higher percentage of lean cuts, had larger LEA and less average backfat. Cahill et al. (1960) reported pronounced differences between barrows and gilts beyond 150 lbs. Again, gilts had less backfat, larger LEA, greater yields of lean cuts as well as greater carcass lengths. Martin et al. (1980), in a study of 126 gilts and 132 barrows which were slaughtered at weight intervals between 73 and 137 kg, reported a steady increase in accumulation of lean, fat and bone up to 137 kg. Sex by weight interactions indicated an increasing advantage in gilt carcass leanness as weight increased. They concluded that sex did not affect carcass leanness when slaughtered at or below 126 kg; this is a much higher weight than the 150 pounds where Cahill et al. (1960) found a pronounced difference between barrows and gilts. Richmond et al. (1971) reported that between 23 and 114 kg live weight: carcass, muscle and fat weights per day of age

increased while bone weight per day of age remained relatively constant. However, while carcass and fat weight per day of age increased at increasing rates up to 114 kg liveweight, muscle weight per day of age increased at a declining rate after 91 kg live weight. Thus, fat deposition paralleled muscle growth from 68 to 91 kg live weight after which fat deposition exceeded muscle growth in absolute amount. A study of the literature shows that at a point from 68 to 114 kg gilts begin to show an advantage over barrows in carcass composition. In summarizing test station data, Bruner et al. (1968) and Quijandria et al. (1970) found that barrows were fatter and had smaller LEA even though they grew faster ($P<.05$).

Chemical analysis of pork carcasses also indicate that gilts are leaner than barrows. Pace (1986) reported that the chemical analysis of each primal cut showed gilt carcasses were significantly leaner at all slaughter weights ($P<.05$) than barrow carcasses. At 118 kg, gilt carcasses had approximately 8.4% less chemical fat. Callow (1949) and Davey (1978) also showed that gilts have less carcass fat. Conversly, Fortin (1982) reported no significant difference in carcass composition of 16 Yorkshire barrows and gilts slaughtered between 85 and 112 kg body weight. This weight range, especially at the lighter weights, could explain the difference in results.

There appears to be a greater sex effect on carcass composition at slaughter weights above 68 kg (Pace, 1986; Cahill, 1960 and Martin, 1980).

Weight

Heavier weight hogs have typically been discounted at slaughter markets due to the assumption that as pigs go beyond 104 kg they are excessively fat. For both barrows and gilts, Martin et al. (1980) reported that carcass growth and individual primal cut weights were linear between 73 to 137 kg. Expressed as a percentage of side weight, shoulder and ham decreased, and loin and belly increased as weight of carcass increased. Pace found the relationship among all fat measurements appeared to be linear with an increase in slaughter weight, with the greatest increase in tenth and last rib fat depth measurements occuring between 104 and 118 kg. There also appeared to be a linear increase in muscling score, LEA and USDA carcass grade. However, there was a non-linear ($P<.05$) decrease in the percentage of trimmed four lean cuts, muscle percentage and ham and loin percentage as slaughter weight increased. Hiner et al. (1971) reported the percentage of water, protein and ether extracts were significantly different ($P<.01$) for each of the weight groups (34, 56.7, 79.4, 102.1 and 124.7 kg). Carr et al. (1978) found Hampshires to have a linear relationship of average backfat and slaughter weight but,

Yorkshires exhibited a non-linear response. In addition there was a slight decrease in lean cuts, when expreseed as percent carcass weight, with an increase in weight for each breed. Research by Pace (1986) also noted that with increasing slaughter weights there was a slight decrease in percentage of four lean cuts. Furthermore, Zobrisky et al. (1958) studied various carcass traits of 72 crossbred (Landrace X Poland) pigs slaughtered at 50, 100, 150, 200, 250 or 300 pounds. The fat, lean and bone tissues of the ham, raised to given mathematical powers, are proportional to the fat, lean and bone tissues of the carcass. Relative to live weight; carcass, lean, fat and bone increased exponetially (powers of 0.85, 1.52 and 0.68, respectively) to the increase in ham weight. In a similar study, Allen et al. (1961) determined carcass composition of 56 pigs at slaughter weights ranging from 50 to 200 pounds. Lean tissue increased, but at a decreasing rate, as slaughter weight increased. Fortin (1980) evaluated selected carcass characteristics of 32 Yorkshire pigs slaughtered at 85, 92, 103 and 112 kg. The left sides were divided into shoulder, loin, ham and belly for which untrimmed and trimmed weights were recorded. Fat over the shoulder and the loin increased ($P<.01$) with slaughter weight. The response of fat thickness to the increase in slaughter weight was linear ($P<.01$) at the shoulder, but non-linear at the loin.

Heavier carcasses yielded both heavier trimmed and untrimmed cuts ($P<.01$). Percentages of untrimmed ham, loin and shoulder as well as trimmed ham, loin and shoulder were constant over the four slaughter weights.

Breeds

To a slight degree, carcass composition can be influenced by breed. Carr et al. (1978) in a study with 30 Yorkshire and 70 Hampshire hogs slaughtered at five predetermined weights (45.4, 68.2, 90, 113.6 and 136.4 kg) monitored muscle, fat and bone in heavily muscled pigs. Standard carcass measurements and separation of lean, fat and bone were obtained from the carcass right side. The relationship between average backfat and slaughter weight appeared to be linear for Hampshires while a non-linear response was noted for Yorkshires. The greatest increase in backfat for Yorkshires was between 45.4 and 68.2 kg live weight, whereas for Hampshires the greatest increase in backfat occurred between 68.2 and 90.9 kg. Jones et al. (1980) studied 163 pig carcasses from five breeds and two sex types (barrows and gilts) over a wide range of carcass weights. Significant breed and sex type differences were found in fat deposition when compared on a constant muscle weight basis. There were no significant differences detected for coefficients of variation among breeds using total muscle and total side fat as independent variables. This

would indicate that breed differences in fatness seemed to be influenced more by the initiation of fattening at different muscle weights than by inherent differences in rate of fattening. When the fat depots were examined separately in the fore- and hindquarters, the Duroc x Yorkshire were the fattest breed group and the Hampshire x Yorkshire the least fat. In addition, at a constant slaughter weight, Landrace x Yorkshire-Landrace and Landrace x Yorkshire breed groups generally had more fat in the intermuscular and body cavity depots and less in the subcutaneous depots than the Duroc x Yorkshire breeds. The opposite held true for fat in the forequarter with the latter groups having less fat, although more in the hindquarter.

Nutrition

Most researchers agree carcass composition can be affected by nutrition. The feeding of low energy, high fiber diets to swine has been shown to reduce daily gain, carcass backfat and increase carcass leanness (Bohman et al., 1955). Research conducted by Pearson et al. (1970) suggests that pigs fed lower energy-high fiber diets grew more slowly than pigs fed high energy-normal fiber diets. Daily gains by pigs fed 8.8% fiber diets were approximately 9% lower than pigs fed 3.9% fiber diets. Furthermore, research indicates that higher levels of protein than

normally used will improve growth, feed conversion and carcass leanness (Davey and Bereskin 1978). Higher protein diets generally significantly improve carcass leanness and result in significantly higher cooler shrinkage.

Fat Deposition Patterns

The literature clearly indicates sex, weight, breed and nutrition will affect fat deposition. But, are there predictable patterns in which fat is deposited? If these patterns exist and could be altered, the overall composition of pork carcasses could be affected. Richmond and Berg (1971) used the variables of liveweight, breed group, sex and plane of nutrition to study fat deposition patterns of 92 pigs. Pork sides (half-carcasses) were divided at the 11th and 12th ribs and dissected into individual muscles, fat (intermuscular, subcutaneous and body cavity) and bones. Within each depot type, differential fat deposition between front and hindquarters was most noticeable between 23 and 68 kg liveweight. During this period, more of the intermuscular and body cavity fat was deposited in the front quarter while a greater proportion of the subcutaneous fat was deposited in the hindquarter. Breed, sex and ration did not influence the percentage relationship between depot fat types but did within types. Thus, the fatter carcasses (produced by Duroc x Yorkshire pigs, barrows and high-energy-fed pigs) had a greater proportion of their

intermuscular fat in the hindquarter than did the leaner carcasses (from Hampshire x Yorkshire and Yorkshire and Yorkshire-cross pigs, gilts and pigs fed the low energy ration). In a study with the same pigs, Richmond and Berg (1971) found that as live weight increased from 23 to 114 kg a differential fat deposition pattern occurred. For 23 kg pigs, fat distribution was 78% subcutaneous, 18% intermuscular and 4% body cavity fat. But at 114 kg, 84% was subcutaneous, 13% intermuscular and only 2.3% body cavity fat. In a similiar study, Jones et al. (1980) compared 163 pork carcasses representing five breeds and two sex types over a wide range of carcass weights. Growth coefficients (b values) for intermuscular and subcutaneous fat depots were similiar for the hindquarter but intermuscular fat depot coefficients were slightly higher for the forequarter. The coefficient for body cavity fat was higher than the subcutaneous and intermuscular fat depots for the forequarter and hindquarter. In addition, breed and sex type differences were found in fat depots at a constant weight of muscle for a side. Davies et al. (1977) used carcasses of 15 pigs slaughtered serially from 8 to 62 kg to evaluate the growth rate of the same four fat depots but in relation to total carcass fat. Subcutaneous fat was the predominant fat depot site over the weight range studied. Zobrisky et al. (1958) found a significant positive correlation between the average backfat thickness

and ham subcutaneous fat weight, ham total fat percentage and ham subcutaneous fat thickness. The identical correlations of 0.91 between last lumbar backfat thickness versus total ham fat weight and ham subcutaneous fat weight, strongly suggests that the last lumbar backfat thickness measurement may be employed to estimate the yield of ham fat. Zobrisky et al. (1958) concluded that differences exist in the growth response of body tissues which are probably due in part to breeding and environmental conditions. Increases of lean and bone tissues are more stable than the increase in fatty tissue. In addition, fatty tissues increase more rapidly than the lean tissues during growth and fattening. If the fattening phase occurs when weight of the fat increases faster than the weight of lean and bone, Zobrisky et al. (1958) concluded that hogs fatten from 49.6 to 303.5 pounds liveweight. Cross et al. (1970) studied muscle scores in relation to fat. This study used 43 pork carcasses with weights from 42.3 to 85.9 kg, and average backfat thickness from 2.3 to 5.3 cm. and muscling scores, from very thin to very thick. Correlation coefficients between muscling scores and percentages of carcass fat, lean and bone were -.36 ($P<.05$), .49 ($P<.01$) and -.35 ($P<.05$), respectively. Thus, superior muscling was associated with a tendency towards less carcass fat, but the correlation between muscle score and percentage of lean cuts was low and nonsignificant. In a study involving the fat,

lean and bone separation of 1006 carcasses, by Kempster and Evans (1979) it was found that lean and bone showed the same developmental pattern. Growth relationships were examined using linear allometric model to examine bone, lean and fat at a constant weights. Relative growth was lowest in the proximal limb joints (ham and shoulder), but increasing inwards to the joints of the back. With minor differences a similiar pattern was found for subcutaneous and intermuscular fat. In a similar study, Richmond and Berg (1971) dissected 73 carcasses from pigs of 68, 91 and 114 kg liveweight to study tissue development and carcass composition. A normal pattern of tissue growth was found to occur; that is, bone growth was relatively slow and muscle growth relatively fast. Fat deposition paralleled muscle growth from 68 to 91 kg liveweight after which fat deposition exceeded muscle growth in absolute amounts. Shields and Graham (1983) studied the quantitative and chemical composition changes of swine from 1.5 to 145 kg body weight. Water, protein and fat weights for 81 crossbred swine increased curvilinearly with increase in empty body weight. The rate of fat deposition increased faster during latter growth stages while water and protein had declining deposition rates. Backfat thickness, longissimus muscle area and body length increased as pig weight increased. Pace (1986) also found differences in fat patterns at heavier slaughter weights. In regression

equations for both USDA carcass grade and four lean cuts, fat measures were used in equations for heavier weights while they did not appear in the equations for lighter weight pigs. In addition, slaughter groups at 104 and 118 kg had higher R^2 values for carcass grade and percentage of four lean cuts due to a greater expression of genetic potential. Furthermore, the relationship of all fat measurements to increase as slaughter weight increases, appeared to be linear. The greatest increase in tenth rib and last rib fat depth measurements occurred between 104 and 118 kg, while at the same time there was a non-linear ($P<.05$) decrease in percentage of four lean cuts, percentage ham and loin and percentage of muscle (Pace, 1986).

2. THE AFFECT OF BODY TYPE, SEX AND WEIGHT ON PERFORMANCE

Body Type

In two studies, researchers (Pace, 1986 and Siemens, 1985) attempted to use linear measurements to predict overall carcass composition. Although several measurements have been reported to be useful in predicting carcass composition, only a few researchers have related linear measurements to performance. Hazel and Baker (1943) studied the relationship between growth rate and nine carcass measurements (market grade, length, body depth, ham depth, ham index, flank thickness, shoulder thickness, ham

thickness and backfat thickness) on 152 barrows which had been self fed a standard feed mixture. The correlations between final market weight at 180 days on feed and carcass measurements varied from 0.18 to 0.32 except for flank thickness which was practically zero. Another study using similiar measurements by Lush (1936) noted a low positive range of correlations of .08 to .16 between rate of gain and backfat thickness and belly thickness, while a low negative range of .01 to .12 was found between rate of gain and body length. Crampton (1940) found no significant relationship between rate of gain and carcass length or carcass leanness (.0385, -.1087 respectively). In another study, Heiderreich (1961) also found a low correlation to exist between rate of gain and carcass yields with only one subset (spring, Landrace x Poland x Duroc barrows) being significant out of five groups. Only Crampton and Ashton (1945), in a study with sixty yorkshire pigs, found a significant correlation between rate of gain and LEA ranging from -.66 to -.85 ($P<.05$) of daily gains measured from 110 to 220 pounds.

Sex

It is evident from the literature that sex does play a role in pig performance. Quijandria et al. (1970) compared barrows to gilts in the Ohio swine evaluation station and found barrows grew faster, had higher feed conversion ratios, were fatter and had smaller LEA. Sather et al.

(1980) found the same with barrows having superior growth rates, but inferior fat measurements in comparison to gilts, which also agreed with Crampton et al. (1945) who reported significant differences in rate of gain with male pigs being superior. Pace (1986) also reported that barrows reached their assigned slaughter weight with less days on feed (8.36 days). Although rate of gain is higher for barrows, feed efficiency did not differ signficantly between barrows and gilts as reported by Siers (1975) and Bruner and Swiger (1968).

Weight

Researchers have studied the relationship of slaughter weight and feedlot performance. Cristian et al. (1980) reported pigs slaughtered at 113.5 kg grew faster ($P<.01$), but were less efficient overall than pigs slaughtered at 98.5 kg. In a similar study, Carr et al. (1978) found average daily gains were greatest between 68.2 and 90.9 kg and decreased as pigs reached heavier weights. Allen et al. (1961) studied 56 pigs slaughtered at weights of 50, 100, 150 or 200 lbs to determine carcass composition. Lean meat increased at a decreasing rate as slaughter weight increased. The conversion of feed to the longissimus dorsi muscle was 16.7% protein at 200 pounds live weight, compared with 19.6% conversion up to 150 lbs.

3. LINEAR MEASUREMENTS

Current feeder pig grades are in need of a thorough study because they do not accurately predict the slaughter potential of feeder animals (Brooks, 1984). There appears to be a real need for examination of the grading system for feeder pigs on the basis of their predicted production efficiency and carcass merit. A descriptive and accurate system of grouping feeder pigs according to their slaughter endpoint characteristics would be beneficial to the pork industry. Such a grading system would provide clearer communication between feeder pig producers and slaughter hog producers (Siemens et al., 1985).

Several researchers have looked at live animal and carcass measurements to classify feeder pigs and market hogs. Cross et al. (1970) found correlation coefficients between muscling scores and percentages of carcass fat, lean and bone to be -.36 ($P<.05$), .49 ($P<.01$) and -.35 ($P<.05$), respectively, for hogs ranging in weights from 42.3 to 85.9 kg. Phillips (1940) reported the correlation for live ham plumpness scores to a carcass index for ham plumpness had a positive value of $r=.80$. Zobrisky et al. (1958) in a study of 72 hogs, found ham circumference was significantly correlated with weight of ham lean ($r=.64$, $P<.01$) and fat weight ($r=.89$, $P<.01$), indicating an increase in both lean and fat, with increasing circumference. Futhermore they

found an increase in ham circumference resulted in an increase in ham width, depth and length measurements during the growth interval studied. In addition, backfat thickness and ham fat thickness increased 2.4% and 3.5%, respectively, per percentage increase in ham circumference. After conversion by a logarithmic function, Zobrisky et al. noted that ham length and ham circumference, had an almost perfect relationship. In addition to measurements on the carcass, there have also been studies in which ham circumference was measured on the live hog. Handlin et al. (1960) analyzed data on 68 hogs tested during three years, with 70 days on test measurements being adjusted for weight. They reported that hogs with wider hams had wider loins ($r=.497$, $P<.01$), were wider behind the shoulders($r=.354$, $P<.01$) and hogs with the widest hams and greatest ham measurements produced carcasses with the greatest percent ham ($r=.388$, $P<.01$). In addition, the hogs with the greatest percentage ham had a larger percentage of lean cuts ($r=.818$, $P<.01$). Prince et al. (1981) concluded that ham circumference was the best single predictor of lean ($R^2=.79$) in pigs weighing 25 to 45 kg and that body weight, average backfat, loin depth and body length all significantly ($P<.01$) contributed to an improvement in R^2 value from .79 to .89.

Handlin et al. (1960) reported that as hogs increased in body length there was a significant decrease in body depth, body width and ham width, ($r= -.319$, $-.337$, $-.240$

(P<.01), respectively). Hetzer and Miller (1972) found that in Duroc and Yorkshire hogs length and height are negatively correlated genetically with backfat and width and circumferences are positively correlated with backfat. Bratzler and Magerun (1953) scored 434 market hogs for body length, finish and estimated yield of preferred cuts. The highest correlations reported were between body length and backfat at 181 (-.57) and 200 lbs (-.66) Moderate correlations were reported from 201 to 220 lbs (-.29 to -.42) and very low correlations from 221 to 240 of (-.13 to -.18). Heidenreich (1961) reported scores for body length were negatively correlated (-.26, (P<.01)) with carcass fat in the Landrace x Poland cross. In contrast, Feason and Leroy (1959) found that body length measured on living animals may not be useful in predicting length of the animal because averages of five repeated measurements were unsatisfactory. Jones (1971) found a correlation of only .37 and .63 between carcass length and body length for 225 and 300 pound market hogs, respectively. In addition, Bowland (1964) reported that body length was of limited value in predicting carcass merit.

Depth and capacity have also been studied and correlated with carcass merit. Handlin (1960) reported hogs which had more height had greater depth and produced a higher percentage of lean cuts (.565 and .178, respectively). Hetzer et al. (1950) also studied

measurements of capacity and found that for barrows a regression equation using width of middle, ham width and depth of middle explained 38.7% of the variation in lean meat in the ham; but for gilts, width of middle, ham width and depth of chest explained 47.1% of that variation. Futhermore, for both barrows and gilts, depth of middle was the most important measurement in determining combined yield of ham, loin, bacon, picnic and butt shoulder. Although several measurements are significant for carcass merit, many studies have reported little success in developing a regression equation. Hetzer et al. (1950) found highly significant correlations between the scores for various characteristics in a group of 145 market hogs and the yield of several different cuts from their carcasses. None of the correlations, however, were large enough to be very useful. Reinmiller et al. (1940) studied the carcass yields of 69 Poland China hogs in their relation to the scores and measures for various characteristics. Both scores and measurements were of little value for predicting yields of ham, loin, shoulder and belly. Only live hog score for grade was found to be of practical value for estimating carcass score. Heidenreich et al. (1961) also reported that most live scores were not significant for carcass yields.

4. LIVE ANIMAL EVALUATION TECHNIQUES

Ultrasonic techniques

The use of high frequency sound waves to detect differences in animal tissue density and thus measure depth of particular tissue layers has been used extensively in recent years. Hazel and Kline (1959) used an ultrasonic device to estimate fat thickness on 56 market hogs. After removing differences due to sex and carcass weight, the correlation between ultrasonic fat depth and percentage of lean cuts was -.90. The corresponding correlation with a ruler (probe) measurement of fat depth was -.89. Fortin et al. (1981) compared measurements made by a ruler and an ultrasonic device and generally found that ultrasonic fat measurements resulted in smaller residual standard error values than ruler fat measurements. Sex, slaughter location and warm carcass weight influenced ($P<.01$) the relationship between backfat thickness and yield. Price et al. (1960) also showed that live probe, carcass backfat and ultrasonic measurements of fat were equal in value for predicting lean and primal cut-out.

Ultrasonic devices have been found to be very useful in predicting LEA. Ramsey et al. (1972) reported measurements of muscle depth from ultra tracing of the longissimus muscle in the carcass were highly correlated ($r=.91$) with actual muscle area at the 10th rib. The correlations between

muscle depth and ham and loin percentages (r=.57) and lean cut percentage (r=.59) were compared to the actual LEA and these two cutout measures (r=.59). The method was then tested on 74 pigs with correlations of r=.67 with 10th rib and r=.74 with last rib muscle area. Anderson and Wahlstrom (1969) found ultrasonic measurements of fat and muscle at 5 cm laterally off the midline, at the tenth rib and at a 80° angle and 10 cm off the midline at a 50° angle as well as the top ham fat depth and slaughter weight were practical and relatively simple measurements to obtain for the prediction of kg of lean cuts.

Measurements And Probes

Heidenreich et al. (1961) studied live scores and body measures in comparison to carcass yields on 199 hogs over a two-year period. They found that live hog measurements and backfat probes had a higher relationship to carcass merit than did the subjective scores studied. Lidvall et al. (1972) also compared live hog lengths and carcass lengths and reported a combination of poll-to-tail length, unshrunk live weight, breed effects and sex accounted for 72% of carcass length variation. Phillips and Dawson (1936) looked at three methods of obtaining measurements: a) Direct method b) Scaling instruments and c) Photographic (measurements from life size photo). The direct method was more accurate than the scaling instruments or photographic

method except for measuring the length from ear to tail and length from tail to shoulder by the scaling method.

Other Devices

Domermuth et al. (1976) found that either the EMME or ^{40}K in combination with shrunk body weight are useful in predicting weight of carcass protein (R^2=.78 and .78, respectively in experiment 1) and lean cuts (R^2=.80 and .82, respectively). These relationships were lower in experiment 2 and in field study where shrunk body weight showed less variability indicating the importance of body weight in predicting body composition.

5. SUMMARY OF LITERATURE

Researchers generally agree that sex, weight, breed and nutrition all play a role in affecting fat deposition. Sex appears to have a dramatic effect and becomes apparent at a point from 68 to 114 kg where gilts begin to show an advantage over barrows in carcass leaness. Gilts in general had larger LEA, less average backfat, longer carcasses, greater percentage of lean cuts, and less carcass chemical fat. Weight also plays a large role. All researchers agree that there is a non-linear decrease in percentage of four lean cuts, muscle, and ham and loin although the live weights at which these changes take place varies. Furthermore, chemical fat increases with an increase in

slaughter weights. Breed also seems to play a role, although minor, when compared to sex and weight. These differences vary from study to study with no real established trend in fat deposition. Nutrition can also play a role in fat deposition, with increased crude protein, higher energy and lower fiber resulting in superior carcass leanness.

The literature not only shows factors that affect fat deposition, but that there are some distinct patterns in which fat is deposited. Researchers agree that subcutaneous fat is the predominant fat depot on a percentage basis and some report a difference in forequarter and hindquarter fat deposition with a greater proportion of subcutaneous fat in the hindquarter at lighter weights. Also, most agree fatty tissue increases more rapdily than lean tissue during growth and fattening and fat parallels muscle growth until about 90 kg after which fat exceeds muscle growth in absolute amounts. And finally, fat growth is slowest at anterior and posterior extremeties and increases inwards to the midline of the back.

The researchers also agree that body type, sex and weight influence performance. Body type seems to influence the rate of gain, although usually poorly correlated, and can be used with other variables in predicting performance. Sex and weight, on the other hand, play an important role in performance. Barrows grew faster than gilts, although feed

efficiency did not differ from gilts. In addition, hogs from 70 to 90 kg seemed to have the greatest average daily gains and were more efficient than heavier weight hogs. Linear measurements can be used to improve regression equations to predict carcass merit. Although most linear measurements have a low correlation to carcass merit, the overall affect could be useful to group feeder pigs into more descriptive classifications of feeder pigs.

Ultrasonic devices can be very useful in studying live animal composition. Futhermore, body length seems to be one measurement that could be measured through the use of photographs and then enlarging them to life size to obtain a measurement in the relaxed state.

Chapter II

EFFECTIVENESS OF SUBJECTIVE AND OBJECTIVE FEEDER PIGS MEASUREMENTS OF AVERAGE DAILY GAIN AND LEAN GAIN PER DAY ON FEED

1. SUMMARY

Prediction equations were developed to estimate average daily gain and lean gain per day on feed. The data for this study was obtained from 220 feeder pigs that included 80 U.S. No. 1, 80 U.S. No. 2 and 60 U.S. No. 3 feeder pigs purchased at a Tennessee graded feeder pig sale. Average daily gain (ADG) was calculated using final weight minus initial weight divided by days on feed. Lean gain per day on feed (LG/DOF) was calculated using a regression equation including: adjusted hot carcass weight, muscle score, last rib fat thickness, days on feed, initial weight and a sex adjustment (NPPC, 1983). Subjective evaluations and objective measurements were used in stepwise regression analysis to develop prediction equations with sex being included as an independent variable in each analysis. Only those variables which were significant ($P<.15$) were included in the models. Additionally, models were developed for barrows and gilts as well as slaughter groups SG I, II and III (91kg, 104kg and 118 kg, respectively) with only significant variables ($P<.15$) being reported. Objective evaluations had a slightly higher R^2 value than subjective measurements for average daily gain (.15 vs. .13), but

subjective traits tended to have a higher R^2 value for LG/DOF than did objective traits (.06 versus .03). Objective and subjective traits were poor predictors of ADG and LG/DOF; however, they were superior to feeder pig grades which explained only 3% and 1% of the variation in ADG and LG/DOF, respectively. The independent variable sex accounted for 4% to 7% of the variation in LG/DOF and 11% to 23% of the variation in ADG. Futhermore, barrows gained ($P<.05$) more per day than gilts (.75 vs. .70 kg/day) and having slightly more lean gain per day on feed (.59 vs. .58 kg/day) although not significant ($P>.05$). In addition, equations for SG III (118 kg) explained substantially more of the variation in LG/DOF by objective measures than did equations for SG I and SG II (31% vs. 4% and 6%; respectively). Subjective traits followed the same trend although R^2 values were lower. Thus, as pigs approached heavier weights and greater variation in fat deposition, objective and subjective measures of feeder pig body type explained more of the variation in LG/DOF. The opposite was true for average daily gain in which equations for SG I tended to have higher R^2 than SG II and III. Objective traits of SG I explained 38% of the variation while SG II and III explained only 28 and 17%, respectively. This may be due to the SG I hogs being in the rapid growth phase of the growth curve. This may also explain why prediction equations were more successful by slaughter endpoints than

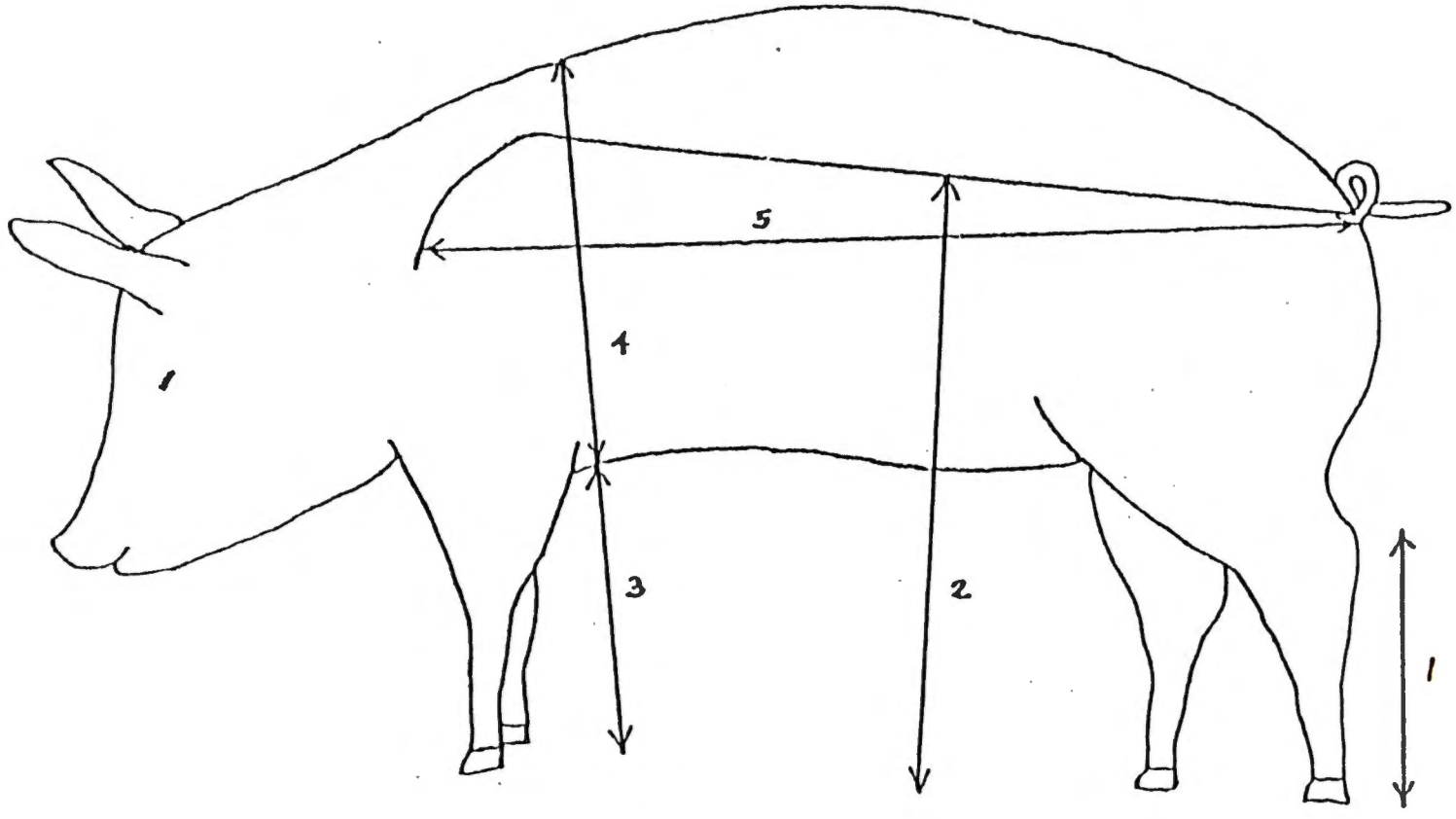
by pooled slaughter groups. When models were sorted by sex, no variables entered the model at (P<.15) significance level for LG/DOF. Only one variable entered the model for average daily gain and explained only 1% of the variation. Body types, either assessed subjectively or objectively, were poor predictors of ADG and LG/DOF. However, body type characterization is superior to feeder pig grades as a predictor of feeder pig performance.

2. INTRODUCTION

Research has been conducted to use linear measurements in regression equations in hopes of improving prediction of carcass merit (Pace, 1986 and Siemens, 1985). Once feeder pigs are designated into groups based on body type, the influence of performance can be studied. This experiment was conducted to characterize feedlot performance of hogs based on objective and subjective descriptions of feeder pigs. This information could be important in determining the expected difference in performance of feeder pig body type classifications.

3. Materials and Methods

Two hundred twenty feeder pigs (80 U.S. No. 1, 80 U.S. No. 2 and 60 U.S. No. 3 feeder pigs) were purchased through a Tennessee graded feeder pig sale. Feeder pigs were then delivered to the University of Tennessee Plateau Experiment Station feeder pig facility where the pigs were subjectively evaluated by trained evaluators on a scale of 1 to 5 for: frame height (1 = very short, 5 = very long), frame length (1 = very short, 5 = very long), overall frame (1 = very short overall, 5 = very long overall), muscle score (1 = thin, 5 = very thick), estimated propensity to fatten (1 = tend to fatten at low slaughter weight, 5 = tend to fatten at heavier slaughter weight), body width (1 = very narrow, 5 = very wide), belly depth (1 = very shallow, 5 = very deep) and bone (1 = very fine, 5 = very heavy). Objective feeder pig traits included: initial weight, length from poll to tail, body girth posterior to front leg as well as ultrasonic measurements of fat depth at the first rib, last rib and last lumbar vertebrae and an estimate of tenth rib longissimus muscle depth. A photographic slide of each pig was taken and the following life scale measurements were obtained from the developed slide (Figure 1): hock length, body depth, height from floor to belly, height of midpoint between shoulder and tail and length from point of shoulder to tail. A scatter plot of poll to tail length versus



1 = Hock Length
2 = Height of Midpoint between Shoulder and Tail
3 = Height from Floor to Belly
4 = Body Depth
5 = Length from Point of Shoulder to Tail

Figure 2.1 I. Objective Measurements from a Photograph

initial weight was generated to allot similar pigs to three slaughter endpoints of 91, 104 or 118 kg (SG I, SG II and SG III, respectively). The pigs were then assigned to similar pen groups, fed ad libitum a 16% corn-soybean meal-premix ration and were slaughtered as they reached their assigned slaughter weight (± 2 kg) at a local packing plant. Leaf fat was removed and hot carcass weight recorded. Carcasses were chilled 24 hours and one side was then transported to the University of Tennessee meat laboratory. Carcasses were standardized (Grisdale, 1984) by removing the jowl (at the atlas vertebrae), the hanging tender and the tail (between the first and second coccygeal vertebrae). Other carcass data collected included medial backfat thickness at the first rib, last rib and last lumbar vertebra, medial tenth rib fat depth, carcass length (anterior edge of the first rib to the anterior edge of the aitch bone) and muscle score in accordance with both 1970 and 1984 grade standards (USDA, 1970; USDA, 1984).

The data were analyzed by stepwise regression (SAS,1985) with only those variables that were significant ($P<.15$) included in each model. Sex was included in the model as both a subjective and objective trait. All subjective and objective traits were regrouped by one standard deviation into 3 subclasses to allow for more equal subclass size due to the low observation numbers in the extreme ranges of the traits. Overall sample means were

calculated with mean separation by Duncan's Multiple Range Test ($P<.05$).

4. Results and Discussion

Evaluation of Subjective and Objective Models

Stepwise regression analysis was performed on both subjective and objective variables to obtain the best model to predict LG/DOF and ADG by pooled slaughter weight and sex.

Regression coefficients, standard errors (SE), coefficients of determination (R^2) and residual standard errors of estimates (SEE) for predicting LG/DOF and ADG by subjective and objective variables are presented in Tables 2.1-2.4.

LG/DOF Prediction Equations by Pooled Slaughter Groups

Prediction equations by overall slaughter groups for objective variables produced R^2 values ranging from .01 to .03 (Table 2.1). The single variable belly height and accounted for only 1% of the variation in LG/DOF in the first equation (EQN 1) and the addition of sex to the model (EQN 2) increased the R^2 only .02 with no reduction in SEE.

Prediction equations for objective traits tended to have higher R^2 values compared to subjective variables. The

Table 2.1. Regressions Equations Using Objective Measurements of Feeder Pigs to Predict Lean Gain per Day on Feed.

Equation	Model	Intercept	b values	SE	R^2	SEE
Slaughter Weight I (91 kg)						
Overall						
1	Belly Height	.27	-.01	.01	.01	.002
2	Belly Height	.29	-.01	.01	.03	.002
	Sex		-.01	.01		
3	Sex	.30	-.02	.01	.04	.000
Slaughter Weight II (104 kg)						
4	Last Rib Fat	.29	-.02	.01	.06	.000
Slaughter Weight III (118 kg)						
5	Body Depth	.31	-.02	.01	.09	.001
6	Body Depth	.30	-.03	.01	.13	.001
	Poll to Tail Length		.01	.01		
7	Body Depth	.31	-.02	.01	.18	.001
	Poll to Tail Length		.01	.01		
	Last Lumbar Fat		-.01	.01		
8	Belly Height	.32	-.02	.01	.23	.001
	Body Depth		-.02	.01		
	Poll to Tail Length		.02	.01		
	Last Lumbar Fat		-.02	.01		
9	Belly Height	.30	-.02	.01	.27	.001
	Body Depth		-.02	.01		
	Poll to Tail Length		.02	.01		
	Sex		.02	.01		
	Last Lumbar Fat		-.02	.01		
10	Belly Height	.33	-.02	.01	.31	.001
	Body Depth		-.02	.01		
	Length Shl to Tail		-.01	.01		
	Poll to Tail Length		.03	.01		
	Sex		.02	.01		
	Last Lumbar Fat		-.02	.01		

best single variable model for subjective measures (Table 2.2, EQN 1) was frame height although explaining only 2% of the variation in LG/DOF. The best two variable model included sex which increased the R^2 value to .04 (EQN 2). Finally, with the addition of body depth the R^2 value increased to .06 (EQN 3), but again no difference in SEE for any of the models.

Both objective and subjective models for pooled slaughter groups included the variable sex as well as a height indicator; belly height (subjective) and frame height (objective). The subjective models also included body depth as a variable. Subjective and objective model explained very little of the variation and were of little value for predicting LG/DOF for pooled slaughter groups.

Prediction Equations for LG/DOF by Slaughter Groups

Subjective and objective traits were poor predictors of LG/DOF at slaughter endpoints of 91 kg and 104 kg (Tables 2.1 and 2.2). At 91 kg, the best single variable (Table 2.1, Eqn 3) was sex which accounted for 4% of the variation. For SG II, the best single model using objective traits was ultrasonic last rib fat (EQN 2) which explained 6% of the variation. For subjective traits (Table 2.2) at 91 kg, sex was the best single variable (EQN 4) and frame height (EQN 5) was added in the best two variable models resulting in R^2 values of .07 and .11, respectively. No variables met the .15 significance level for entry into subjective models

Table 2.2. Regression Equations Using Subjective Measurements of Feeder Pigs to Predict Lean Gain Per Day on Feed.

Equation	Model	Intercept	b values	SE	R^2	SEE
Overall						
1	Frame Height	.24	.01	.01	.02	.002
2	Frame Height	.26	.01	.01	.04	.002
	Sex		-.01	.01		
3	Frame Height	.22	.02	.01	.06	.002
	Body Depth		.01	.01		
	Sex		-.01	.01		
Slaughter Weight I (91 kg)						
4	Sex	.30	-.02	.01	.07	.002
5	Frame Height	.28	.01	.02	.11	.002
	Sex		-.02	.01		
Slaughter Weight II (104 kg)						
no variables met .15 significance level for entry into the model						
Slaughter Weight III (118 kg)						
6	Muscle Score	.22	.02	.01	.10	.001
7	Frame Length	.19	.02	.01	.16	.001
	Muscle Score		.02	.01		
8	Frame Length	.17	.02	.01	.20	.001
	Muscle Score		.01	.01		
	Body Width		.02	.01		

Table 2.3. Regression Equations Using Objective Measurements of Feeder Pigs to Predict Average Daily Gain.

Equation	Model	Intercept	b values	SE	R^2	SEE
Overall						
1	Sex	.83	-.07	.01	.14	.008
2	Belly Height	.87	-.01	.01	.15	.008
	Sex		-.07	.01		
Slaughter Weight I (91 kg)						
3	Sex	.83	-.08	.03	.11	.012
4	Ht - Shld to Tail MP	.93	-.04	.02	.20	.011
	Sex		-.08	.03		
5	Hock Length	.89	.04	.02	.24	.011
	Ht - Shld to Tail MP		-.06	.02		
	Sex		-.08	.03		
6	Hock Length	.77	.05	.02	.30	.010
	Ht - Shld to Tail MP		-.07	.02		
	Sex		-.08	.02		
	Last Lumbar Fat		.05	.02		
7	Hock Length	.82	.07	.02	.38	.009
	Belly Height		-.06	.02		
	Ht - Shld to Tail MP		-.06	.02		
	Sex		-.09	.02		
	Last Lumbar Fat		.05	.02		
Slaughter Weight II (104 kg)						
8	Sex	.84	-.08	.02	.20	.006
9	Body Depth	.79	.03	.02	.23	.006
	Sex		-.09	.02		
10	Belly Height	.82	-.03	.02	.28	.005
	Belly Depth		.04	.02		
	Sex		-.08	.02		
Slaughter Weight III (118 kg)						
11	Sex	.82	-.05	.02	.11	.006
12	Sex	.76	-.06	.02	.17	.006
	Last Rib Fat		.04	.02		

(Table 2.2) at 104 kg. At SG III (118 kg) substantially more of the variation was explained by both objective and subjective traits. The increase in R^2 could be due to greater fat deposition as pigs approached heavier weights. The best single variable for objective traits was body depth resulting in an R^2 value of .09 (Table 2.1, EQN 5). The addition of poll to tail length and ultrasonic lumbar fat thickness resulted in an increase in R^2 to .18 (EQN 7). Finally, with a six variable model of belly height, body depth, length from shoulder to tail and poll to tail, sex and ultrasonic lumbar fat thickness there was an improvement in R^2 value to .31 (EQN 10). Subjective traits also had improved R^2 for lean gain by SG III (Table 2.2). The best single variable model was muscle score resulting in an R^2 value of .10 (EQN 1). The addition of frame length and body width increased R^2 values to .20 (EQN 2). The only similarities between the variables included in objective and subjective traits for SG III was sex and an indicator of length; frame length (subjective) and poll to tail length and shoulder to tail length (objective). Objective traits also included a height and a fat indicator for feeder pigs while additional subjective traits were muscle and width scores. Although R^2 were improved by slaughter weight the amount of variation explained by the model was very low.

Prediction Equations for Average Daily Gain by Pooled Slaughter Groups

Prediction equations using objective variables groups for pooled slaughter groups produced R^2 values ranging from .14 to .15 (table 2.3, EQN 1 and 2). Sex was used as both a subjective and objective variable and explained 14 percent of the variation in ADG, (EQN 1, Tables 2.3 and 2.4). Although belly height was added to the pooled objective model, belly height contributed only 1% to the R^2 value.

Prediction Equations for Average Daily Gain by Slaughter Groups

Prediction equations with objective measurements were improved measures for SG I with R^2 values ranging from .11 to .38 (Table 2.3). The best single variable model again was sex which explained 11% of the variation (EQN 3). With the addition of hock length, belly height, midpoint height from shoulder to tail and ultrasonic lumbar fat thickness, the R^2 increased to .38 (EQN 7). Generally these variables can be classified into height, fat and sex (Table 2.3, EQN 1-5). Subjective measures had substantially lower R^2 for SG I and SG II(Table 2.4, EQN 2 and 3), with sex being the only variable entering into the model (R^2=.10 and .23 respectively). SG II had lower R^2 values than SG I for objective measures with a range of .20 to .28 (Table 2.3, EQN 8-10). The best single variable model was sex (EQN 8) which explained 20 % of the variation. Finally, in SG III

Table 2.4. Regression Equations Using Subjective Measurements of Feeder Pigs to Predict Average Daily Gain.

Equation	Model	Intercept	b values	SE	R^2	SEE
Overall						
1	Sex	.83	-.07	.01	.14	.008
Slaughter Weight I (91 kg)						
2	Sex	.83	-.07	.03	.10	.012
Slaughter Weight II (104 kg)						
3	Sex	.84	-.08	.02	.23	.006
Slaughter Weight III (118 kg)						
4	Sex	.81	-.05	.02	.10	.006
5	Frame Overall	.75	.03	.02	.15	.006
	Sex		-.05	.02		

(118 kg) R^2 values ranged from .11 to .17 (Table 2.3, EQN 9 and 10) for objective measures and .10 to .15 (Table 2.4, EQN 3 and 4) for subjective measures. Again the single best variable models for objective and subjective measures were sex which explained 11 and 10%, respectively of the variation. Sex was the best single variable for both objective and subjective traits by slaughter group for average daily gain and had R^2 values ranging from .10 to .23. This is in general agreement with the findings of Quijandria et al. (1970), Sather et al. (1980) and Crampton et al. (1945) that barrows reached their assigned slaughter weight with less days on feed. Models for SG I had substantially higher R^2 values than did Models for SG II and SG III. This is probably due to the SG I hogs being in a more rapid phase of the growth curve in SG I. Finally, ADG as predicted by objectively and subjectively measured traits were poor predictors of average daily gain.

USDA Feeder Pig Grades as Predictors of Lean Gain and Average Daily Gain

Feeder pig grades, like subjective and objective traits, were poor predictors of LG/DOF and ADG (Tables 2.5 and 2.6). Feeder pig grades as a single variable had an R^2 of only .03 for ADG and .01 for LG/DOF. Objective and subjective traits, although low for prediction of ADG and

Table 2.5. Analysis of Variance for Average Daily Gain.

	df	Mean squares	F	R^2
Feeder Pig Grade	2	.119	2.72	.03

Table 2.6. Analysis of Variance for Lean Gain Per Day On Feed.

	df	Mean squares	F	R^2
Feeder Pig Grade	2	.011	1.11	.01

LG/DOF, were still better predictors of ADG and LG/DOF than feeder pig grades.

Mean ADG and LG/DOF for Subjective Measurements

Subjective traits were regrouped with 1 = shorter, fatter, thinner muscled pigs and 3 = larger, trimmer, heavier muscled pigs. Mean separation was performed using Duncan's Multiple Range Test ($P<.05$) with results presented in Table 2.7. No significant difference was found for either ADG or LG/DOF for any of the subclasses using subjectively evaluated feeder pig traits.

Mean ADG and LG/DOF for Objective Measurements

The same numerical regroupings were then performed for subjective traits with results presented in Table 2.8. Larger framed pigs had higher average daily gain (ADG) ($P<.05$) than did average framed pigs (1.66 vs. 1.57, respectively). In addition, U.S. No. 3 feeder pigs had superior ADG than did number 1 pigs (1.62 vs. 1.53). This is probably due to a mismanagement problem rather than a grade allocation. USDA feeder pig grade No. 3 pigs have a higher number of mismanaged pigs and probably have greater compensatory gains.

Table 2.7. Average Daily Gain and Lean Gain Per Day on Feed for Objectively Evaluated Traits.

TRAIT / SCORE		ADG	LG/DOF	TRAIT / SCORE		ADG	LG/DOF
SHOULDER	1	.73	.25	BODY	1	.71	.25
TO	2	.71	.26	GIRTH	2	.72	.29
TAIL	3	.71	.26		3	.72	.26
SHOULDER	1	.73	.26	BODY	1	.73	.24
TO	2	.72	.26	DEPTH	2	.72	.26
TAIL (MP)	3	.72	.26		3	.73	.25
POLL	1	.68	.26	HOCK	1	.73	.25
TO	2	.72	.26	LENGTH	2	.71	.26
TAIL	3	.72	.26		3	.62	.25
BELLY	1	.72	.27	LAST	1	.71	.29
HEIGHT	2	.72	.26	RIB	2	.72	.25
	3	.70	.25	FAT TK	3	.73	.26
LOIN	1	.72	.26	LAST	1	.69	.27
DEPTH	2	.72	.26	LUMBAR	2	.73	.26
	3	.72	.26	FAT TK	3	.72	.26
FIRST	1	.72	.26				
RIB	2	.72	.26				
FAT TK	3	.71	.25				

Table 2.8. Average Daily Gain and Lean Gain Per Day on Feed for Subjectively Evaluated Traits.

TRAIT / SCORE		ADG	LG/DOF	TRAIT / SCORE		ADG	LG/DOF
FRAME HEIGHT	1	.73[ab]	.26	SEX	B	.75[a]	.27
	2	.71[b]	.26		G	.70[b]	.26
	3	.75[a]	.26				
FRAME ALL	1	.74	.26	BODY DEPTH	1	.68	.25
	2	.71	.26		2	.72	.26
	3	.74	.27		3	.73	.27
FRAME LENGTH	1	.74	.26	EST. FAT	1	.76	.25
	2	.71	.26		2	.72	.26
	3	.73	.26		3	.72	.26
MUSCLE SCORE	1	.73	.25	BONE	1	.75	.26
	2	.72	.26		2	.72	.26
	3	.72	.26		3	.74	.27
FEEDER PIG GRADE	1	.69[b]	.26	BODY WIDTH	1	.75	.25
	2	.72[ab]	.26		2	.72	.26
	3	.73[a]	.25		3	.72	.26

a, b = (P<.05)

Chapter III

USEFULNESS OF FEEDER PIG SUBJECTIVE AND OBJECTIVE MEASUREMENTS FOR PREDICTING PORK CARCASS GRADE AND LEAN CUT PERCENTAGE

1. SUMMARY

One hundred eighty-six feeder pigs were selected to represent grades of U.S. No.1, U.S. No.2 and U.S. No.3. Various height, length, fat thickness and body dimensions were evaluated, both subjectively and objectively. A canonical variate analysis was performed on the live animal measurements to determine the usefullness of these descriptions in predicting on carcass grade and yield of lean cuts. Canonical variate analysis was used to transform a set of observed variables into a smaller number of composite variables (Z_1 and Z_2).

Use of visual and objective measurements of feeder pigs to predict slaughter grade was only slightly successful. The first two canonical variates (Z_1, Z_2) for both objective and subjective measures explained only 13.53 and 14.59% of the variation, respectively, among the four slaughter grades (U.S. No.1, U.S. No.2, U.S. No.3 and U.S. No.4). When used to predict subclasses of lean cut percentages canonical variates (Z_1 and Z_2) of objective and subjective measures explained 18.62 and 14.60%, respectively, of the variation. The cannonical analysis for both slaughter grade and

percentage four lean cuts explained very little of the variation; therefore, no meaningful biological explainations could be given to the two cannonical variables (Z_1 and Z_2). Both subjective and objective traits were sorted by slaughter endpoints (91 kg, SG I; 104 kg, SG II; 118 kg, SG III) and canonical analysis was used to predict lean cut percentages. The variation in lean cut percentages of SG III explained by objective and subjective traits was greatly improved. The first two canonical variates for objective traits explained 59.42% of the variation in lean cut percentage. The first canonical (Z_1) combined two major contrasts of carcass characteristics and body dimensions. There was a positive weighting of fat deposition traits and body depth contrasted with a strong negative weight for sex. The second canonical (Z_2) segregated the subclasses according to body depth and girth as reflected by the large positive weighting on these variables corresponding to negative weighting on belly height and hock length.

The first two canonical for subjective traits explained 47.83% of the total variation. The first canonical (Z_1) for subjective traits contrasted fat deposition with differences in body dimensions, while the second canonical also had a positive weighting on muscle score and body width.

Canonical analysis was more successful for heavier slaughter weight groups probably due to the more mature hogs

being in a flatter portion of the growth curve. At these heavier weights, the difference in subjective and objective measures had a more dramatic impact on the ability to predict lean cut percentage as indicated by larger canonical variates. The Z_1 and Z_2 variates for both objectively and subjectively measured traits generally consisted of a muscularity description contrasted with a fat deposition and a variate describing a body dimension.

The canonical variate analysis predicted slaughter grades and lean cut percentage classes more successfully than USDA feeder pig grades. For pooled slaughter weight endpoints, the first two canonical variates correctly predicted 44.5 to 47.3% of the actual percent lean cut classes as compared to only 28.3% predicted correctly by feeder pig grades. In addition, for SG III (118 kg) the first two canonical variates predicted 54.6 to 65.5% correctly, of percent lean cuts classes for slaughter endpoint three (118 kg) as compared to only 25.5% correctly predicted by feeder pig grades

2. INTRODUCTION

The USDA feeder pig grades are intended to indicate the logical slaughter potential of the hog when marketed at a weight of 104 kg. Current USDA feeder pig grades need to be evaluated for their effectiveness in predicting logical

slaughter potential of slaughter hogs (Siemens, 1985 and Pace, 1986). Recent studies (Brooks, 1984; Pace, 1986) have shown that the current feeder pig grades do not accurately estimate the ultimate carcass grade. An alternative grouping by body type appears to be a more descriptive classification of feeder pigs. Such a grading system would provide clearer communication between feeder pig producers and slaughter hog producers (Siemens, 1985).

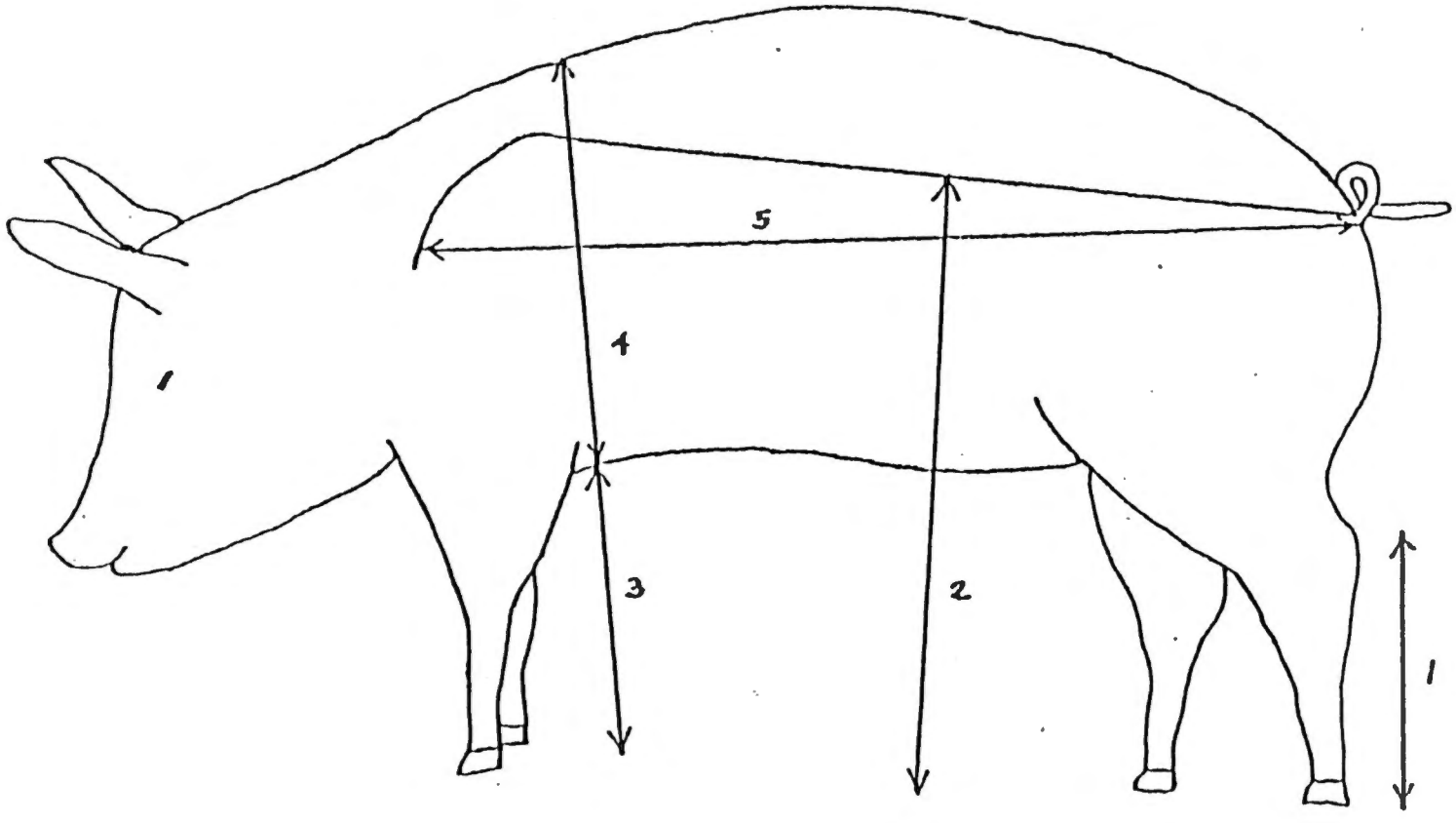
The objectives of this study were to:

1. Determine if feeder pig objective and subjective measurements could be used in predicting slaughter potential.
2. Identify objective and subjective descriptions that may be used in classifying feeder pig slaughter potential.

3. MATERIALS AND METHODS

Two hundred twenty feeder pigs (80 U.S. No. 1, 80 U.S. No. 2 and 60 U.S. No. 3 feeder pigs) were purchased through a Tennessee graded feeder pig sale. Feeder pigs were then delivered to the University of Tennessee Plateau Experiment Station feeder pig facility where the pigs were subjectively evaluated by trained evaluators on a scale of 1 to 5 for: frame height (1 = very short, 5 = very tall), frame length

(1 = very short, 5 = very tall), overall frame (1 = very short overall, 5 = very long overall), muscle score (1 = thin, 5 = very thick), estimated propensity to fatten (1 = tend to fatten at light slaughter weight, 5 = tend to fatten at heavier slaughter weight), body width (1 = very narrow, 5 = very wide), belly depth (1 = very shallow, 5 = very deep) and bone (1 = very fine, 5 = very heavy). Furthermore, feeder pig traits objectively measured included: initial weight, sex, length from poll to tail, body girth posterior to front leg as well as ultrasonic measurements of fat depth at the first rib, last rib and last lumbar vertebrae and an ultrasonic measurement of tenth rib longissimus muscle depth. A photographic slide of each pig was taken and the following life scale measurements were obtained from the developed slide (Figure 3.1): hock length, body depth, height from floor to belly, height of midpoint between shoulder and tail and length from point of shoulder to tail. A scatter plot of poll to tail length versus initial weight was generated to allot similar pigs to slaughter endpoints of 91, 104 or 118 kg (SG I, SG II and SG III, respectively). The pigs were then assigned to similar pen groups, fed ad libitum a 16% corn-soybean meal-premix ration and were slaughtered as they reached their assigned slaughter weight ($\pm$ 2 kg) at a local packing plant. Leaf fat was removed and hot carcass weight recorded. Carcasses were chilled 24 hours and one side was then transported to the University of



1 = Hock Length
2 = Height of Midpoint between Shoulder and Tail
3 = Height from Floor to Belly
4 = Body Depth
5 = Length from Point of Shoulder to Tail

Figure 3.1 II. Objective Measurements from a Photograph

Tennessee meat laboratory. Carcasses were standardized (Grisdale, 1984) by removing the jowl (at the atlas vertebrae), the hanging tender, and the tail (between the first and second coccygeal vertebrae). Other carcass data collected included medial backfat thickness at the first rib, last rib and last lumbar vertebra, medial tenth rib fat depth, carcass length (anterior edge of the first rib to the anterior edge of the aitch bone), and muscle score in accordance with both 1968 and 1985 grade standards (USDA, 1968; USDA, 1985). The sides were then cut into the primal cuts of ham, loin, shoulder, belly and spareribs (Cole, 1951). Trimmed primals were then weighed and separated into soft tissue, skin and bone. The separations were weighed and soft tissue was ground and sampled from the shoulder, loin, ham, belly and miscellaneous which included meat trimmings as well as meat on the neck bones and spareribs. Analysis for muscle, fat and protein was then performed using a Dickey John Foss Superscan Complete Meat Analyzer (Pace, 1985; Pace et al., 1985).

A canonical variate analysis (SAS, 1985) was used to determine the relationship of the feeder pig objective and subjective traits to USDA slaughter grade and percentage yield of lean cuts from the carcasses of the finished hogs. Canonical variate analysis provides a method of transforming data into a set of composite variables. Interpretation of variates involves consideration of standardized

discriminant function coefficients (standardized weights) and product-movement correlations between each composite variate and the individusl body measurements. Both magnitude and sign of the standardized weights and correlations are used for interpretive purposes (Tatum, 1986). The absolute magnitude of an individual standardized weight reflects the contribution of its respective body measurement to variation in the composite (Fornell, 1978). Futhermore, the sign of each standardized weight provides insight into direction of the relationships between its corresponding character and other characters in the response (Tatum, 1986). The data was also analysed using a canonical discriminant procedure (SAS, 1985) in order to evaluate the successfulness of the composite variable Z_1 and Z_2 in predicting the percent lean cut subclasses and slaughter grade. Lean cut percentages were divided into subclasses (group 1 = > 60.4%; group 2 = 57.4 to 60.3%; group 3 = 54.4 to 57.3% and group 4 = > 57.3%).

4.RESULTS AND DISCUSSION

Use of Objective and Subjective Measurements of Feeder Pigs to Predict Slaughter Grades

Objective measurements of feeder pigs were only slightly successful in predicting slaughter grade according to results of the canonical analysis (Table 3.1). The first canonical (Z_1) contrasted a positive weighting on fat

deposition and body dimensions with a negative weighting on frame length and height and explained 10.2% ($P<.06$) of the among sub-class variation. The second canonical variate (Z_2) was considerablly less successful because it explained only 3.3% of the among subclass variation. Objective measures were poor predictors of slaughter grades due to the low overall variation explained by the first two canonical variates and the extremely low eigenvalues.

Subjective evaluations of feeder pigs were evaluated by canonical analysis for their usefullness in predicting slaughter grade (Table 3.2). Again, the first canonical variate (Z_1) included a positive weighting on estimated propensity to fatten, as well as frame length and overall frame which was contrasted to body depth and muscle score as indicated by low or negative values. The first canonical variate explained 11.1% of the among subclass variation of body measurements ($P<.004$). The second canonical again was unsuccessful and explained only 3.5% of the among subclass variation. Subjective measures were also poor predictors of slaughter grades as indicated by the low variation explained and low eigenvalues. Futhermore, no particular feeder pig subjective evaluation was apparent in describing the Z_1 or Z_2 variate.

Table 3.1. Canonical Variate Analysis of Objective Feeder Pig Measurements to Predict Carcass Grade.

Body measurement	Canonical variate Z_1	Canonical variate Z_2
Body Depth	.36	.36
Belly Height	.34	.32
Body Girth	.35	-.14
Hock Length	-.46	.17
Loin Depth	.18	-.54
Last Lumbar Fat	.27	-.06
Poll to Tail Length	.07	.58
Shoulder to Tail Length	-.12	.29
First Rib Fat	.47	-.13
Shl-Tail Mid Point Height	-.14	.27
Last Rib Fat	.21	-.18
Sex	.20	.42
Eigenvalue	.12	.04
Variation explained (%)	10.21	3.32
Correlations between body measurements and canonical variates		
Body Depth	.87	.49
Belly Height	.87	.46
Body Girth	.98	-.22
Hock Length	-.98	.20
Loin Depth	.48	-.82
Last Lumbar Fat	.97	-.12
Poll to Tail Length	.20	.91
Shoulder to Tail Length	-.56	.72
First Rib Fat	.90	-.14
Shl-Tail Mid Point Height	-.56	.64
Last Rib Fat	.87	-.43
Sex	.61	.73

Table 3.2. Canonical Variate Analysis of Subjective Feeder Pig Evaluations to Predict Carcass Grade.

Body measurement	Canonical variate Z_1	Z_2
Body Width	.13	.26
Bone	.39	.47
Body Depth	-.20	-.45
Propensity to Fatten	.55	.16
Frame Height	.25	-.16
Frame Length	.55	-.07
Frame Overall	.37	-.08
Muscle Score	.09	.36
Eigenvalue	.13	.04
Variation explained (%)	11.10	3.49
Correlations between body measurements and canonical variates		
Body Width	.67	.72
Bone	.82	.55
Est. Body Depth	-.63	-.77
Propensity to Fatten	.88	.14
Frame Height	.72	-.26
Frame Length	.98	-.07
Frame Overall	.90	-.11
Muscle Score	.35	.78

Effectiveness of Objective and Subjective Measurements of Feeder Pigs in Predicting Percent Lean Cuts

The first canonical variate (Z_1), which had positive weightings on length indicators, sex and loin depth and negative weightings on body depth and indicators of fat deposition, explained 12.0% ($P<.02$) of the among subclass variation of body measurements (Table 3.3). The second canonical contained a positive weighting on several variables including indicators of body dimension, fat deposition, muscle and sex. The total variation by the two canonical variates was 18.6% but eigenvalues were very low. Furthermore, the appendix indicates little success in separating lean cut percentage subclasses by either canonical variate as the . In Table 3.4 shows the distribution of predicted lean cut percentage subclasses by the canonical procedure. The lean cut percentages correspond to the current USDA slaughter grade ranges for percentage of lean cuts. Only 44.5% of the feeder pigs were properly placed into the correct lean cut percentage subclass. The poor success rate was especially evident for the US No.2 and No.4 lean cut percentage ranges.

The canonical analysis of data to determine the usefullness of feeder pig subjective traits to predict lean cut percentage was also slightly better than the prediction of slaughter grades. The first canonical variate (Z_1) explained 11.0% of the among sub-class variation ($P<.005$) of

Table 3.3. Canonical Variate Analysis of Objective Feeder Pig Measurements to Predict Lean Cut Percentages.

Body measurement	Canonical variate Z_1	Canonical variate Z_2
Body Depth	-.52	.44
Bellly Height	-.05	-.06
Body Girth	-.05	.48
Hock Length	.03	-.13
Loin Depth	.24	.52
Last Lumbar Fat	-.25	.44
Poll to Tail Length	.02	.12
Shoulder to Tail Length	.32	.30
First Rib Fat	-.29	.40
Shl-Tail Mid Point Height	.18	-.03
Last Rib Fat	-.33	.41
Sex	.43	.56
Eigenvalue	.15	.07
Variation explained (%)	12.02	6.6
Correlations between body measurements and canonical variates		
Body Depth	-.85	.52
Belly Height	-.15	-.14
Body Girth	-.15	.94
Hock Length	.34	-.87
Loin Depth	.53	.81
Last Lumbar Fat	-.58	.73
Poll to Tail Length	.11	.48
Shoulder to Tail Length	.83	.54
First Rib Fat	-.62	.60
Shl-Tail Mid Point Height	.67	.08
Last Rib Fat	-.66	.59
Sex	.73	.68

Table 3.4. Comparison of Actual Pork Carcass Lean Cut Percentages to Predicted Lean Cut Percentages by Canonical Analysis of Objective Feeder Pig Traits.

			Actual Lean Cut Percentage[a] 1	2	3	4	Correctly Predicted
Predicted % Lean Cuts[a]	1	No.	33	4	11	5	33/53
		%	62.3	7.6	20.8	9.4	62.3
	2	No.	14	8	11	7	8/40
		%	35.0	20.0	27.5	17.5	20.0
	3	No.	16	3	25	7	25/51
		%	31.4	5.9	49.0	13.7	49.0
	4	No.	9	4	10	15	15/38
		%	23.7	10.5	26.3	39.5	39.5
Total Correctly Predicted							81/182 = 44.5%

a 1= > 60.4 lean cut percentage, 2= 57.4 to 60.3%, 3= 54.4 to 57.3%, 4= > 57.3%

the body measurements (Table 3.5). There was a positive weighting on body width, muscle score, protensity to fatten and frame length. In addition, Z_2 explained 3.6% of the among subclass variation with a positive strong weighting on frame height, overall frame and frame length contrasted to a moderate negative weighting to estimated body depth. In the appendix, canonical Z_1 partially separated group 1 from group 4, with groups 2 and 3 being more clustered together. The variate Z_2 did not separate the four groups. Canonical variate one seemed to separate groups 1 and 2 from groups 3 and 4, thus body width, muscle score, estimated fat and frame length separated these groups. Table 3.6 shows the prediction of groups was only slightly successful as indicated by 47.2% of the feeder pigs properly placed into the correct group for percent lean cuts at slaughter.

Canonical Analysis of Subjective and Objective Measurements of Feeder Pig Traits to Predict Lean Cut Percentage by Slaughter Weight Endpoint.

Because of low prediction values with pooled slaughter weights, canonical analyses were performed by slaughter weight endpoints. With both subjective and objective measured traits, as slaughter weight increased there was a concomitant increase in both the percentage of variation explained by the two canonical variates and an improvement in the probability of those values (Tables 3.7 and 3.8).

Table 3.5. Canonical Variate Analysis of Subjective Feeder Pig Evaluations to Predict Lean Cut Percentages.

Body measurement	Canonical variate Z_1	Z_2
Body Width	.57	-.02
Bone	.39	.23
Body Depth	-.33	-.10
Propensity to Fatten	.58	.25
Frame Height	.21	.78
Frame Length	.50	.47
Frame Overall	.39	.62
Muscle Score	.66	.15
Eigenvalue	.13	.04
Variation explained (%)	11.00	3.60
Correlations between body measurements and canonical variates		
Body Width	.98	-.02
Bone	.94	.30
Body Depth	-.87	-.15
Propensity to Fatten	.96	.23
Frame Height	.42	.90
Frame Length	.88	.46
Frame Overall	.74	.67
Muscle Score	.96	-.12

Table 3.6. Comparison of Actual Pork Carcass Lean Cut Percentages to Predicted Lean Cut Percentages by Canonical Analysis of Subjective Feeder Pig Traits.

			Actual Lean Cut Percentage[a]				Predicted Correctly
			1	2	3	4	
Predicted Percent Lean Cuts	1	No.	36	1	11	5	26/53
		%	67.9	1.89	32.5	9.4	67.9
	2	No.	13	8	13	6	8/40
		%	32.5	20.0	32.5	15.0	20.0
	3	No.	14	3	27	7	27/51
		%	27.5	5.9	52.9	13.7	52.9
	4	No.	9	5	9	15	15/38
		%	23.7	13.2	23.7	39.5	39.5
Total Correctly Predicted							86/182 = 47.2%

Table 3.7. Canonical Analysis of Subjectively Measured Traits to Predict Lean Cut Percentage by Slaughter Weight Endpoints.

		Slaughter Group		
		I	II	III
Variation explained (%)	Z_1	13.75	26.83	31.37
	Z_2	10.21	12.52	16.46
	Total	23.96	39.35	47.83
			PR>F	
Wilks' Lambda		.620	.050	.009
Hotelling-Lawley Trace		.650	.040	.010
Roys' Greatest Root		.240	.002	.001

Table 3.8. Canonical Analysis of Objectively Measured Traits to Predict Lean Cut Percentages by Slaughter Weight Endpoints.

		Slaughter Group		
		I	II	III
Variation explained (%)	Z_1	23.58	20.94	32.29
	Z_2	14.04	16.96	27.13
	Total	37.62	37.90	59.42
			PR>F	
Wilks' Lambda		.680	.400	.020
Hotelling-Lawley Trace		.670	.420	.010
Roys' Greatest Root		.080	.080	.001

Three statistical tests were selected to test hypothesis of the canonical analysis. Roys' Greatest Root which tests only the best canonical variate, whereas Hotelling-Lawley Trace and Wilks' Lambda test all of the canonicals combined. The increasing ability to predict lean cut percentages was probably due to evaluating later maturing hogs at a point where fat differences are more apparent. Difference in feeder pig types thus had a greater impact on carcass composition and lean cuts percentage at heavier weights. For subjectively measured traits, the percent among subclass variation increased from 23.96% of the variation in SG I to 47.83% in SG III (Table 3.9). The probability F also improved for Wilk's Lambda from .62 to .009.

For objectively measured traits (Table 3.8) the percent variation also had a dramatic increase from SG I to SG III (37.6 to 59.4%), respectively). The probability using the Wilk's Lambda test also increased from .68 to .02.

Table 3.9 detail the standardized coefficient weights and the product movement correlations for each of the objective traits to predict SG III lean cut percentage. The first and second canonical variate of SG III explained 59.4% of the among subclass variation (Table 3.9) in predicting percent lean cuts using objective traits. The first variable (Z_1) explained 32.2% of the among subclass variation. Z_1 contrasted fat deposition indices and body

Table 3.9. Canonical Variate Analysis of Slaughter Group III (118 kg) Using Objective Feeder Pig Measurements to Predict Percentage of Lean Cuts.

Body measurement	Canonical variate Z_1	Z_2
Body Depth	.47	.71
Belly Height	.19	-.01
Body Girth	.28	.76
Hock Length	.14	-.03
Loin Depth	-.22	.43
Last Lumbar Fat	.48	.19
Poll to Tail Length	.21	.47
Soulder to Tail Length	-.04	.25
First Rib Fat	.26	.34
Shl-Tail Mid Point Height	.01	.29
Last Rib Fat	.46	.20
Sex	-.65	.30
Eigenvalue	1.08	.44
Variation explained (%)	32.29	27.13
Correlations between body measurements and canonical variates		
Body Depth	.66	.75
Belly Height	.97	-.04
Body Girth	.42	.88
Hock	.54	-.09
Loin Depth	-.53	.80
Last Lumbar Fat	.96	.29
Poll to Tail Length	.50	.87
Shoulder to Tail Length	-.18	.90
First Rib Fat	.71	.70
Shl-Tail Mid Point Height	.04	.89
Last Rib Fat	.95	.32
Sex	-.92	.33

depth contrasted with a strong negative weight for sex. The low magnitude of height and length measurements indicate that differences among fat and body depths were not always proportional to corresponding differences in frame lengths and heights. The second canonical variate (Z_2) accounted for 27.1% of the among subclass variation in the body measurements and segregated the subclasses according to differences in body depth and girth with corresponding negative weighting on belly height and hock length. Examination of the correlations of Z_2 revealed that as body dimensions increased, hock length and belly height decreased; thus, deeper bodied pigs tended to be shorter in hock length and belly height. Table 3.10 also reveals a 65.5% success rate in predicting actual percentage of lean cut range from feeder pig objective measurements. It is also worth noting that when the prediction was incorrect that the analysis generally placed the feeder pig in the adjoining percent lean cut subclass (Table 3.10).

The canonical varitates of SG III to predict subclasses of lean cut percentages by subjective traits explained 47.8% of the among subclass variation (Table 3.11). The first variate (Z_1) explained 31.4% of the among subclass variation and provided a positive weighting on protensity to fatten contrasted to negative or low values for body dimensions (i.e., differences in body depth, frame height, bone and frame overall). Correlations showed that as estimated

Table 3.10. Comparison of Actual Pork Carcass Lean Cut Percentages to Predicted Lean Cut Percentages by Canonical Analysis of Objective Traits for Slaughter Group III.

			Actual Percent Lean Cuts 1	2	3	4	Correctly Predicted
Predicted Percent Lean Cuts	1	NO.	11	1	0	1	11/13
		%	84.6	7.7	0	7.7	84.6
	2	No.	2	2	4	0	2/8
		%	25.0	25.0	50.0	0	25.0
	3	No.	2	1	14	4	14/21
		%	9.5	4.8	66.7	19.1	66.7
	4	No.	0	0	4	9	9/13
		%	0	0	30.8	69.2	69.2
Percent correctly predicted							36/55 = 65.5%

a Lean cut percentage subclasses: 1= > 60.4%; 2= 57.4 to 60.3%, 3= 54.4 to 57.3%, 4= > 57.3%

Table 3.11. Canonical Variate Analysis of Slaughter Group III (118 kg) Using Subjective Feeder Pig Evaluations To Predict Percentage Lean Cuts.

Body measurement	Canonical variate Z_1	Canonical variate Z_2
Body Width	.13	.60
Bone	-.20	.14
Body Depth	-.26	.32
Propensity to Fatten	.39	-.16
Frame Height	-.16	.35
Frame Length	.18	.41
Frame Overall	.01	.32
Muscle Score	.30	.53
Eigenvalue	.77	.23
Variation explained (%)	31.37	16.46
Correlations between body measurements and canonical variates		
Body Width	.29	.90
Bone	-.46	.21
Body Depth	-.76	.60
Propensity to Fat.	.73	-.20
Frame Height	-.50	.69
Frame Length	.50	.72
Frame Overall	.02	.72
Muscle Score	.62	.71

propensity to fatten increased there is an increase in the canonical variate, whereas body depth, frame height and bone would result in a decrease in Z_1. The low magnitude of overall frame indicates that overall frame was disproportionate to corresponding differences in estimated fat; that is, a change in canonical variate would not always result in a proportionate change in frame size indicators. Canonical variate two (Z_2) appears to be composed of body form or shape parameters due to relatively high weights to body width and muscle score. Canonical variate Z_2 contributed to 16.5% of the total variation explained. The correlations showed that as body width and muscle score increased, estimated fat decreased. Furthermore, as body shape increased there was a fairly large postive correlation with frame height (.69), frame length (.72) and overall frame (.72). Finally, in Table 3.12 a greater number of feeder pigs were classified correctly as to their expected yield of lean cuts as compared to pooled SG. Most of the hogs were either classified correctly or only misclassified by one subclass. For the SG III, 55.5% were predicted correctly by two canonical variates using subjective measures.

Table 3.12. Comparison of Actual Pork Carcass Lean Cut Percentages to Predicted Lean Cut Percentages by Canonical Analysis of Subjective Traits for Slaughter Group III.

			Actual Percent Lean Cuts 1	2	3	4	Correctly Predicted
Predicted Percent Lean Cuts	1	No.	7	0	4	2	7/12
		%	53.9	0	30.8	15.4	53.9
	2	No.	0	5	3	0	5/8
		%	0	62.5	37.5	0	62.5
	3	No.	2	2	13	4	13/21
		%	9.5	9.5	61.9	19.1	61.9
	4	No.	3	0	5	5	5/13
		%	23.1	0	38.5	38.5	38.5
Percent Correctly Predicted							30/54 = 55.5%

a Lean cut percentage subclasses: 1= > 60.4%; 2= 57.4 to 60.3%, 3= 54.4 to 57.3%, 4= > 57.3%

Comparison of Feeder Pig Grades to Canonical Variates Developed by Subjective and Objective Measures in Predicting Percent Lean Cut Classes.

A comparison was made between USDA feeder pig grades (USDA, 1985) and actual percentages of lean cuts. Feeder pig grades correctly identified 28.3% of the final carcass grades (Table 3.13). This compares to 44.5 to 47.2% predicted correctly by canonical analysis using objective and subjective measures (Tables 3.4 and 3.6). In addition, there were more pigs mispredicted by more than one lean cut subclass by feeder pig grades than by canonical variates. Finally, a comparison of feeder pig grades and canonical variates of objective and subjective measures revealed a higher percentage correctly predicted by canonical analysis for SG III. Canonical variates successfully predicted 54.6 to 65.5% the percentage lean cut class as compared to only 25.5% by feeder pig grades (Table 3.14). The low percentage of correctly predicted percentge lean cuts emphasizes the need for a modification of the feeder pig grade system (Pace, 1986; Siemens, 1985 and Brooks, 1984).

Table 3.13. Comparison of Actual Pork Carcass Lean Cut Percentages to Predicted Lean Cut Percentages by Canonical Analysis of Feeder Pig Grades.

			Actual Percent Lean Cuts				Correctly
			1	2	3	4	Predicted
Predicted Percent Lean Cuts	1	No.	22	16	17	11	22/66
		%	33.3	24.2	25.8	16.7	33.3
	2	No.	20	17	24	15	17/76
		%	26.3	22.4	31.6	19.7	22.4
	3	No.	11	8	15	15	15/49
		%	22.4	16.3	30.6	30.6	30.6
Percent Correctly Predicted							54/191 = 28.3%

a Lean cut percentage subclasses: 1= > 60.4%; 2= 57.4 to 60.3%, 3= 54.4 to 57.3%, 4= > 57.3%

Table 3.14. Comparison of Actual Pork Carcass Lean Cut Percentages to Predicted Lean Cut Percentages by Canonical Analysis of Feeder Pig Grades for Slaughter Group III.

			Actual Percent Lean Cuts				Predicted
			1	2	3	4	Correctly
Predicted Percent Lean Cuts	1	No.	6	3	7	5	6/21
		%	28.6	14.3	33.3	23.8	28.6
	2	No.	5	2	9	4	2/20
		%	25.0	10.0	45.0	20.0	10.0
	3	NO.	2	2	6	4	6/14
		%	14.3	14.3	42.9	28.6	42.9
Percent Correctly Predicted							14/55 = 25.5%

a Lean cut percentage subclasses: 1= > 60.4%; 2= 57.4 to 60.3%, 3= 54.4 to 57.3%, 4= > 57.3%

Chapter IV

Relationships Among Selected Pork Carcass Fat Deposition Areas

1. SUMMARY

Two hundred twenty feeder pigs were purchased and then assigned to different slaughter endpoints of 91, 104 and 118 kg (SG I, II and III, respectively). Standard carcass fat measurements were then recordedand regression equations were developed to study interrelationships among the fat depot measurements.

The best fit line for the relationship between average backfat and last rib fat thickness was a linear response with R^2 values ranging from .65 to .68 R^2 for SG I, II and III. Quadratic responses were noted for the following fat measurements: first rib and average backfat, first rib and last rib, tenth rib three-quarter and average backfat, and tenth rib three-quarter and last rib. The best fit lines for first rib fat and other fat measurements tended to be concave. This is probabaly due to a first rib fat being an earlier maturing fat deposition area. In addition, the best fit lines for tenth rib three-quarter fat were convex suggesting that this fat depot is a relative later maturing fat site. The best fit plot of tenth rib fat and last

lumbar fat compared to average backfat and last rib fat were linear responses with low to moderate R^2 values (.46 to .76).

2. INTRODUCTION

A major revision was made recently in the USDA feeder pig grades to coordinate them with concurrent changes in the hog industry (USDA, 1984). A 1980 grade survey found that over 70% of the pork carcasses being produced were U.S. No. 1 grade, resulting in a greater amount of variation in yield that was not accounted for by the grades (USDA, 1984). The changes simplified the standards by basing the grade on the backfat thickness over the last rib (instead of average backfat for the old standards) along with a single muscle adjustment. Because of the fat thickness measurement change in the grade standards, the objective of this study was to determine the relationships between easy to measure fat depths average backfat and last rib fat.

3. MATERIALS AND METHODS

Two hundred twenty feeder pigs (80 U.S. No. 1, 80 U.S. No. 2 and 60 U.S. No. 3 feeder pigs) were purchased through a Tennessee graded feeder pig sale. Feeder pigs

were then delivered to the University of Tennessee Plateau Experiment Station feeder pig facility. A scatter plot of poll to tail length versus initial weight was generated to allot similar pigs to three slaughter endpoints of 91, 104 or 118 kg (SG I, SG II and SG III, respectively). The pigs were then assigned to similar pen groups, fed ad libitum a 16% corn-soybean meal-premix ration and were slaughtered as they reached their assigned slaughter weight (± 2 kg) at a local packing plant. Leaf fat was removed and hot carcass weight recorded. Carcasses were chilled 24 hours and one side was then transported to the University of Tennessee meat laboratory. Carcasses were standardized (Grisdale, 1984) by removing the jowl (at the atlas vertebrae), the hanging tender and the tail (between the first and second coccygeal vertebrae). Other carcass data collected included medial backfat thickness at the first rib, last rib and last lumbar vertebra, medial tenth rib fat depth, carcass length (anterior edge of the first rib to the anterior edge of the aitch bone) and muscle score in accordance with 1970 and 1984 grade standards (USDA, 1970; USDA, 1984).

Regression equations were then developed to study relationships among several fat deposition sites. Best fit lines were graphed to depict relationships and where

significant, quadratic and cubic responses were used; but if nonsignificant, a linear response was graphed (SAS, 1985).

4. RESULTS AND DISCUSSION

The relationship of average backfat to last rib fat by slaughter group is shown in Figure 4.1. The response was linear for all three slaughter groups with R_2 ranging from .65 to .68. Average backfat thickness remained greater than last rib fat thickness for all three slaughter groups until average backfat thickness of 50 mm which indicates that the last rib fat is a later developing fat deposition site. Figures 4.2 and 4.3 depict the relationship between average backfat and last rib fat with first rib fat. In both cases, the best fit line was a quadratic response. Figure 4.2 illustrates that average backfat increased faster than first rib fat until approximately 70 mm, although first rib fat remained greater than average backfat throughout the curve. In Figure 4.3, last rib fat also increased faster than first rib fat upto approximately 50 mm.

The relationship of average backfat and last rib fat with the medial tenth rib fat are illustrated in Figures 4.4 and 4.5. These best fit lines were linear and both had R_2 values of .46. Tenth rib fat exceeded average backfat at approximately 42 mm. Relative to tenth rib fat, last rib

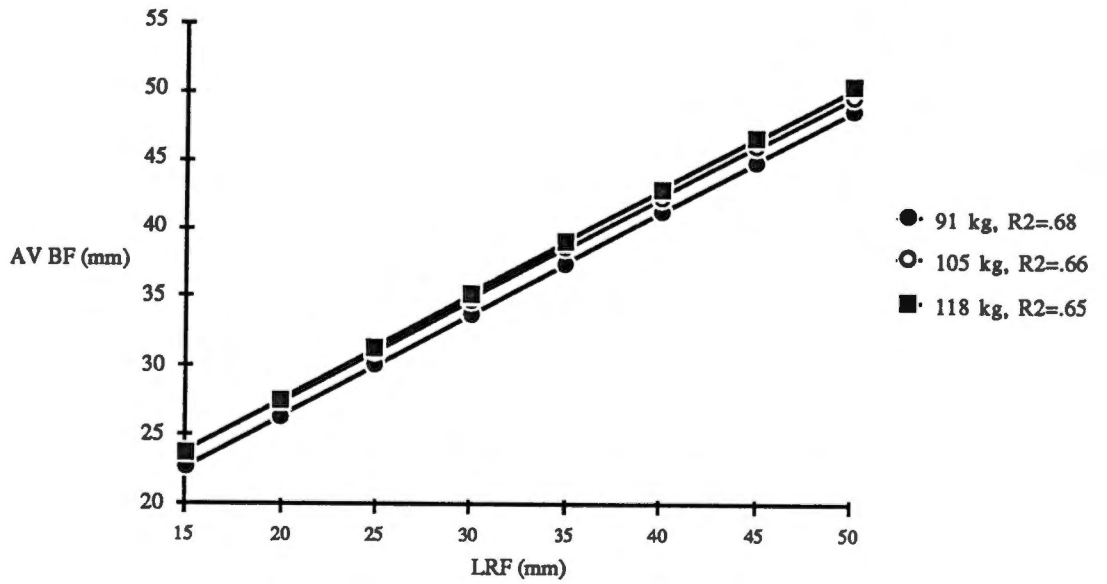


Figure 4.1

Relationship of Average Backfat to Last Rib Fat Deposition by Slaughter Weight

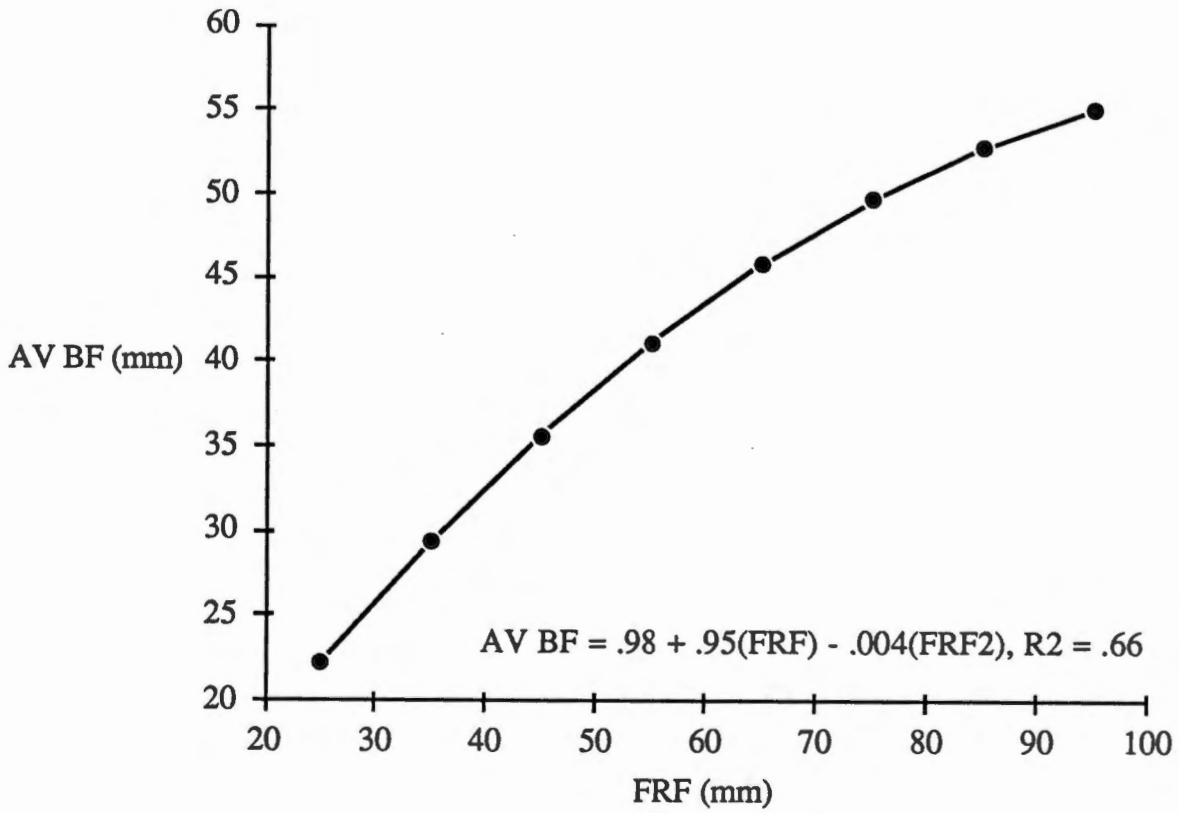


Figure 4.2

Relationship Between Average Backfat
and First Rib

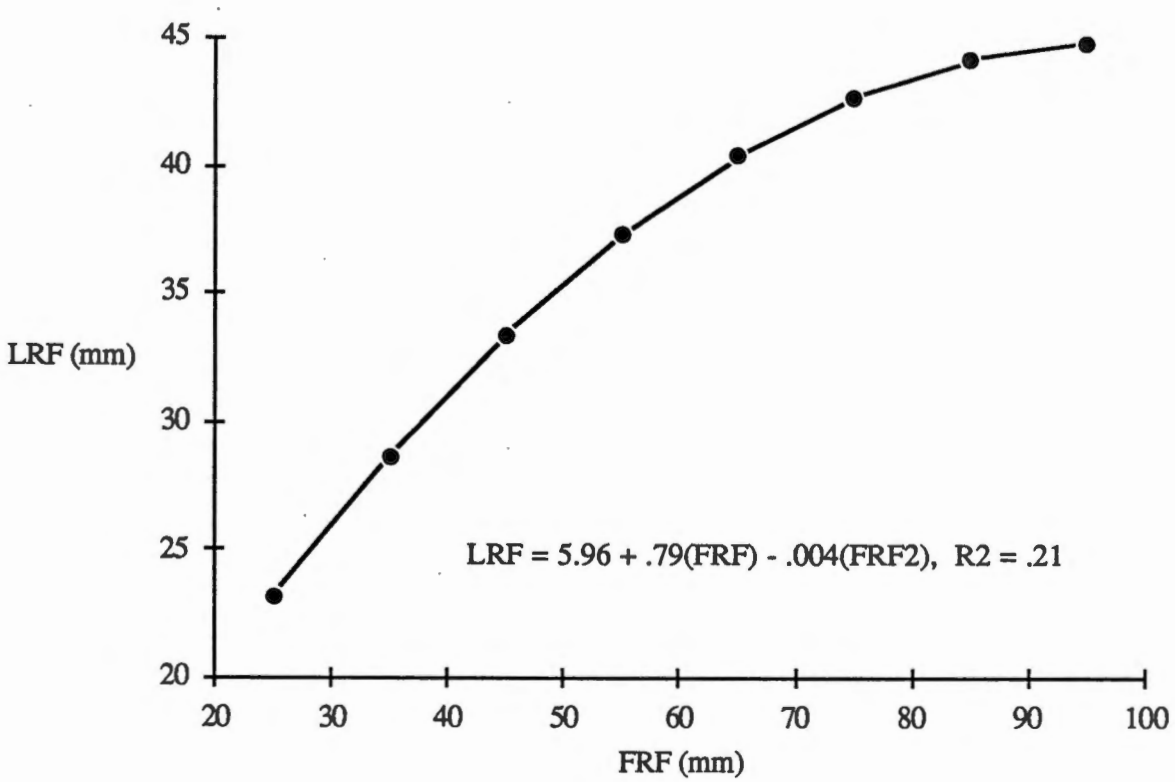


Figure 4.3

Relationship Between First Rib Fat
and Last Rib Fat

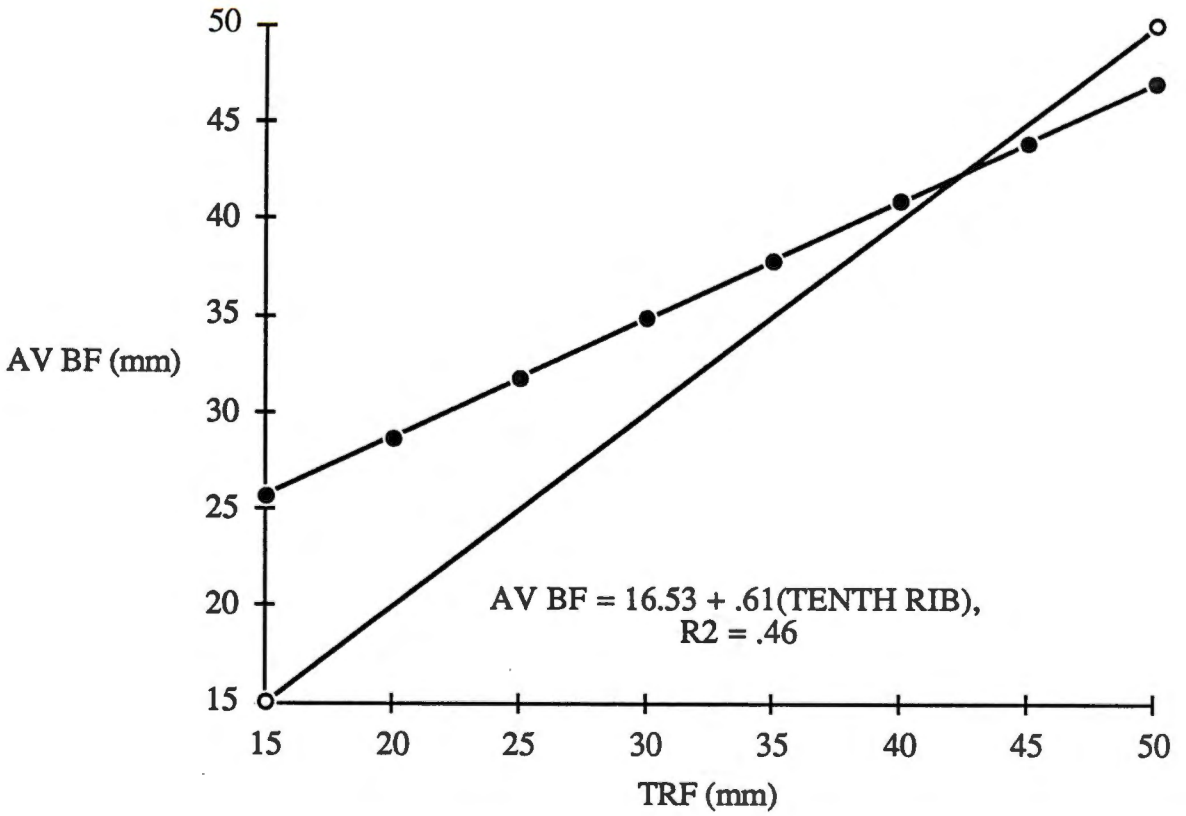


Figure 4.4

Relationship Between Average Backfat and Tenth Rib Fat

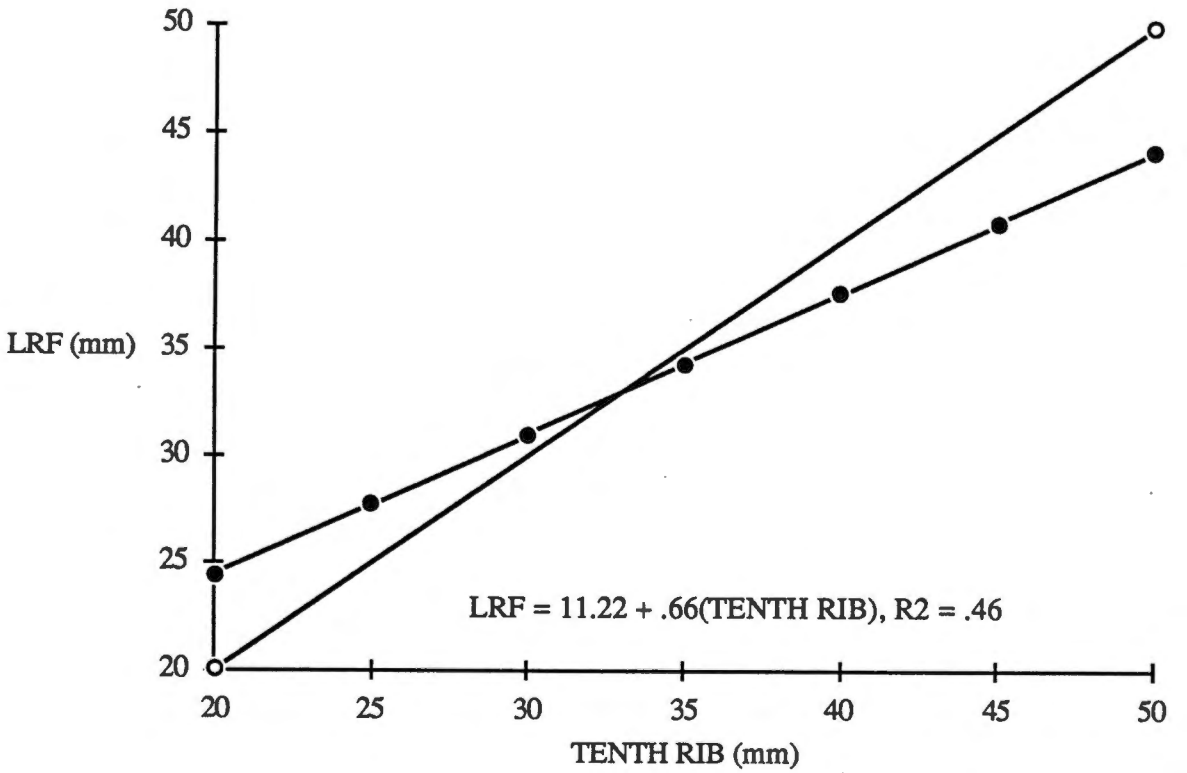


Figure 4.5

Relationship Of Last Rib Fat and
Tenth Rib Fat

fat increased at a faster rate up to 34 mm after which tenth rib fat depth increased at a faster rate. This may be due to tenth rib fat being a slightly earlier maturing fat depot than last rib because of being more anteriorly located.

Figures 4.6 and 4.7 illustrate the relationships between average backfat and last rib fat with the tenth rib three-quarter measurement. Both best fit lines were quadratic relationships. These plots suggest that average backfat and last rib fat increase at a slower rate than the tenth rib three-quarter until apprximately 40 and 45 mm. Average backfat and last rib fat both were greater than the tenth rib three-quarter fat measurement for the fat depth ranges in used in this study.

Finally, last lumbar fat was a linear response in relation to average backfat and last rib fat as depicted in Figures 4.8 and 4.9. Last lumbar fat never exceeded average backfat in the range of fat measurements studied. This relationship has a high R^2 value of .76, probabily due to last lumbar fat being a component of average backfat. Last lumbar fat did not exceed last rib fat until approximately 35 mm. The regression of last lumbar fat on last rib fat resulted in a R^2 value of .53.

The relationship between last rib and average backfat was a linear response. In addition, first rib and tenth rib three-quarter fat had a quadratic response to last rib and average backfat. First rib plots with last rib fat and

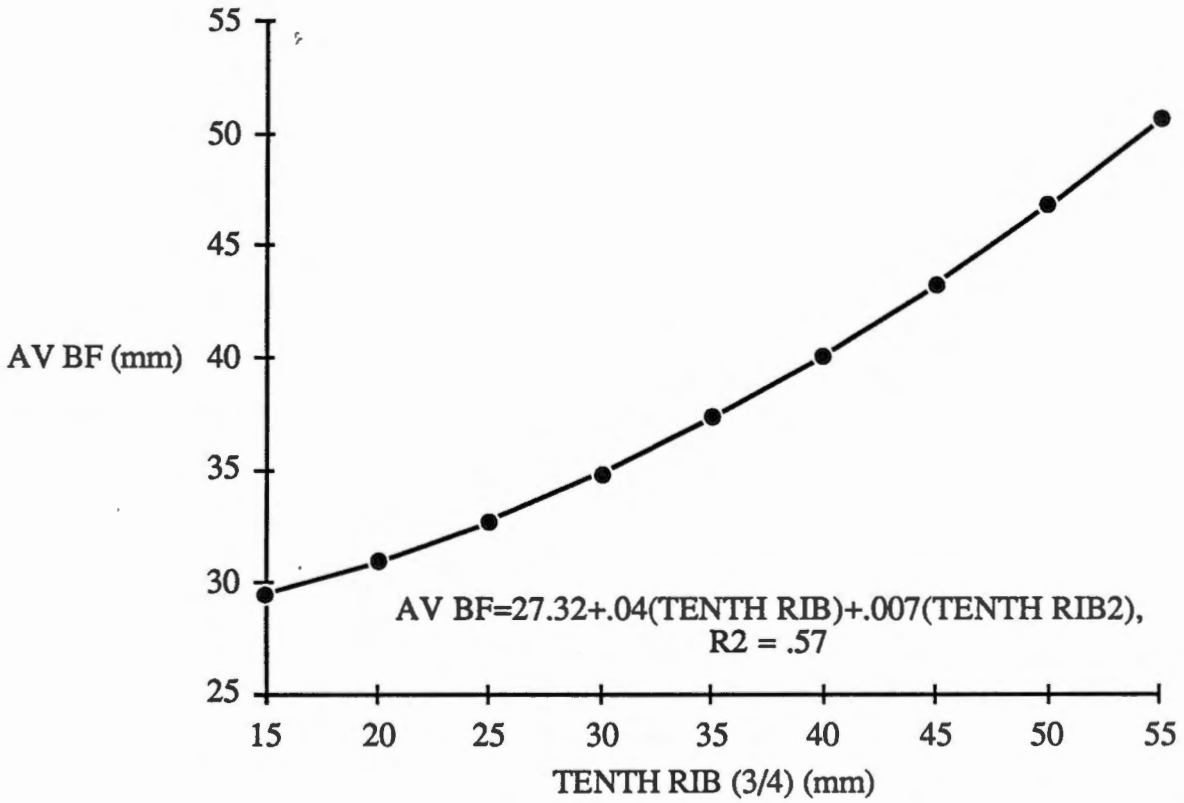


Figure 4.6

Relationship Between Average
Backfat and Tenth Rib (3/4) FAt

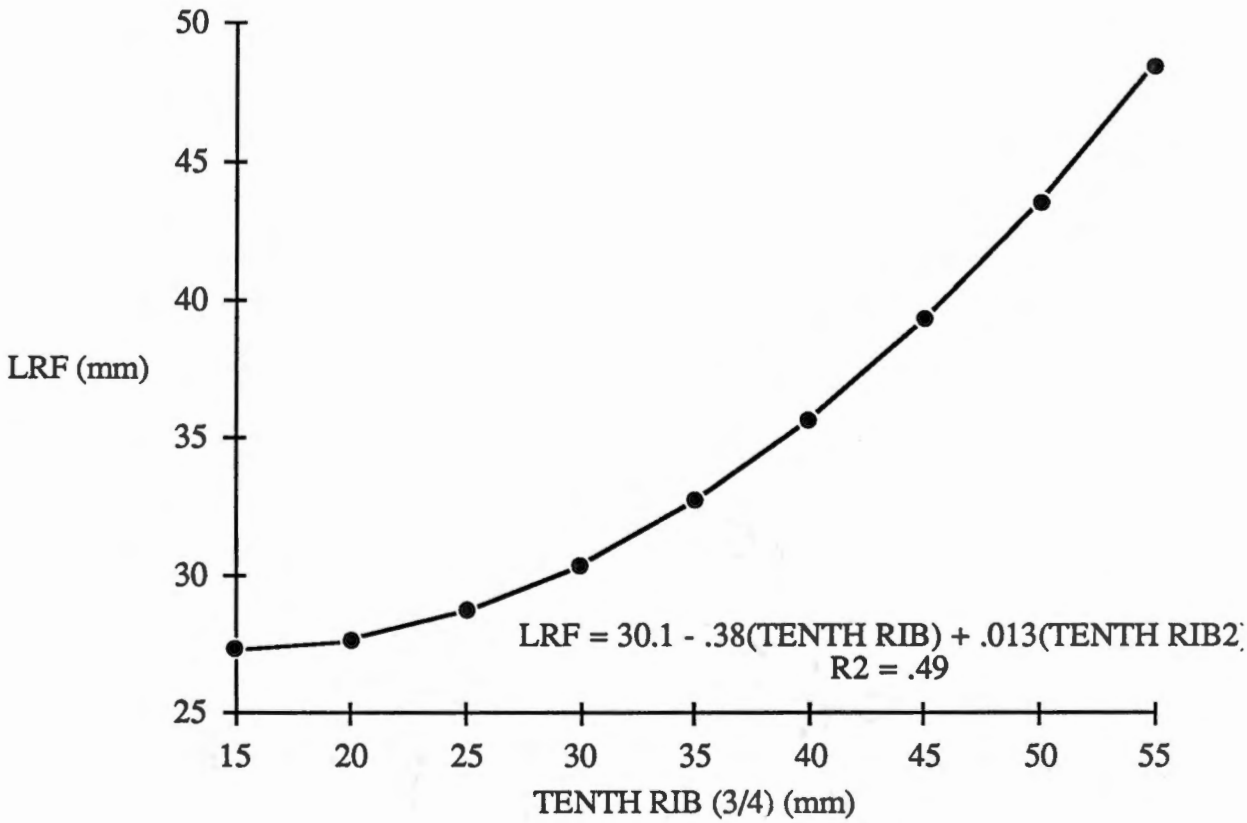


Figure 4.7

Relationship Between Last Rib Fat
and Tenth Rib (3/4) Fat

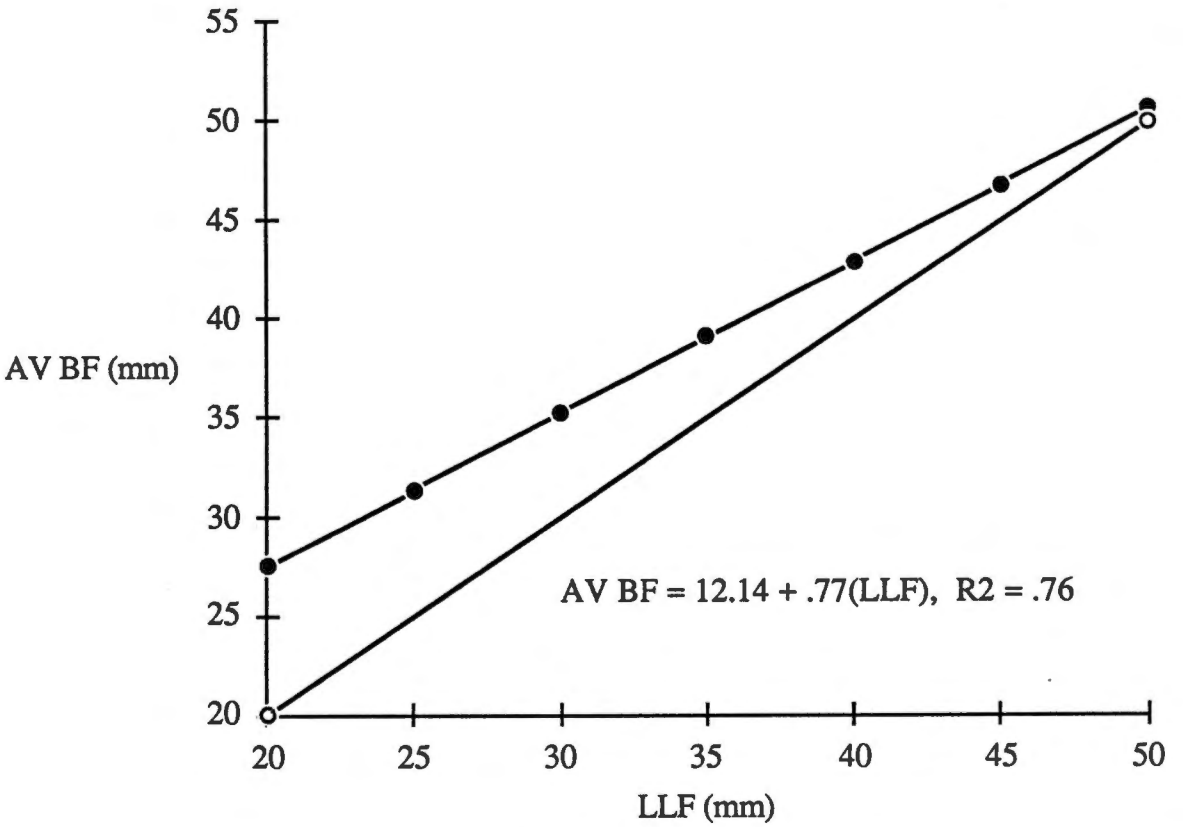


Figure 4.8

Relationship Between Average Backfat and Last Lumbar Fat

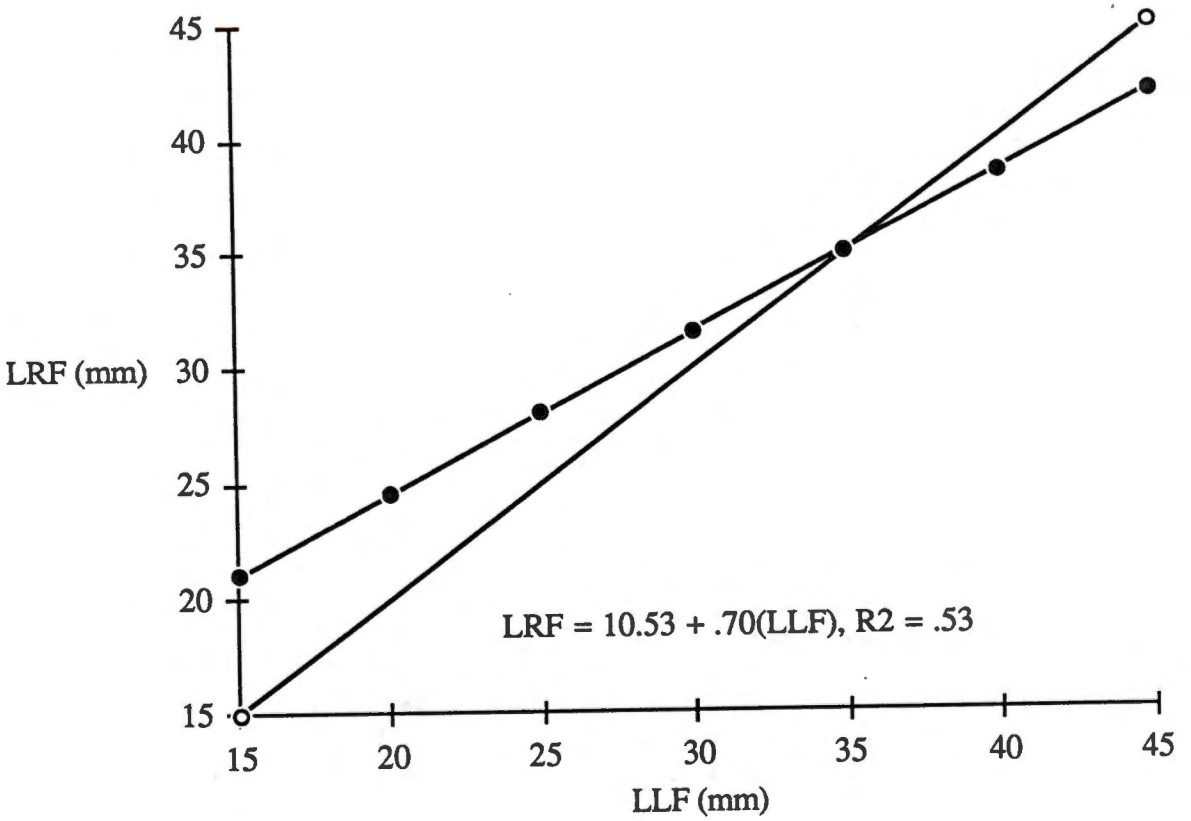


Figure 4.9

Relationship of Last Rib Fat and
Last Lumbar Fat

average backfat were concave best fit line whereas tenth rib three-quarter responses to last ribfat and average backfat were convexlines. Graphic interelationships suggest that posterior fat deposition sites increased at faster rates during the later part of the fattening phase. This is in disaggrement with Kempster and Evans (1979) study, which stated that relative growth of fat depots was lowest in the proximal limb (ham and shoulder) however, incresed inwards towards the back. This difference in results is probabily due to coefficent of fat measurements being used. In addition, the best fit lines suggest that dorsal measurements increased faster than ventral measurements.

Chapter V

EFFECTS OF FEEDER PIG SUBJECTIVE AND OBJECTIVE MEASUREMENTS ON FAT DEPOSITION PATTERNS

1. SUMMARY

Seventy-two fat measurements were taken systematically on 186 pork carcasses in order to attempt to characterize fat deposition patterns of slaughter hogs. Predicted fat values were developed by a polynomial equation to characterize the mean surface fat plane of the slaughter hogs. Six predicted values were then choosen which characterize the overall change in fattening patterns. The six predicted fat values were: 1) second rib-medial edge, 2) second rib-60% of the distance from the medial edge to the belly edge, 3) last rib-medial edge, 4) last rib-60% of the distance from the medial edge to the belly edge, 5) third sacral-medial edge and 6) third sacral-60% of the distance from the medial edge to the belly edge. A multivariate analysis of variance was then performed using the six predicted fat values as the dependent variables and objective and subjective feeder pig measurements as the independent variables. The objective measurements, estimated bone and estimated body depth, both influenced fat deposition patterns. In addition, some influence was also

expressed by overall frame, body width and frame height. None of the subjective measurements affected the fat deposition pattern (P>.05).

2. INTRODUCTION

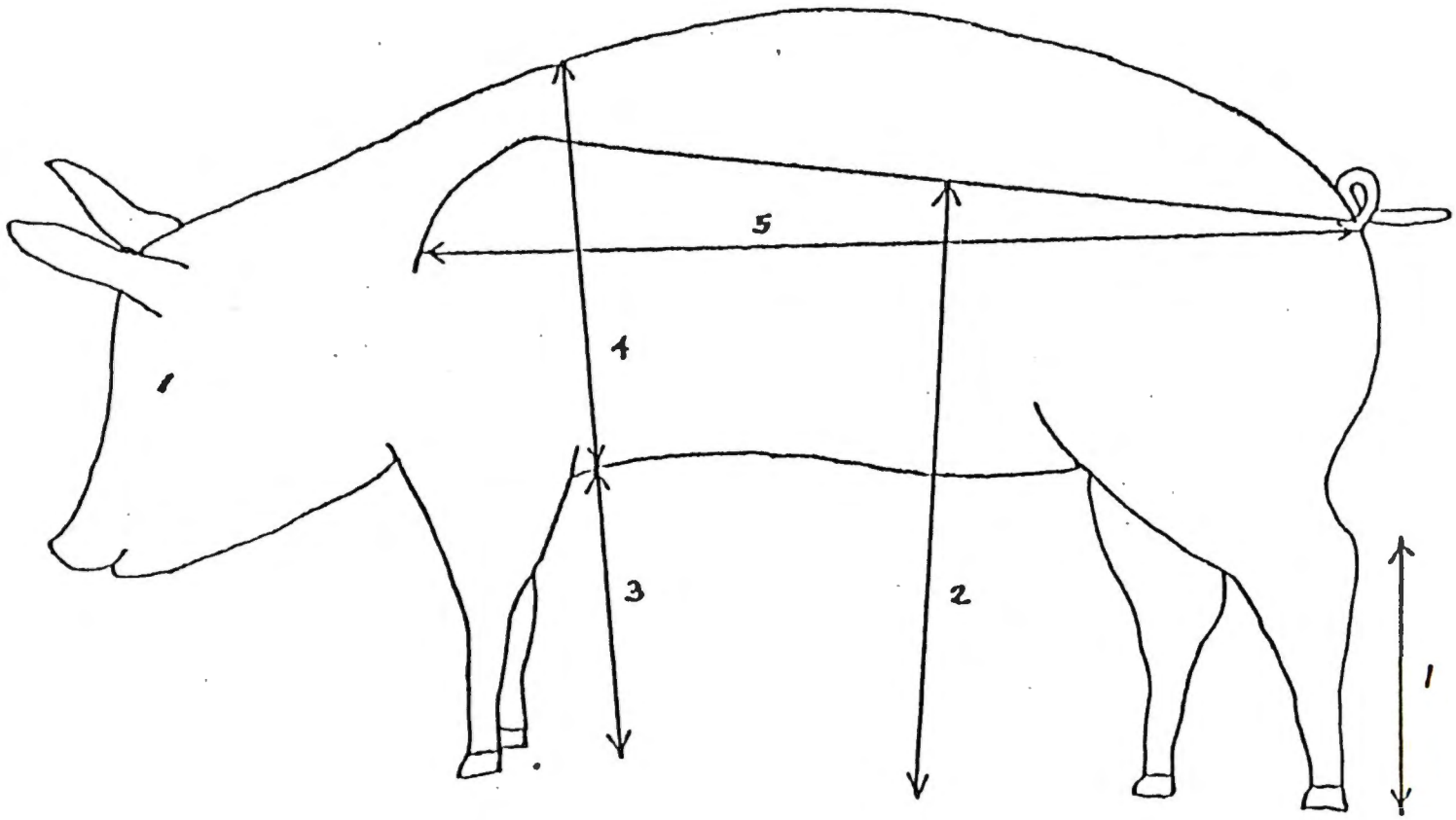
Research has being conducted to use linear measurements in regression equations in hopes of improving prediction of carcass merit (Pace, 1986 and Siemens, 1985). Once feeder pigs are designated into groups on body type, will there be a difference in fat depositon patterns?

This experiment was conducted to characterize fat deposition patterns of hogs based on objective and subjective descriptions of feeder pigs.

3. MATERIALS AND METHODS

One hundred hundred and eight-six feeder pigs (80 U.S. No. 1, 80 U.S. No. 2 and 60 U.S. No. 3 feeder pigs) were purchased through a Tennessee graded feeder pig sale. Feeder pigs were then delivered to the University of Tennessee Plateau Experiment Station feeder pig facility where the pigs were subjectively evaluated by trained evaluators on a scale of 1 to 5 for: frame height (1 = very short, 5 = very tall), frame length (1 = very short, 5 = very tall), overall frame (1 = very short overall, 5 = very long overall), muscle score (1 = thin, 5 = very thick),

estimated propensity to fatten (1 = tend to fatten at light slaughter weight, 5 = tend to fatten at heavier slaughter weight), body width (1 = very narrow, 5 = very wide), belly depth (1 = very shallow, 5 = very deep) and bone (1 = very fine, 5 = very heavy). Feeder pig traits objectively measured included: initial weight, sex, length from poll to tail, body girth posterior to front leg as well as ultrasonic measurements of fat depth at the first rib, last rib and last lumbar vertebrae and an ultrasonic measurement of tenth rib longissimus muscle depth. A photographic slide of each pig was taken and the following life scale measurements were obtained from the developed slide (Figure 5.1): hock length, body depth, height from floor to belly, height of midpoint between shoulder and tail and length from point of shoulder to tail. A scatter plot of poll to tail length versus initial weight was generated to allot similar pigs to slaughter endpoints of 91, 104 or 118 kg (SG I, SG II and SG III, respectively). The pigs were then assigned to similar pen groups, fed ad libitum a 16% corn-soybean meal-premix ration and were slaughtered as they reached their assigned slaughter weight ($\pm$ 2 kg) at a local packing plant. Leaf fat was removed and hot carcass weight recorded. Carcasses were chilled 24 hours and one side was then transported to the University of Tennessee meat laboratory. Carcasses were standardized (Grisdale, 1984) by



1 = Hock Length
2 = Height of Midpoint between Shoulder and Tail
3 = Height from Floor to Belly
4 = Body Depth
5 = Length from Point of Shoulder to Tail

Figure 5.1 III. Objective Measurements from a Photograph

removing the jowl (at the atlas vertebrae), the hanging tender and the tail (between the first and second coccygeal vertebrae). Other carcass data collected included medial backfat thickness at the first rib, last rib and last lumbar vertebra, medial tenth rib fat depth, carcass length (anterior edge of the first rib to the anterior edge of the aitch bone) and muscle score in accordance with 1970 and 1985 grade standards (USDA, 1970; USDA, 1984). Carcasses were then cut into the primal cuts of ham, loin, shoulder, belly and spareribs (Cole, 1951). Upon cutting the carcasses into primals a series of fat depth measurements were taken at 20% increments along the length from the medial split surface to the belly edge. Therefore, five measurements were recorded at the jowl, second rib, sixth rib, tenth rib, last rib, third lumbar, last lumbar and third sacral. The ham was also divided into 4 slices as measured from the butt face to the stifle joint. Ham slices one through three were also measured at 20% intervals along the circumference. Ham slice four was measured at only 25% intervals because of the smaller overall circumference. Each of these measurements were to the lean or false lean surface.

A polynomial equation was used to predict fat values to charactarize the mean surface fat plane of the slaughter hogs. The lateral measurements started at a point adjacent to the split surface to the belly seperation. The medial

measurements started at the jowl and continued along the split surface to the ham. The prediction equation of the surface plane consisted of: lateral + lateral ^{3} + medial + medial ^{2} + medial ^{3} + (lateral*medial) + (lateral*lateral*medial). Six predicted values were then chosen which characterize the overall change in fattening patterns which were at 11, 45 and 74% of the medial measurements and at 0 and 60% of the lateral measurements. A multivariate analysis of variance was then performed using the six predicted fat values as the dependent variables and the objective and subjective feeder pig measures as the independent variables (SAS, 1985).

4. RESULTS AND DISCUSSION

Predicted fat values were derived by a quadratic equation to characterize the mean surface fat plane of the slaughter hogs. The predicted fat values were then ploted along with laterial and medial percentages producing a three-dimensional plot, which corresponded to the seventy-two fat measurements taken (Figure 5.2). As depicted by the laterial measurement, starting at a point adjacent to the split surface (0%) and moving towards the belly separation (100%), fat depth decreased. In addition, although visually hard to perceive, the fattest medial measurement is located at approximately 11.0%, corresponding

to the second rib fat measurement. From this point (11%) continuing on to a posterior point, the predicted fat values decreased until fat measurements at ham slice 4 (94.0% of the lateral measurement).

A contour plot was then used for interpretive advantages (Figure 5.3). On any given line of a the contour plot, a fat measurement corresponds to the legend listed below the diagram. Once again as you go from 0 to 100% (dorsal to ventral) the lateral predicted fat depths decrease. The fattest point along the medial measurement was between the second and third rib (11.0%) and fat depth decreased from the 11% point to the 94% point. Six predicted values were then choosen which characterized the overall changes in the mean surface fat plane. These points were at the second-third rib section, the last rib and at the third sacral vertebrae taken both at the medial split surface (0% lateral measurement) and at 60% the distance from the split surface ventral to the belly separation. A multivariate analysis of variance was then performed using the six predicted fat values as the dependent variables and the objective and subjective feeder pig measures as the independent variables. The effects of estimated bone dimensions ($P<.04$) and estimated body depth ($P<.09$) both influenced fat deposition patterns (Table 5.1). In addition, some influence was also expressed by overall frame, body width and frame height ($P<.18$, $P<.16$ and $P<.19$

Table 5.1. Multivariate Analysis of Variance for Swine Fat Deposition Patterns as Influenced by Subjective Feeder Pig Measurements.

Body Measurement	DF	Multivariant Value P>F	Wilks' Lambda Test P>F
Bone	48	.555	.037
Est. Body Depth	36	.654	.090
Est. Fat	54	.599	.315
Frame Overall	36	.678	.176
Frame Length	42	.725	.781
Muscle Score	60	.601	.537
Body Width	60	.537	.156
Frame Height	42	.643	.187

Table 5.2. Results of Multivariate Analysis of Variance for Fat Deposition Patterns of Hogs as Influenced by Objective Feeder Pig Measurements.

Body Measurement	DF	Multivariant Value P>F	Wilks' Lambda Test P>F
Body Depth	12	.952	.794
Belly Height	12	.900	.152
Body Girth	12	.915	.289
Hock Length	12	.922	.373
Loin Depth	12	.915	.282
Last Lumbar Fat	12	.980	.994
Poll to Tail	12	.969	.959
Shoulder to Tail	12	.919	.325
First Rib Fat	12	.952	.790
Mid Point Height	12	.916	.292
Last Rib Fat	12	.939	.604

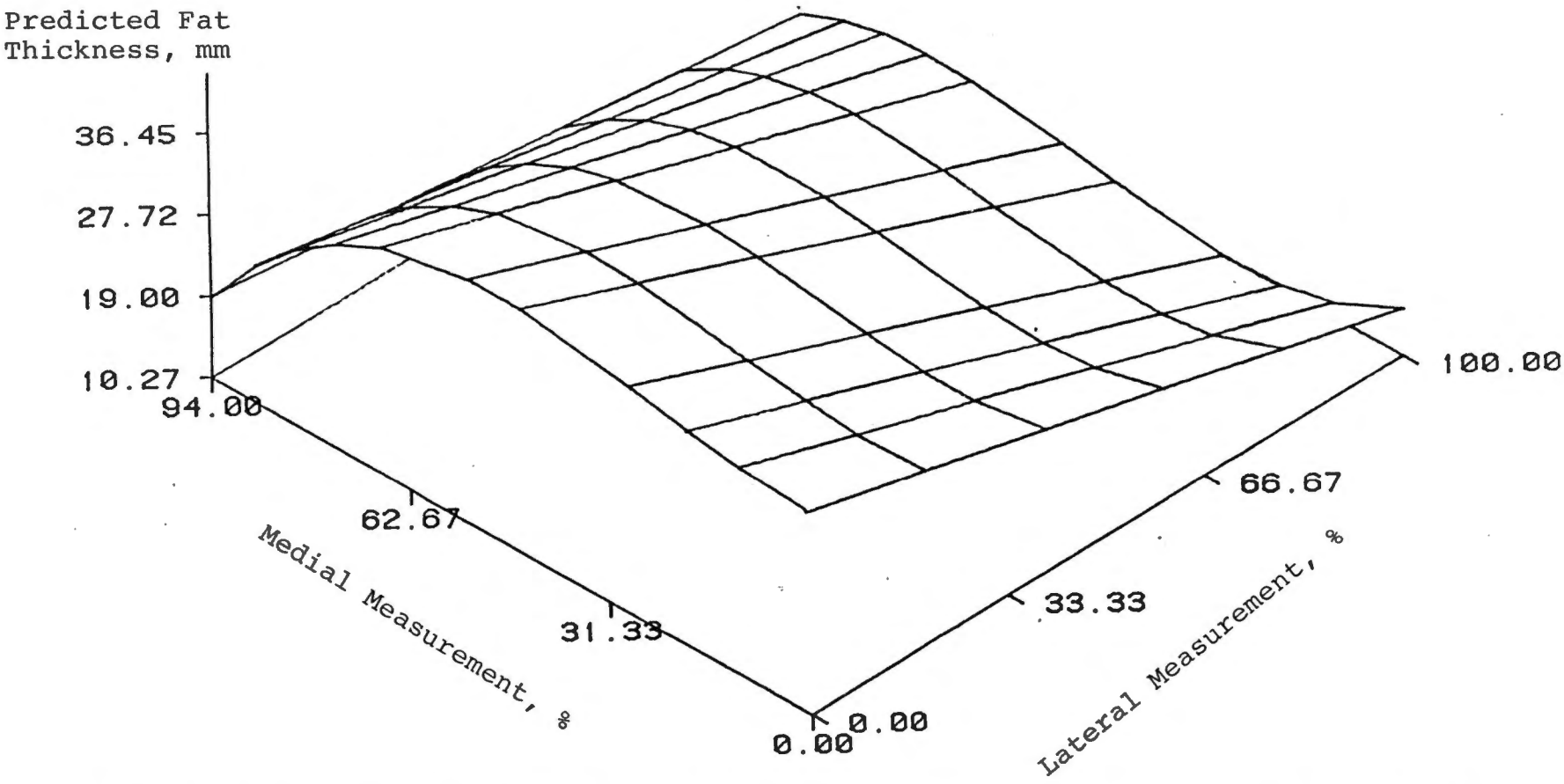


Figure 5.1 Plot of Predicted Fat Thickness Measurements to Characterize the Mean Surface Fat Plane for Slaughter Hogs

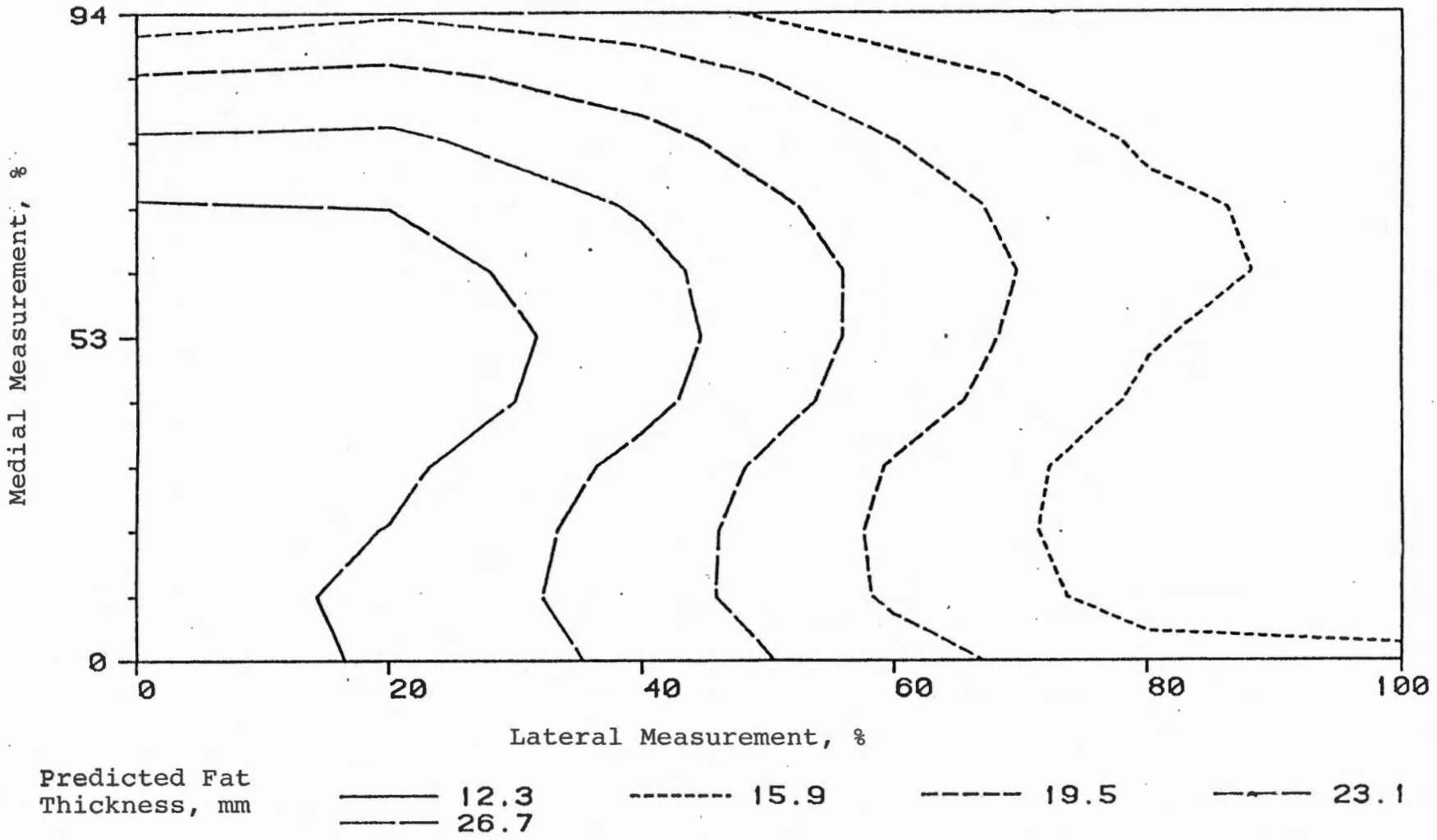


Figure 5.3 Contour Plot of Predicted Fat Thickness Measurements for Slaughter Hogs

respectively). None of the objective measures (Table 5.2) influenced fat deposition (P>.15). and few subjective measures had an effect on fat deposition patterns. The relationship of estimated bone and fat deposition was not expected and is difficult to explain.

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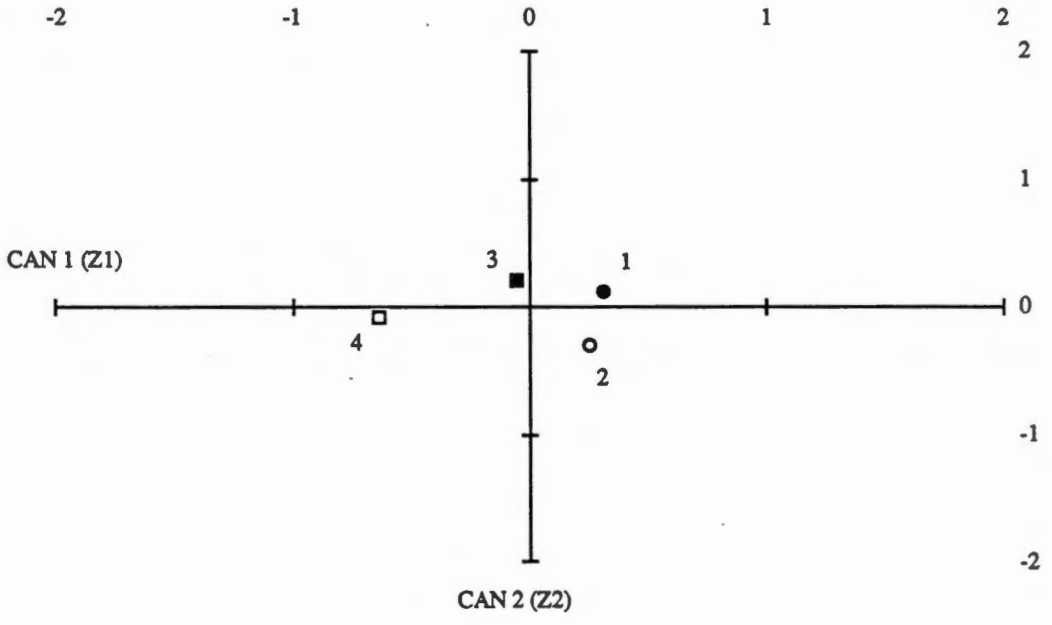
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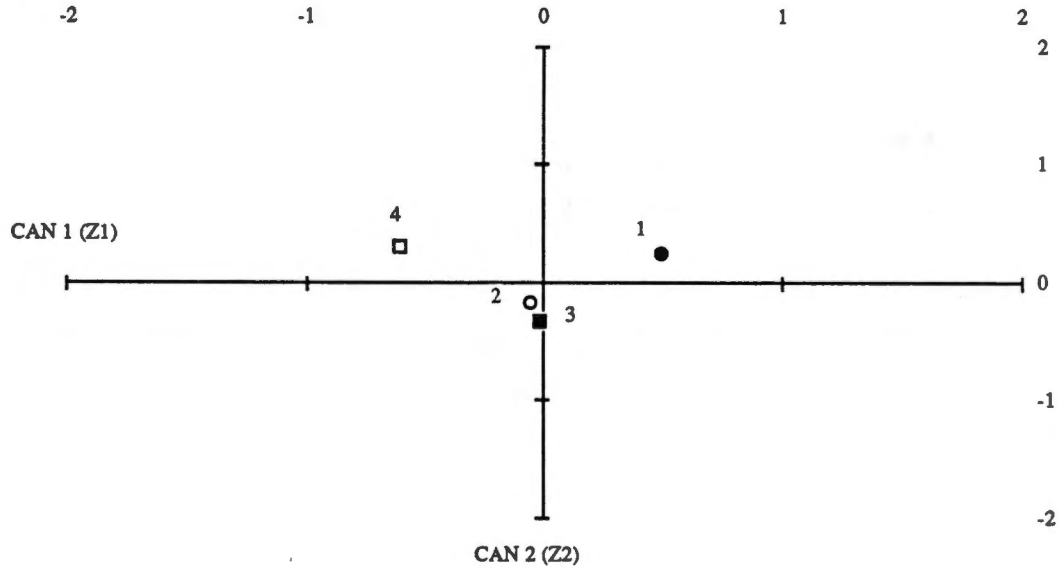
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APPENDIX



Canonical Variates Plot of The Subclass Means for Predicting Lean Cut Percentaes by Objective Traits



Canonical Variates Plot of the Subclass Means for Predicting Lean Cut Percentages by Subjective Traits

VITA

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