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Carcass Evaluation in Live Hogs

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This bulletin is a report of research under Project 3, "Improvement of swine through breeding," Department of Animal Husbandry in cooperation with the Regional Swine Breeding Laboratory, A.H.R.D., A.R.S., U.S. Department of Agriculture.

Carcass Evaluation in Live Hogs

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In general, two possible methods are available for altering the composition of the hog: (1) alteration of external environmental factors such as feeding and management practices and (2) changing the internal environment or physiological constitution of the animal by modifying his genetic makeup through breeding. Both methods are being used to alter swine type with a moderate degree of success.

If full use is to be made of these methods of altering carcass composition, however, more accurate means of evaluating prospective breeding animals than personal judgement must be developed.

The most fundamental concept of successful livestock breeding is intelligent selection of parental stock for those characteristics deemed desirable. Selection may be based on three criteria (1) individuality of the animal under consideration, (2) pedigree, line, or family from which he comes, and (3) performance of his progeny. Selection on the basis of individuality can be classified as a direct method and the latter two as indirect methods. The statistical concepts of "repeatability" and "heritability" are widely used in conjunction with selection to ascertain the emphasis which specific traits merit in a selection procedure.

The absence of accurate methods of estimating carcass merit in the live hog has led to the use of indirect methods of selection in countries such as Canada, England, and Denmark with selection of breeding animals based on progeny slaughter studies. In such work, the assumption is made, and substantiated, that the carcass traits exhibited by the progeny are indicative of similar traits exhibited in the parents. An alternate indirect method of selection used to some extent in this country has been the establishment of inbred lines from ancestors of known carcass quality with test samples taken within these lines and their crosses.

Subjective live-hog scores have been used almost universally in the past to predict carcass composition. Not until quite recently has the accuracy of such scores been seriously questioned. These inquiries have led to a limited number of studies to ascertain the value of subjective scores. Body measurements have been used in some instances in attempts to increase the reliability of carcass evaluation from the live hog. The most recent advance in the field has been made by the introduction of the live-hog backfat probing technique, an external measure which comes closer to predicting an actual carcass measure than was previously thought possible.

Objectives of this study were:

1. To determine and evaluate some of the internal and external environmental sources of variation which contribute to variance in live-hog and carcass measurements.
2. To determine the effectiveness of live-hog subjective scores, body measurements, and backfat probes in estimating yield and composition of the carcass.
3. To determine the interrelationships between live-hog subjective scores, body measurements, and backfat probes and to derive the combination of these measures which gives the best estimates of carcass characteristics.
4. To determine the relationships between some economically important characteristics and carcass composition.

REVIEW OF LITERATURE

Factors Affecting Live-hog Measurements, Scores, and Carcass Characteristics.

If live-hog measurements and backfat probes are to be used to estimate carcass yields and composition, it is necessary to qualify the sample studied in regard to genetic and nutritional factors. The importance of factors observed in the live hog cannot be fully appraised since the degree changes in carcass composition are reflected in observable changes in the live-hog measures is not known. Undoubtedly, considerable positive relationship does exist because backfat probe measurements have proven highly correlated with carcass backfat, which, in turn, is associated with intramuscular fat.

Variations in type attributable to genetics are such that an increase of any one specific live-hog measurement may produce a desirable change in carcass composition within one population (breed, line, etc.), while the reverse situation exists in another population. Invariably, most earlier studies have disregarded grouping of data into homogeneous samples or have limited grouping to one classification.

A moderate amount of work has been conducted concerning the *level of nutrition* as an influence on carcass composition. Ellis and Zeller (1934) reported that restricting feed intake was effective in increasing the relative amount of lean meat in the carcass. Using a highly inbred line of large white hogs, McMeekan (1940 and 1941) showed that body tissues exhibit differential growth behavior. Bone and muscular tissue development occurred first, succeeded by fat elaboration. The significance of these studies was to show that rapid early growth intensifies bone and muscle growth, whereas accelerated growth at a later age intensifies fattening. These workers concluded that the genetic makeup can be modified by nutrition.

Work by Winters, Sierk, and Cummings (1949) did not completely agree with the findings of McMeekan. Both McMeekan's and Winters' work showed that animals fed a restricted diet from weaning to market weight produced the leanest carcasses. However, in McMeekan's studies, pigs full-fed during the first period and then limited-fed during the second half yielded better carcasses than those limited- and then full-fed. The work of Winters showed no difference between limited-full, or full-limited feeding methods. The group that received the restricted ration throughout the feeding period required the least feed per 100 pounds of gain.

Gregory (1951) found that the carcasses of limited-fed pigs (87 percent of full feed from weaning to slaughter) yielded 2 percent more lean than those which were full-fed. However, the reduced dressing percentage cancelled the superiority of carcass quality so that no advantage in net carcass value per unit of live weight could be credited to limited feeding.

Cummings and Winters (1951) concluded from a study of factors related to carcass yields in swine that carcass composition was altered by subjecting similar genetic material to different levels of feed intake. By restricting the feed intake within each breed to 3 percent of the body weight, the yield of the five primal cuts was increased 2.4 percent and the fat was reduced 3.6 percent. No differences were observed among the breeds studied (outbred-purebred Poland China, Duroc Jersey, and Chester White) in yield of five primal cuts. However, the Poland Chinas constantly yielded less fat than either of the other two breeds, regardless of the method of feeding. Working with the same three outbred lines and comparing them with inbred lines produced from the Minnesota Swine Breeding Project and market-run hogs, these workers showed that the Minnesota hogs produced carcasses yielding the highest percentage of five primal cuts and the lowest degree of fatness. Carcass differences between lines and crosses have also been revealed at the Oklahoma Experiment Station by Whiteman, Hillier, and Whatley (1951). Wilson *et al.* (1953) reported that higher levels of protein in the growing-fattening hog ration were conducive to learner carcasses and that the addition of aureomycin and vitamin B_{12} to lower protein rations increased carcass merit.

Other differences can be cited concerning the effects of genetics and nutrition on carcass composition. In general, however, it can be concluded that differences between breeds and between lines in the same breed suggest that heredity as well as nutrition plays an important role in causing variation in carcass composition.

Fourteen carcass characteristics were studied by Foley (1956) on the 118 pigs produced in 1954 for the research project reported herein. The spring-farrowed pigs exhibited highly significant differences between the sire groups for leg length, carcass and live-hog backfat thickness, belly thickness, adjusted loin equivalent and percentage of fat cuts. Significant sire group differences were also found for loin area, ham index, dressing percentage and percentage of five primal cuts. In the fall-farrowed pigs, considerably fewer differences existed in the carcass characteristics between sire groups with only belly thickness and percent bone being significantly different at the 1 percent level. Statistically significant differences were observed for carcass length and loin area. It should be noted that sire group comparisons were made for each season separately and included both barrows and gilts in unequal numbers. For distribution of sexes by sire groups, reference is made to Tables 5 and 7. A review of work of a similar nature by Stothard (1938), Stonaker and Lush (1942), Hazel, Baker and Reinmiller (1943), and others shows sire differences in almost all live-hog characteristics studied, including live-animal scores, various carcass characteristics, and rate of gain.

Seasonal differences in carcass characteristics were observed in the study by Foley (1956), with the fall-farrowed pigs exhibiting larger mean values for all traits studied except carcass length, leg length, and percent bone. Here, as in the sire grouping, uncorrected sex differences existed within the groups, which might have influenced the findings. (The work by Stonaker and Lush, 1942, on live-hog scores also indicated considerable season variation.)

Further variation in carcass characteristics were attributable to sex with comparisons made for each season. In the spring-farrowed litters, barrows exceeded gilts in leg length, carcass and live-hog backfat probes, and percentage of fat, with gilts exceeding in loin and ham area and adjusted loin equivalent. Fall litters showed gilts exceeding in body length, belly thickness and bone, whereas barrows were once again higher in carcass and live-hog backfat.

Considerating data from both seasons, gilts were generally longer in body and had a higher percentage of lean meat than barrows which, in turn, exhibited a greater amount of fat. These findings are in accordance with those of Lacy (1932); Warner, Ellis and Howe (1934); Hammond and Murray (1937); Bennett and Coles (1946); and Fredeen (1953).

Graphic presentations of interaction were shown by Foley which appeared to indicate sire x season interaction in regard to the carcass characteristics studied, although mathematical verification was not submitted.

Effectiveness of Live-hog Subjective Scores, Body Measurements, and Backfat Probes in Estimating Carcass Yields and Composition.

Evaluation of carcass merit from live-hog observations has always been a subject of keen interest to the animal husbandman, and an enormous amount of study has been devoted to the subject. Subjective scoring and ranking on the basis of conformation have been used traditionally. Only recently have carcass studies been conducted in consanguinity with live-hog scoring. A limited amount of work has been conducted on the use of absolute live-hog measurements, with the objectives directed toward increasing the accuracy of carcass estimates. The introduction of live-hog backfat probes has been the most recent and promising advance in the field.

Several workers have reported relationships between various live scores and carcass characteristics. Reinmiller (1940) found a coefficient of correlation of 0.37 between total score for live hogs and their split carcass score. A coefficient of correlation of 0.61 between score for length and measured carcass length was shown by Phillips *et al.* (1940). They also found the correlation between live score for ham plumpness and index of ham plumpness in the carcass to be 0.80. Williams and Krider (1943) found a highly significant correlation of 0.42 between the condition (fatness) as determined by visual observation of the live-hog and carcass backfat. Ensminger *et al.* (1950) also studied relationships between live-animal scores and carcass items. They reported an unusually high coefficient of correlation of 0.99 between score for length of hind leg and measured length of hind leg in the carcass.

Bratzler and Maqerun (1953) scored 434 market-run hogs for body length, finish, and estimation of preferred cuts yield. These scores were then correlated with the corresponding carcass characteristics. Three judges conducted the scoring and individual correlation coefficients were calculated within three slaughter weight groups. Highest correlations were reported for body length and backfat in the 181 to 200-pound (.57 to .66) and 201 to 220-pound (.29 to .42) hogs, with very low correlations for these same items in the 221 to 240-pound hogs (.13 to .18). In all weight groups, the correlations were not statistically significant with respect to the percentage of preferred cuts (-.08 to .35).

Arthaud (1953) undoubtedly conducted the most extensive study of live-animal scores with carcass yields and composition undertaken to date. Fifteen different live-animal scores were correlated with various carcass characteristics in four purebred strains and 23 strain crosses during three seasons. Arthaud, in contrast to earlier workers, continued beyond zero-order correlations and attempted by means of multiple correlation to determine which combination(s) of nine live-animal scores and carcass backfat thickness provided the most accurate estimate of carcass worth. The adjusted loin equivalent was used as a measure of net carcass merit. A multiple correlation value of 0.56 was found between adjusted loin equivalent and eight live-hog scores and average carcass backfat (this was not a live-hog measurement but was taken after slaughter). The eight scores and measured carcass backfat were used as independent variables. When carcass backfat was excluded from the multiple correlation, a value of 0.51 was obtained. The most valuable live-hog scores were: body width, shape of back, shape of ham, quality, leg length, and smoothness of shoulder. Using these six scores together gave a multiple correlation value of 0.51. All of Arthaud's multiple correlations were calculated within-season, feeding level, and breeding groups.

Work to determine the value of body measurements for predicting carcass composition has been very limited. Hetzer *et al.* (1950) studied 141 hogs of six crosses, measuring eight items, namely, length from ear to tail, height at shoulders, width at shoulders, width of middle, width of ham, depth at chest, depth of middle, and circumference at chest. Yield of five primal cuts and yield of lean meat in hams expressed as a percentage of live weight at slaughter were used as bases of carcass evaluation. Upon analyzing the mean values, it was noted that gilts averaged about 0.8 cm. less in width of middle and yielded about 1.0 percent more in the five cuts and 0.72 percent more in lean meat in the ham than barrows. These differences were significant and, therefore, analyses were made for each sex separately. When all eight items were correlated with the yield of the five primal cuts, depth of middle was the most important item for both barrows and gilts, with the coefficients of multiple determination equal to 0.46 and 0.45, respectively. Using only the three items with the greatest predictive influence (width of middle, height at shoulders, and depth of middle for barrows and height at shoulders, width at shoulders, and depth of middle for gilts) values of 0.31 and 0.38 were obtained. From the analysis of the yield of lean meat in the hams, it was found that width at hams was the most important measure for both barrows and gilts, followed by depth of middle and width of middle for the barrows, and depth at chest and width of middle for the gilts.

Hazel and Kline (1952) introduced the "probing" method of measuring backfat thickness in live hogs and presented several correlations of the probes with various carcass characteristics. Ninety-six animals consisting of single and three-breed crosses of inbred lines of Poland, Landrace, Duroc, and Chester White were measured at a slaughter weight of 215 pounds. Computations were made on an intrabreed-group basis to "eliminate" breed differences in fatness and conformation. Most animals studied were barrows, thus no sex differences were to be contended with. They found coefficients of correlation ranging between -0.41 and -0.45 for carcass backfat measurements and lean loin area, lean ham area and percentage of primal cuts. Averages of four live-hog backfat measurements gave correlation values with these same three items which ranged between -0.44 and -0.54. Thus, backfat measurements in the live hog were as accurate for measuring leanness as those taken in the carcass.

In a study by Zobrisky *et al.* (1954), 207 hogs of approximately 206-pound live weight, consisting of 122 Landrace x Poland China crosses, 76 Hampshires, and nine Durocs constituted the experimental animals. No classification or grouping was undertaken, and all correlation statistics were calculated on the sample in its entirety (gross correlations). Most of this work was concerned with carcass evaluation, although they did report some correlations between live-hog backfat probes and carcass composition. Three backfat probes were taken behind the shoulder, in front of the hip bone, and half way between the hip bone and the root of the tail. Coefficients of correlation between averages of these three probes and the percentage of four lean cuts, five primal cuts and the percentage of fat were -0.36, -0.35 and 0.61, respectively. In a comparable study by DePape and Whatley (1954) they found correlation coefficients between averages of six probes in the live hog and carcass backfat to be 0.69 whereas the correlation between this average and the percent of primal cuts was -0.67.

Hetzer, Zeller, and Hankins (1956) made a study of carcass yields as related to live-hog probes in boars, barrows, and gilts from seven inbred lines. Measurements were taken at 150, 175, 200 and 225 pounds behind the shoulder, at the middle of the back, and at the middle of the loin. Intraline regressions of backfat measurements on body weight showed that gilts exceeded both barrows and boars in backfat at 150 pounds, but barrows laid on fat faster until at 200 pounds they exceeded both boars and gilts. Gilts significantly exceeded boars in backfat at all weights. All correlations reported by these workers were made on both an intra-line and intra-sex-and-line basis. As is always the case with such correlations, the intra-sex-and-line correlations were proportionate between the highest and lowest intra-line correlations for each sex separately. The differences between correlations for each sex were not significant in any case. A correlation of .55 ($P < .01$) was shown between average live-hog backfat measurements at 200 pounds and carcass backfat, while values 0.20 ($P < .05$), –0.22 ($P < .05$), and 0.48 ($P < .01$) were reported between live-hog probes (average of all three probes) and dressing percentage, percentage of primal cuts, and percentage fat, respectively. Higher correlations were reported at 225 pounds. When taken at 225 pounds, the probe taken at the middle of the back had the greatest predictive influence on percentage of primal cuts as indicated by a correlation coefficient of –0.34, and was higher than the average of all three probes together where "r" was equal to –0.28. The probe at the loin was the most accurate single location at 225 pounds for measuring the percentage of fat ("r" equaled .50); with the average of all three probes, "r" equaled .54. These researchers concluded that when backfat probes are taken at approximately 200 pounds, they are generally as accurate as carcass backfat in estimating carcass yields.

Relationship Between Growth Rate and Carcass Composition.

Research concerning relationships between various factors of economic importance and carcass composition and quality has not been too rewarding. Apparently, the number of hereditary units influencing expression of these measurable characteristics are myriad, causing an extensive genetic base and thereby facilitating innumerable gene combinations and reassortments.

Lush (1936), in a study of Danish swine, reported very low positive correlations between daily rate of gain and backfat thickness and belly thickness, while a low negative relationship was shown between rate of gain and body length. He concluded that these characteristics were nearly independent of each other and could be considered so in breeding selection.

No significant relationships were reported by Crampton (1940) between rate of gain and length of side or leanness of carcass. Crampton and Ashton (1945) found a significant correlation between rate of gain and loin area. They also showed that a highly significant difference existed between the sexes in rate of gain, with the male pigs superior in this respect.

Dickerson's extensive work (1947) on rate and efficiency of gain related to carcass composition indicated that within a genetic group, rate of gain was positively correlated (.60) with degree of fatness at 225 pounds. Of course, at a given weight, any increase in percentage of fat necessitated a corresponding reduction in bone and muscle, providing the dressing percent remained the same. A negative correlation (–.60 to –.70) was reported between feed requirement and carcass fat.

Working with partially inbred lines of Duroc-Jersey swine, Blunn and Baker (1947) showed a correlation of 0.29 ($P < .01$) between rate of gain from weaning to slaughter and depth of backfat. In their study, a considerable variation in slaughter weight existed (208-255 pounds) for which no correction was made. This may have influenced the magnitude of the correlations reported in this study. Values of -0.36 and 0.18 (both highly significant) were reported for length of hind leg and ham circumference with rate of gain.

Cummings and Winters (1951) studied relationships between various growth-rate factors and yield of five primal cuts, index of fat cuts, and length of carcass for both total and within-breed groups. It is interesting to note that significant breed differences were reported for all factors studied. Growth-rate factors all showed low association with yield of five primal cuts, as well as with the index of fat cuts. Rapid rate of gain in early life was reflected in an increase in carcass length. They concluded that even though the correlations were low, the best carcasses generally came from those genetic groups (consisting of like breeding) making the fastest gains from birth to slaughter.

In 1944 Comstock, Winters, and Cummings, and in 1945, Crampton and Ashton reported significant sex differences in rate of gain. As early as 1932, Lacy demonstrated significant sex differences in certain carcass characteristics. Hammond and Murray (1937) found similar sex differences in carcass characters. Nevertheless, succeeding research workers apparently ignore this (sex) classification, or make no mention of it, when deriving the various correlations between rate of gain and carcass characteristics. Considerable effort has been exerted to remove any variance attributable to genetic differences; such as breed, line, and sire grouping. It would appear that any variable (including sex) which increases sample variance through use of a bimodal distribution would tend to lower the magnitude of the correlations derived therefrom.

MATERIALS AND METHODS

Experimental Animals

The swine used in this study were produced as part of the extensive swine breeding program conducted at the University of Missouri in cooperation with the Regional Swine Breeding Laboratory. In 1953, carcass data were obtained on 81 barrows from spring and fall farrowed litters which were out of Landrace x Poland China crossbred sows sired by Duroc boars. One hundred eighteen barrows and gilts from spring and fall litters were studied in 1954. The 1954 pigs were the progeny of reciprocal crosses between Landrace and Poland lines.

Due to the extent of time involved in collection of these data, it was necessary to execute the research concomitantly with other short-range studies conducted, in part, with subjects of this project. Thus, variations in feeding and management practices were integral parts of this project. At should be pointed out, however, that the superimposition of the projects in no manner reduced the validity of the project reported herein, since all variables so introduced were measurable and could be statistically controlled where deemed advisable.

The male pigs used in this study were castrated at approximately three weeks of age. All animals were immunized for hog cholera and erysipelas at about 56 days of age. At two weeks of age creep feeding was begun in all instances.

Feeding and Management

Spring, 1953. Pigs were allotted randomly at 56 days of age to pasture or dry lot by sire groups. Each of the three sires (Duroc boars 55, 228, and 327) had approximately one-half of his progeny in dry lot and one-half on pasture. Data were obtained on 50 barrows, 28 of which were on dry lot and 22 on pasture. Table 1 summarizes the treatment and sire groupings. The ration used on both pasture and dry lot is given in Table 2. Due to an abnormally hot, dry summer season, little forage was available to those hogs on pasture.

TABLE 1-REPRESENTATION OF TREATMENT AND SIRE GROUPING IN THE SPRING OF 1953

Treatment	Sire 55	Sire 228	Sire 327	Total
Dry lot	8	10	10	28
Pasture	7	8	7	22
Total	15	18	17	50

TABLE 2-BASAL RATION FOR PIGS FATTENED DURING SUMMER, 1953

	Before July 30	After July 30
Ground corn	815	1435
Ground wheat	720	
Tankage	100	200
Soybean oil meal	200	200
Wheat shorts	100	100
Mineral	40	40
Antibiotic*	5	5
B-vitamin supplement**	5	5
A and D supplement†	5	5

*Antibiotic supplement contained 3600 mgm. of chlortetracycline per pound plus unknown quantities of vitamin B_{12}.

**B-vitamin supplement contained 2000 mgm. each of riboflavin, niacin and pantothenic acid per pound.

† A and D supplement contained 2250 IU of vitamin A and 400 IU of vitamin D per gram.

Fall, 1953: All pigs were placed in dry lot as they were weaned at eight weeks of age. The lots were balanced in respect to weaning weight and litter. Data were obtained on 31 barrows approximately equally distributed as to level of feeding previous to slaughter date. All pigs were sired by either Duroc boar 98 or 236. Lots which were full fed were fed from self feeders, whereas the limited fed lots were hand fed a percentage of their body weight based on 85 percent of the amount of feed required for pigs of various weights as stated in the Nation Research Council's recommended allowances for swine (1950). Feed requirements were recalculated each week. Table 3 summarizes the treatment and sire grouping with the ration in Table 4.

TABLE 3-REPRESENTATION OF TREATMENT AND SIRE GROUPINGS IN THE FALL OF 1953

Treatment	Sire 98	Sire 236
Full fed 16 percent protein Chlortetracycline	1	2
Full fed 12 percent protein Chlortetracycline	2	2
Full fed 16 percent protein	3	1
Full fed 12 percent protein	3	1
Limited fed 16 percent protein Chlortetracycline	2	2
Limited fed 12 percent protein Chlortetracycline	3	1
Limited fed 16 percent protein	3	1
Limited fed 12 percent protein	3	1
Totals	20	11

TABLE 4-BASAL RATIONS FOR PIGS FATTENED DURING FALL AND WINTER OF 1953-54

Percent protein	16	12
Ingredients		
Corn	79	89
Soybean oil meal	10	5
Tankage	7	3.5
Wheat shorts	3	1.5
Salt	0.5	0.5
Limestone	0.25	0.6
A and D Supplement*	0.25	0.25
B-vitamins**,†	†	†

*A and D supplement contained 2250 IU of vitamin A and 400 IU of vitamin A and 400 IU of vitamin D per gram.

**B-vitamins in mgm. per pound of ration were riboflavin 0.8, pantothenic acid 4.5, nicotinic acid 5.0, and choline chloride 100.

† Those lots receiving Chlortetracycline were given 18 mgm. per pound of ration.

Spring, 1954: Pigs were weaned at eight weeks of age and allotted at random to pasture or dry lot by sire groups. Each of the 12 sires had approximately one-half of his progeny in dry lot and one-half on pasture. Data were obtained on 61 barrows and 11 gilts distributed by sire group and treatment as shown in Table 5. Extremely dry weather occurred in 1954 and, as in 1953, little forage was available. The ration used on both pasture and dry lot is presented in Table 6.

TABLE 5-REPRESENTATION OF TREATMENT AND SIRE GROUPING IN THE SPRING OF 1954

	Dry Lot		Pasture	
Sire	Barrows	Gilts	Barrows	Gilts
Landrace 5	1	1		3
Landrace 105	3		2	
Landrace 333	3		3	
Landrace 149	2		3	
Poland 93	2	1	1	1
Poland 305	3		4	
Landrace 3	1	1	2	
Landrace 8	1	1	1	1
Poland 295	4		4	
Poland 92	4		4	
Poland 296	4	1	2	
Poland 175	3		4	1
Total	31	5	30	6

TABLE 6-BASAL RATION FOR PIGS FATTENED DURING SUMMER OF 1954

Shelled Corn	
Protein supplement	Free choice
Soybean oil meal	200
Tankage	300
Wheat shorts	100
Vitamins A and D*	5
B-vitamin supplement**	8
Antibiotic supplement†	5
Salt	12

*A and D supplement contained 2250 IU of vitamin A and 400 IU of vitamin D per gram.

**B-vitamin supplement contained 2000 mgm. of riboflavin, 40000 mgm. of niacin, and 9000 mgm. of pantothenic acid per pound.

† Antibiotic supplement contained 36000 mgm. of Chlortetracycline per pound plus unknown quantities of vitamin B_{12}.

Fall, 1954: At eight weeks of age all pigs were allotted at random to concrete lots and fed until reaching an approximate slaughter weight of 200 pounds. Data were obtained on 23 barrows and 23 gilts representing the progeny of 11 boars, 10 of which were the same as sired the 1954 spring pigs, plus Poland boar 13. Table 7 presents the sire groupings, and Table 8 shows the ration fed.

TABLE 7-REPRESENTATION OF SIRE GROUPS IN THE FALL OF 1954

Sire Number	No. of barrows	No. of gilts
Landrace 5	1	1
Landrace 333	2	4
Landrace 149	1	1
Poland 93	1	2
Poland 305	3	2
Landrace 8	2	4
Poland 295	2	2
Poland 92	2	1
Poland 296	1	1
Poland 175	5	3
Poland 13	3	2
Total	23	23

TABLE 8-BASAL RATION FOR PIGS FATTENED DURING FALL AND WINTER OF 1954-55.

Corn	432
Wheat	435
Tankage	80
Linseed oil meal	40
Salt	5
Limestone	3
Antibiotic supplement*	1.5
B-vitamin supplement**	1.0
Vitamins A and D†	2.5

Corn was substituted for wheat on January 1, 1955.

*Antibiotic supplement contained 3600 mgm. of Chlortetracycline per pound.
**B-vitamin supplement contained 2000 mgm. of riboflavin, 4000 mgm. of niacin and 9000 mgm. of pantothenic acid per pound.
† Vitamin A and D supplement contained 2250 IU of vitamin A and 400 IU of vitamin D per pound.

An early weaning experiment was conducted in the fall of 1954 in which some of the pigs were weaned at two and six weeks of age while those weaned at the customary eight weeks were used as controls. The pigs weaned at two weeks had a dry feed (starter) placed before them in a shallow pan. The starter ration was fed for one week and during the second week the starter ration was mixed with creep ration. From the second week (pigs were four weeks old) until they were placed on a fattening ration (eight weeks) they received the creep ration alone. Those pigs which were weaned at six weeks had access to the creep ration until eight weeks of age, when they were placed on the fattening ration. The age of weaning did not appear to be a logical source of variation or variable in the factors to be considered, thus weaning age was not isolated and controlled or measured.

Table 9 gives starter and creep rations for completeness of the record.

TABLE 9-EARLY WEANED PIG STARTER AND CREEP RATIONS FED IN THE FALL, 1954

	Starter	Creep
Corn	4.5	68.5
Rolled oats	10.0	---
Wheat shorts	4.5	---
Dried skim milk	40.0	---
Soybean oil meal	10.0	16.0
Tankage	---	8.0
Fish meal	3.0	3.0
Alfalfa meal	---	2.5
Salt	0.6†	0.5
Limestone	0.5	0.2
Bonemeal	1.0	---
Bloodflour	5.0	---
Corn distillers' solubles	5.0	---
Dextrose	9.0	---
Lard	5.0	---
Antibiotics*	+	+
Vitamins**	+	+

*Terramycin or aureomycin 20 mgm. per pound in creep and 40 mgms. per pound in starter ration.

**Vitamins A, D, B_2, B_{12}, pantothenic acid, and nicotinic acid in creep and all known vitamins in starter ration.

† Trace mineralized salt (Fe, Mn, Cu, Zn, and Co).

Live-Animal Scores

All pigs were given subjective scores ranging from 1 to 9 for body length, meatiness, quality, finish, and conformation at the time they were weighed off for slaughter (approximately 200 pounds). Scoring was done by a committee of two, three, or four members of the Animal Husbandry staff. Average scores of all judges were used in all calculations. A general description of the scoring system follows:

Body length—long bodied hogs were given the highest numerical scores.

Meatiness—muscling was considered synonymous with meatiness and the hogs appearing to have the most muscle were given the highest scores.

Quality—in swine, quality is usually associated with a trim middle and jowl, freedom from flabbiness or wrinkles, smooth shoulders, and attractive hair coat. Pigs having these attributes were given the higher scores for quality.

Finish—finish is dependent upon the amount of fat an animal carries. Therefore, those pigs with the highest degree of finish received the highest scores.

Conformation—symmetry and the proper proportions of the various parts of the hog were prime considerations in scoring for conformation with those animals having the most desirable conformation receiving the highest scores.

Note that in all instances, with the exception of finish, a high numerical score is indicative of a desirable characteristic of a "meat-type" hog.

Live-animal Measurements

All live-hog measurements were made at the time of scoring and recorded in millimeters. The measurements taken were:

Backfat probes—taken in the manner prescribed by Hazel and Kline (1952). Incisions approximately one-fourth inch deep and one-half inch long were made through the skin at three locations as shown below. Probes were made in duplicate, one on each side, about two inches from the midline.

Shoulder probe—taken in the region of fifth-sixth thoracic vertebrae.

Hip probe—taken in the region of the fourth-fifth lumbar vertebrae.

Ham probe—taken in the region of the second-third sacral vertebrae.

Body length—measured with a steel tape along the midline from base of skull to base of tail.

Heart girth—the circumference of the body taken just posterior to the forelegs.

Flank circumference—the circumference of the body just anterior to the hind legs.

Method of Slaughter and Obtaining Carcass Measurements and Yields.

Hogs attaining a weight of approximately 200 pounds, on the predetermined weekly weigh-day, were fasted for 24 hours, reweighed, and slaughtered. All animals were dressed packer style (head off, jowl and feet on, and leaf fat, and kidneys in). To equalize all hogs in regard to fill, at the time of obtaining the slaughter weight, the following procedure was utilized to derive a value referred to henceforth as the "adjusted live weight." Digestive tract (including stomach, spleen, intestinal fat, small and large intestines) was removed and weighed to the nearest one-half pound. The digestive tract weight was subtracted from the live-hog weight. Contents of the digestive tract were removed and the tract was then reweighed. The weight of the empty tract, plus 3.5 pounds, was added to the weight of the live hog. In this manner, all animals had an equal fill.

After a 48-hour chill, the carcass was cut into standard wholesale cuts and trimmed as outlined in the Proceedings of the 1952 Reciprocal Meat Conference. Weights were recorded for skinned hams, picnics, Boston butts, loins, bellies, lean trim, backfat, leaf fat, fat trimmings, jowl, feet, tail and kidneys, spare ribs, and neck bones.

Two linear carcass measurements were taken: (1) carcass length as measured in millimeters from the anterior edge of the first rib to the anterior edge of the aitch bone and (2) hind leg length, which was the distance from the anterior edge of aitch bone to the coronary band of the hoof.

Calculation of Carcass Yields

Three bases of gross carcass evaluation were used throughout this research, which were derived as follows:

1. Percentage of "adjusted live weight" in fat (backfat, leaf fat, and fat trimmings).
2. Percentage of "adjusted live weight" in five primal cuts (trimmed loins, skinned hams, bellies, picnics, and Boston butts).
3. Adjusted loin equivalent.

The adjusted loin equivalent is a measure of net carcass merit which has been developed at the University of Missouri Swine Breeding Laboratory. It is obtained by adjusting the wholesale cuts by factors indicative of their relative value, in terms of the trimmed loin, and evaluating the primal cuts on a basis of subjective quality scores.

Derivation

Wholesale cuts were given relative values based on Chicago wholesale prices from 1937-1947, as follows:

Trimmed loins	1.0
Skinned hams	0.9
Bellies and skinned shoulders	0.8
Lean trimmings (including jowl)	0.7
Leaf fat, backfat, and fat trimmings	0.2
Bone (including spare ribs, kidneys, neck bones)	0.1

These relative values were used in weighting the absolute yields, thereby arriving at a value termed as the "unadjusted loin equivalent." The four primal cuts on the basis of finish and lean area, with those cuts having the most finish and least lean area receiving a score of 1; as finish decreased and lean increased, the score increased to a maximum value of 9. The "unadjusted loin equivalent" was then "adjusted" by applying the following factors to the primal cuts.

Score	*Factor*	*Score*	*Factor*
1	.80	6	1.05
2	.85	7	1.10
3	.90	8	1.15
4	.95	9	1.20
5	1.00		

The resulting value was termed the "adjusted loin equivalent" and is a measure of net carcass value per unit of live weight.

Dressing percentage was obtained by expressing the chilled carcass weight in terms of the adjusted live weight.

RESULTS AND DISCUSSION

Factors Affecting Live-hog Measurements, Scores and Carcass Yields

To increase the reliability of correlation studies, it was necessary to determine and evaluate some of the internal and external environmental sources of variation which significantly contributed to the variance in live-hog and carcass measures. The measures of gross carcass evaluation (adjusted loin equivalent, percentage of five primal cuts, and percentage of fat); live-animal measurements; and live-animal scores were studied.

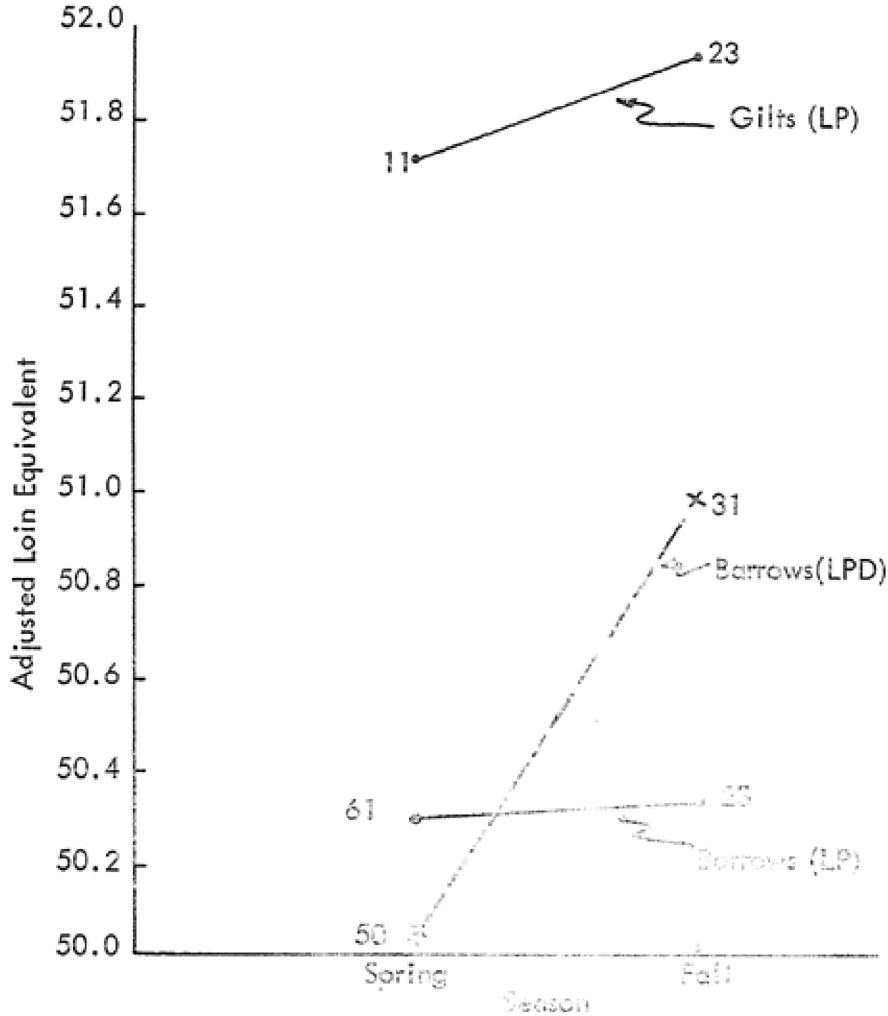
Figures 1 through 11 present the mean values of the measures of gross carcass merit and live-hog measurements; with classifications made on the basis of sex, season, and breed. Original data used in compiling these figures were obtained on 199 animals of which 81 were barrows of the Landrace x Poland x Duroc cross studied in 1953, with 84 barrows and 34 gilts of the Landrace x Poland cross studied in 1954. Several comments are necessary regarding the presentation used here. Ordinarily, data classified on three-criterian basis would be analyzed by the analysis of variance method for proportional or equal subclass numbers. Such a straightforward analysis, however, was not possible in this work, due to the nonorthogonal nature of the sample studied. Furthermore, in 1953, slaughter data were available for barrows only, both in the spring and fall seasons. The data summarized in Figures 1 through 11 were therefore analyzed as two separate nonorthogonal, two-criteria problems, with analyses being made within breed-cross and within male (barrow) sex. The "F" values for each classification and interactions are given at the bottom of each figure. An example of the methods used for deriving these "F" values is presented in Appendix II.

In breed-cross comparisons, i.e. Landrace x Poland x Duroc with Landrace x Poland, confounding of cross and year existed. Since each cross was studied in one year only, there was no method of correcting for this problem. It does not rationally appear that the nature of this confounding was detrimental, due to the climatic similarity of the years 1953 and 1954, both of which were extremely dry and hot during the summer months and mild and dry throughout the winter seasons.

Note in Tables 3 and 4 that a variation in feeding method existed in the fall of 1953. This was the result of an experiment conducted at that time to determine the effect of the level of protein, level of feeding, and aureomycin supplementation on carcass characteristics and economic factors. The results of this work indicated that for the most part, no single variable or any combination of the dietary variables had a marked effect on carcass yields or live-hog measurements. It was concluded that feeding is not an effective means of altering carcass composition within the range of practical Corn Belt rations used in this study. On the basis of this work and that of other workers (see Review of Literature), nutritional variations were, for the most part, disregarded throughout this study.

Figure 1. Mean Adjusted Loin Equivalent Classified by Season, Sex, and Breed-Cross

Figures indicate number of animals comprising mean.



Within LP Breed-Cross:

$F_{sex} = 15.89^{**}$

$F_{season} = .08$

$F_{interaction} = .05$

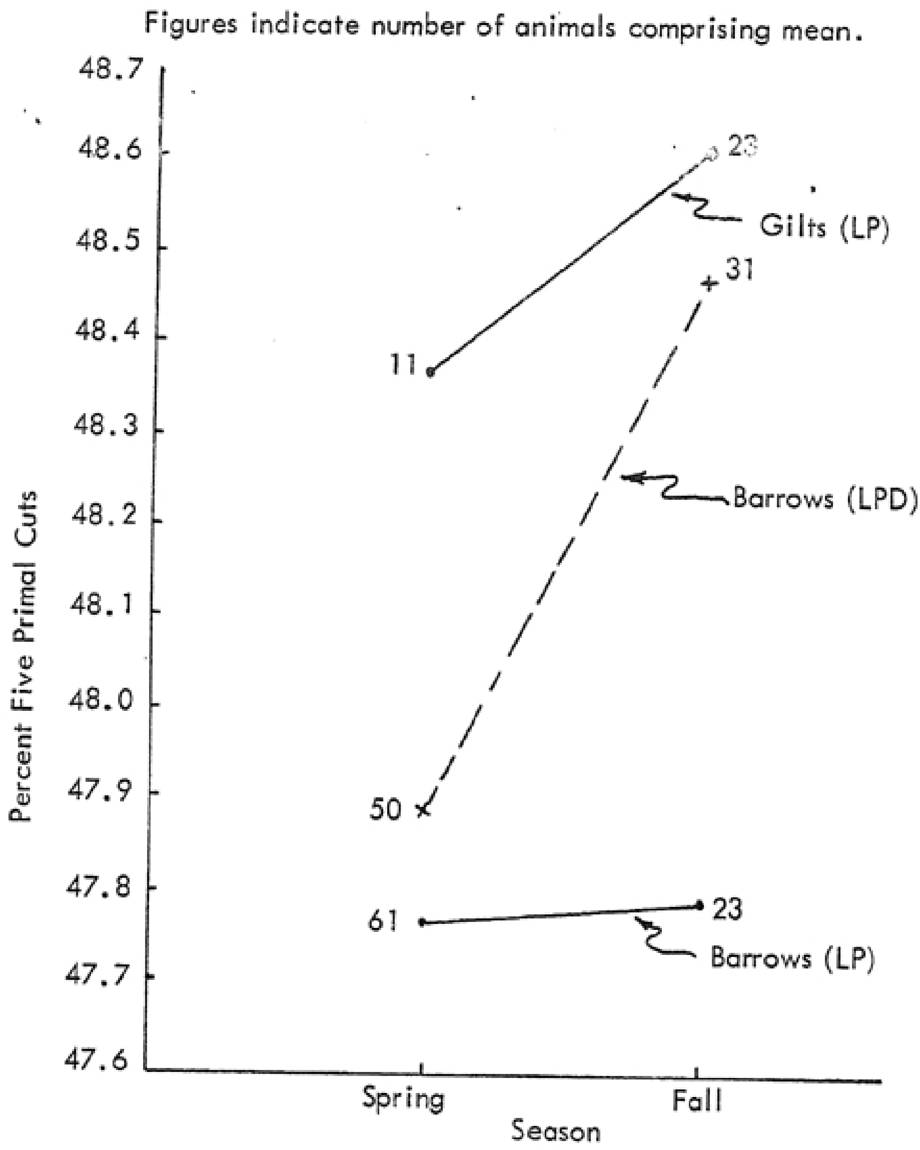
Within Male Sex:

$F_{breed} = .37$

$F_{season} = 2.23$

$F_{interaction} = 1.86$

Figure 2. Mean Percentage of Five Primal Cuts Classified by Season, Sex, and Breed-Cross



Within LP Breed-Cross:

$F_{sex} = 5.80^*$

$F_{season} = .08$

$F_{interaction} = .88$

Within Male Sex:

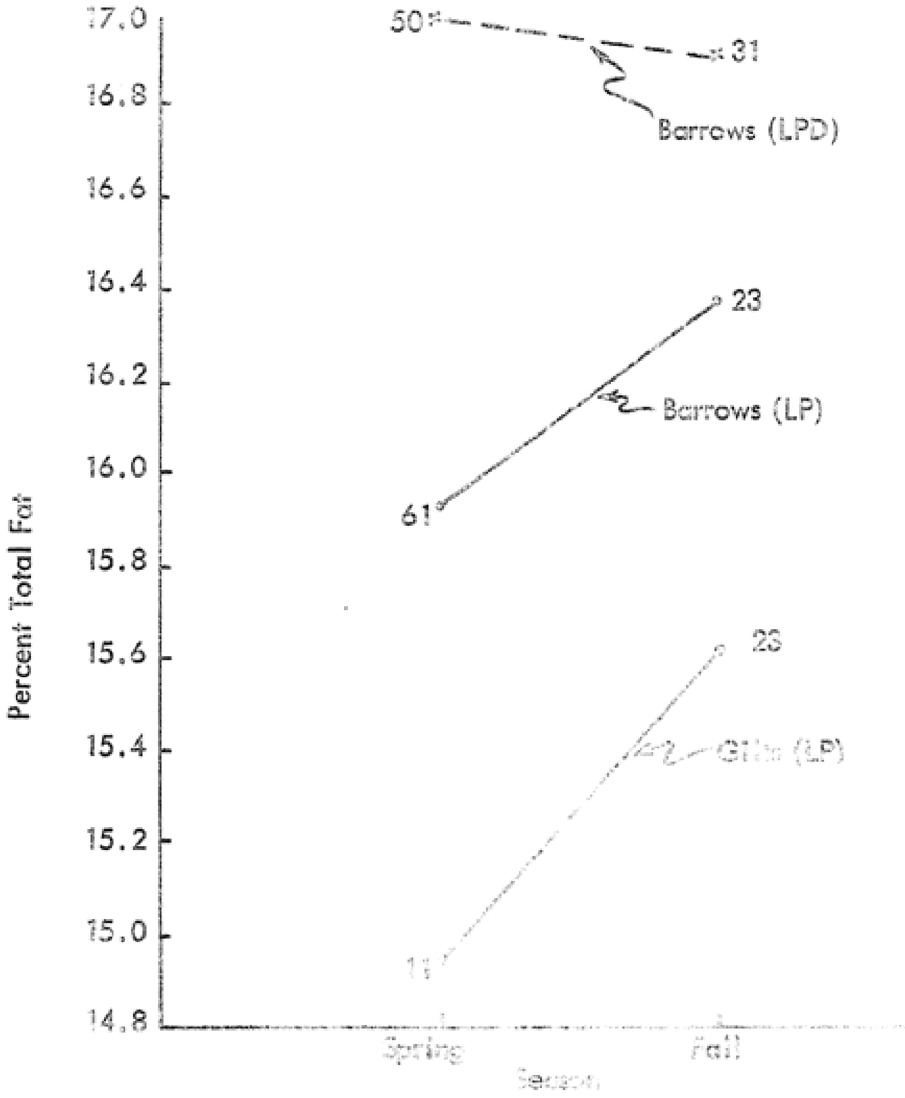
$F_{breed} = 3.01$

$F_{season} = 2.48$

$F_{interaction} = .36$

Figure 3. Mean Percentage of Total Fat Classified by Season, Sex, and Breed-Cross

Figures indicate number of animals comprising mean.



Within LP Breed-Cross:

$F_{sex} = 6.08^*$

$F_{season} = 2.09$

$F_{interaction} = .07$

Within Male Sex:

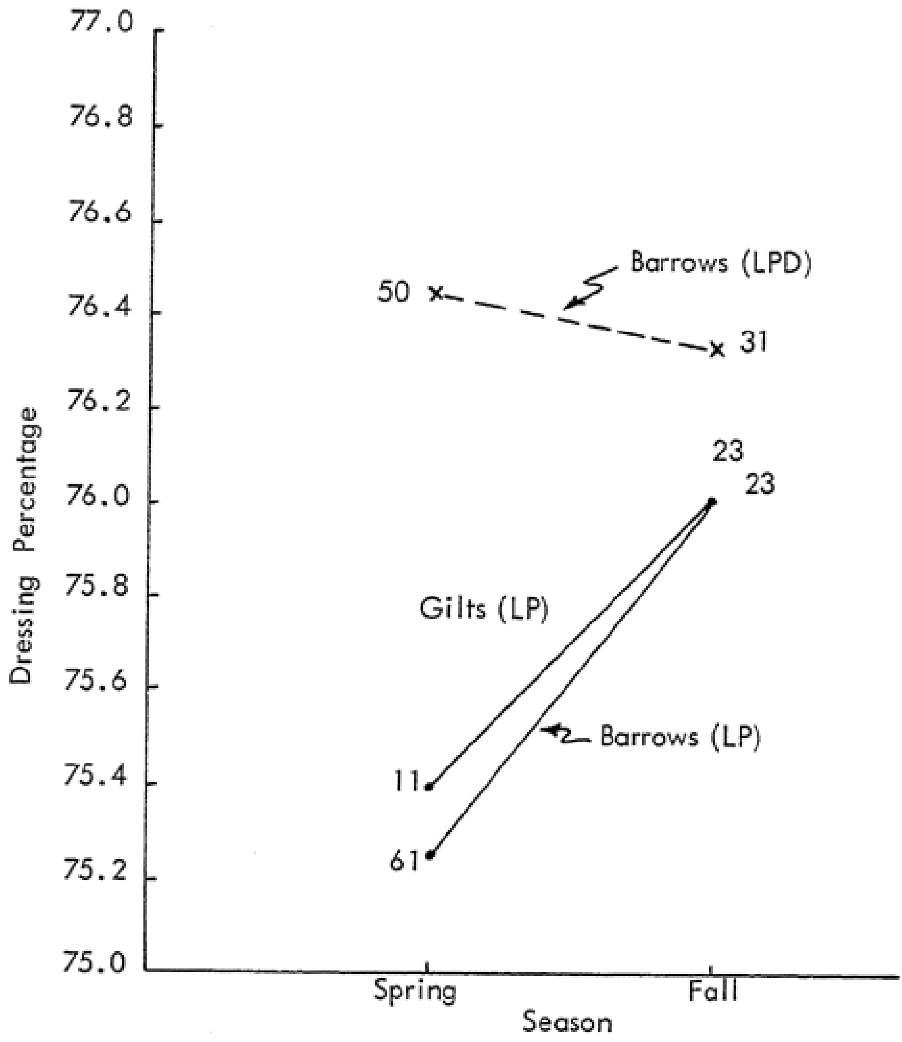
$F_{breed} =$ [illegible]

$F_{season} =$ [illegible]

$F_{interaction} = .64$

Figure 4. Mean Dressing Percentage Classified by Season, Sex, and Breed-Cross

Figures indicate number of animals comprising mean.



Within LP Breed-Cross:

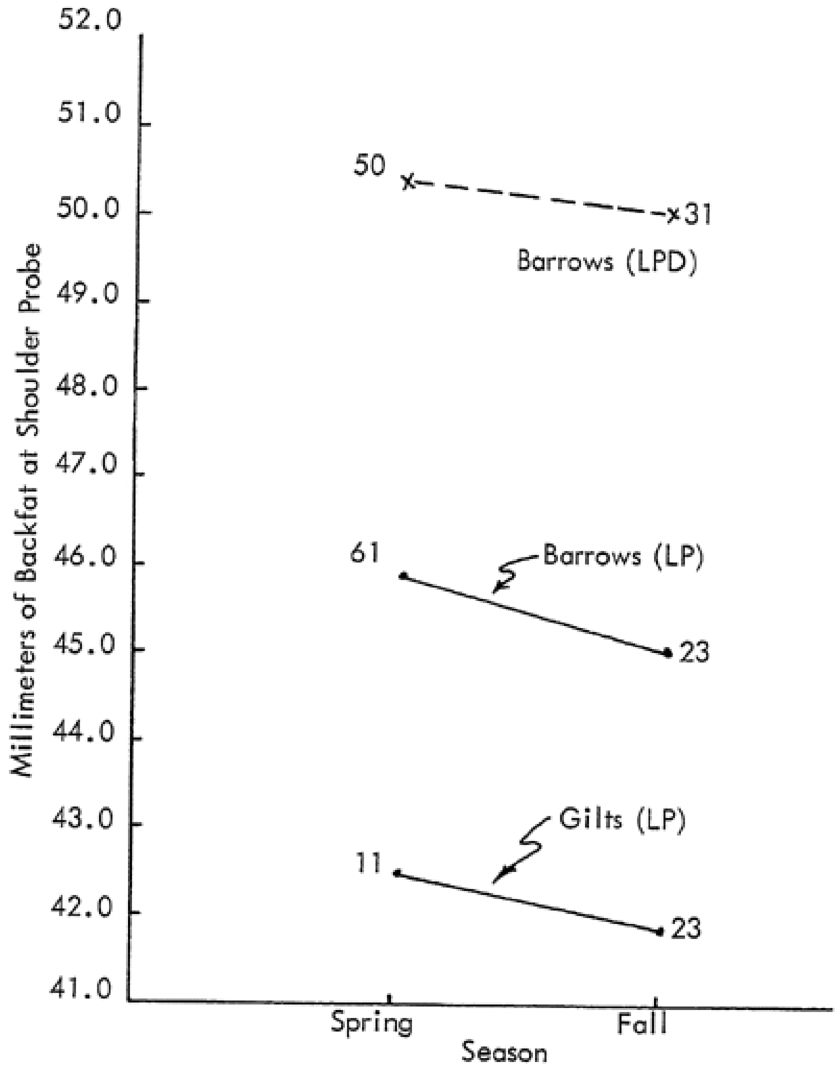
$F_{sex} = .90$
$F_{season} = 7.96^{**}$
$F_{interaction} = .01$

Within Male Sex:

$F_{breed} = 8.58^{**}$
$F_{season} = 2.30$
$F_{interaction} = 2.40$

Figure 5. Mean Millimeters Live-Hog Backfat at Shoulder Probe Classified by Season, Sex, and Breed-Cross

Figures indicate number of animals comprising mean.



Within LP Breed-Cross:

$F_{sex} = 5.64^*$

$F_{season} = .42$

$F_{interaction} = .02$

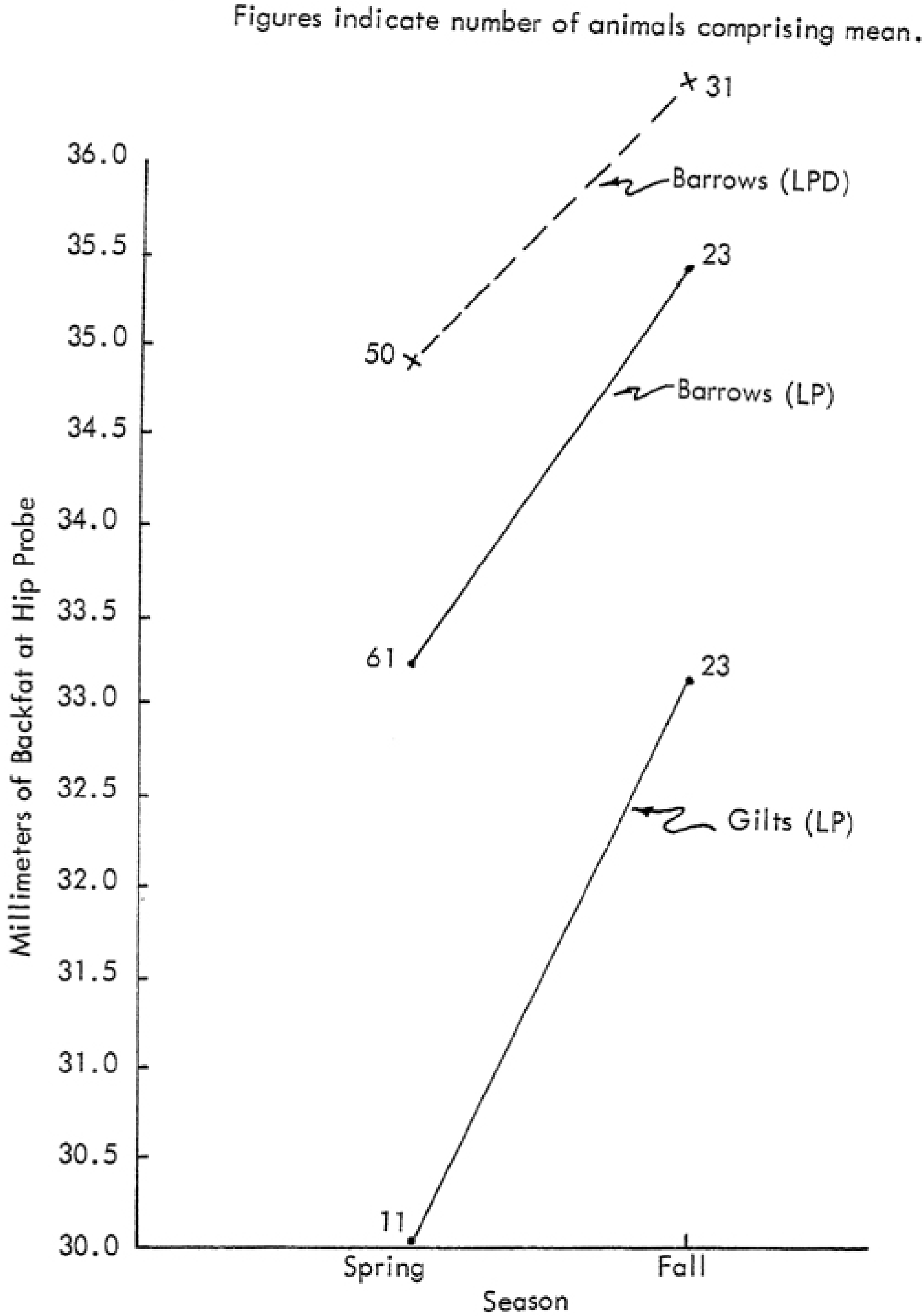
Within Male Sex:

$F_{breed} = 17.38^{**}$

$F_{season} = .25$

$F_{interaction} = .09$

Figure 6. Mean Millimeters Live-Hog Backfat at Hip Probe Classified by Season, Sex, and Breed-Cross



Within LP Breed-Cross:

$F_{sex} = 6.20^*$

$F_{season} = 5.66^*$

$F_{interaction} = .15$

Within Male Sex:

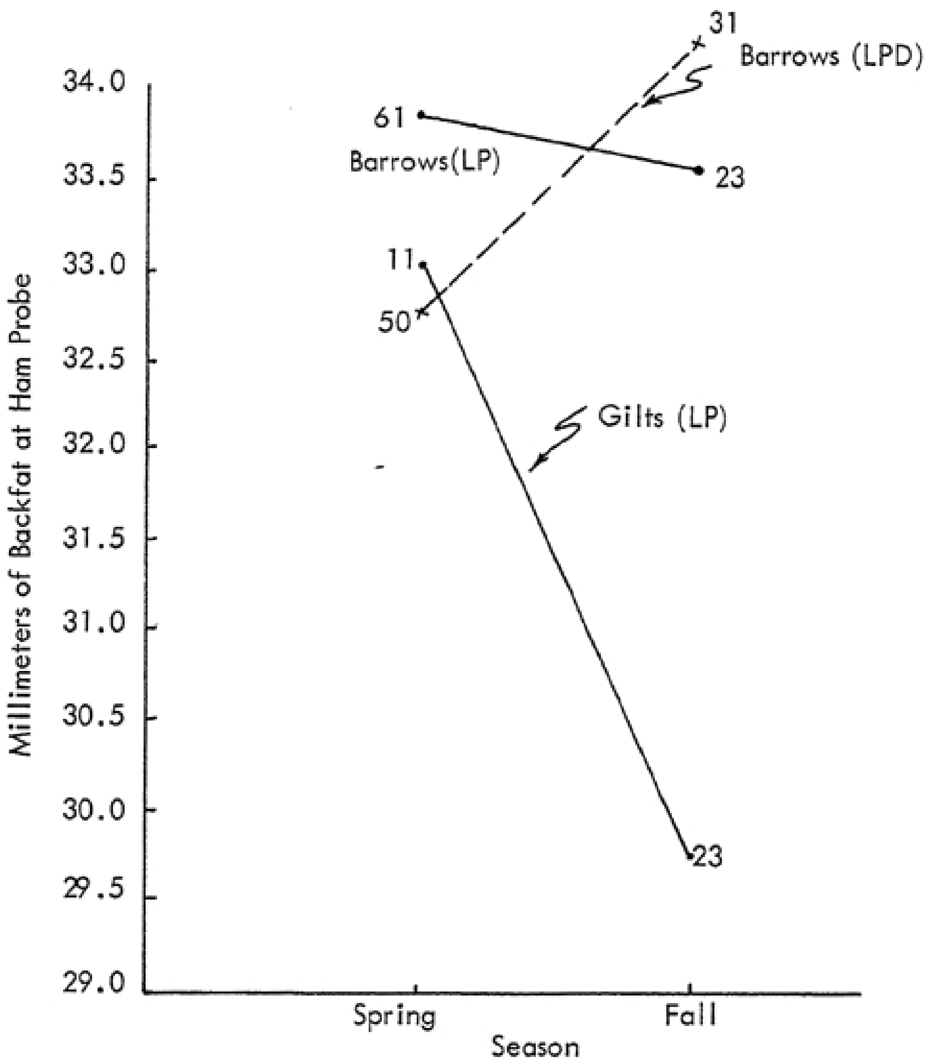
$F_{breed} = 2.44$

$F_{season} = 4.62^*$

$F_{interaction} = .11$

Figure 7. Mean Millimeters Live-Hog Backfat at Ham Probe Classified by Season, Sex, and Breed-Cross

Figures indicate number of animals comprising mean



Within LP Breed-Cross:

$F_{sex} = 5.77^*$

$F_{season} = 3.22$

$F_{interaction} = 2.34$

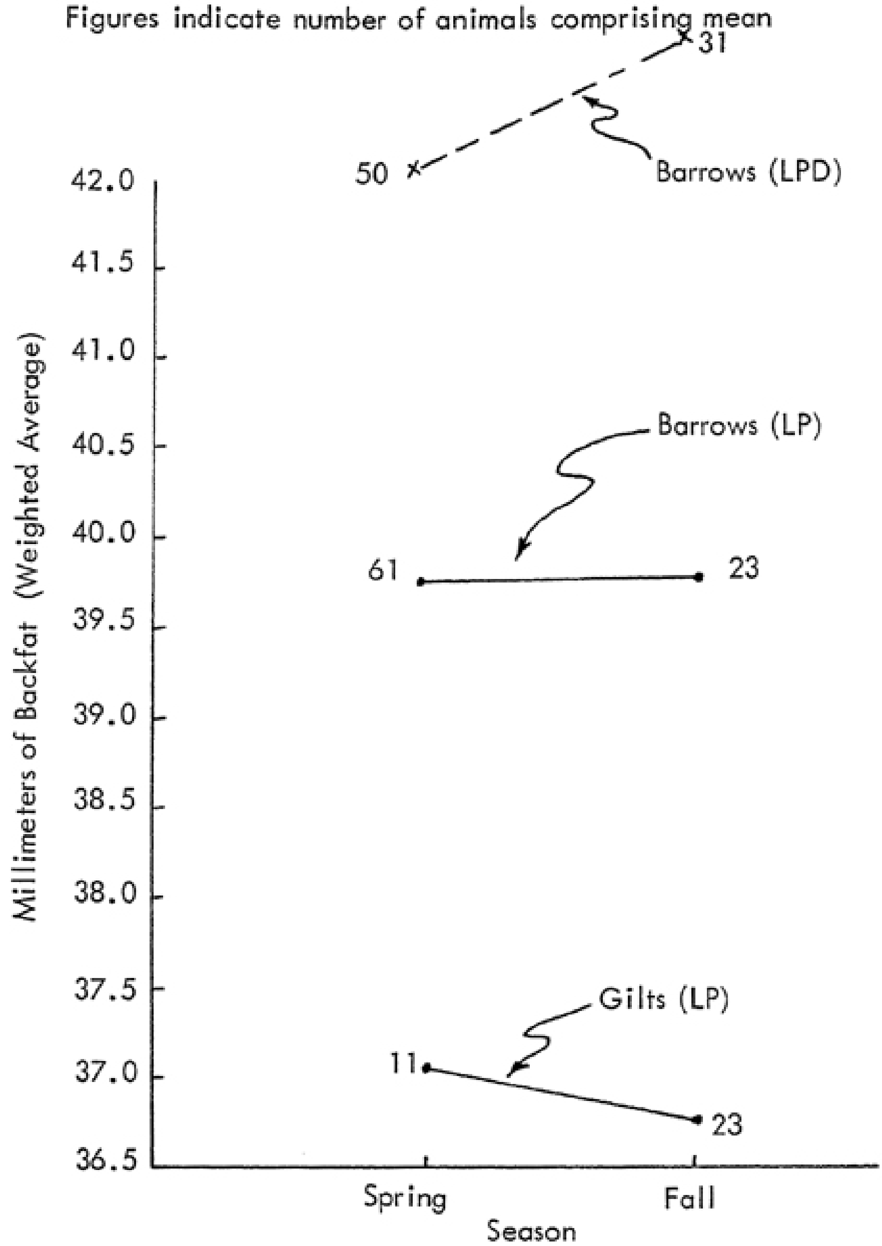
Within Male Sex:

$F_{breed} = .08$

$F_{season} = .52$

$F_{interaction} = 1.28$

Figure 8. Mean Millimeters Live-Hog Backfat (Weighted Average) Classified by Season, Sex, and Breed-Cross



Within LP Breed-Cross:

F_{sex} = 7.04*

F_{season} = .01

$F_{interaction}$ = .15

Within Male Sex:

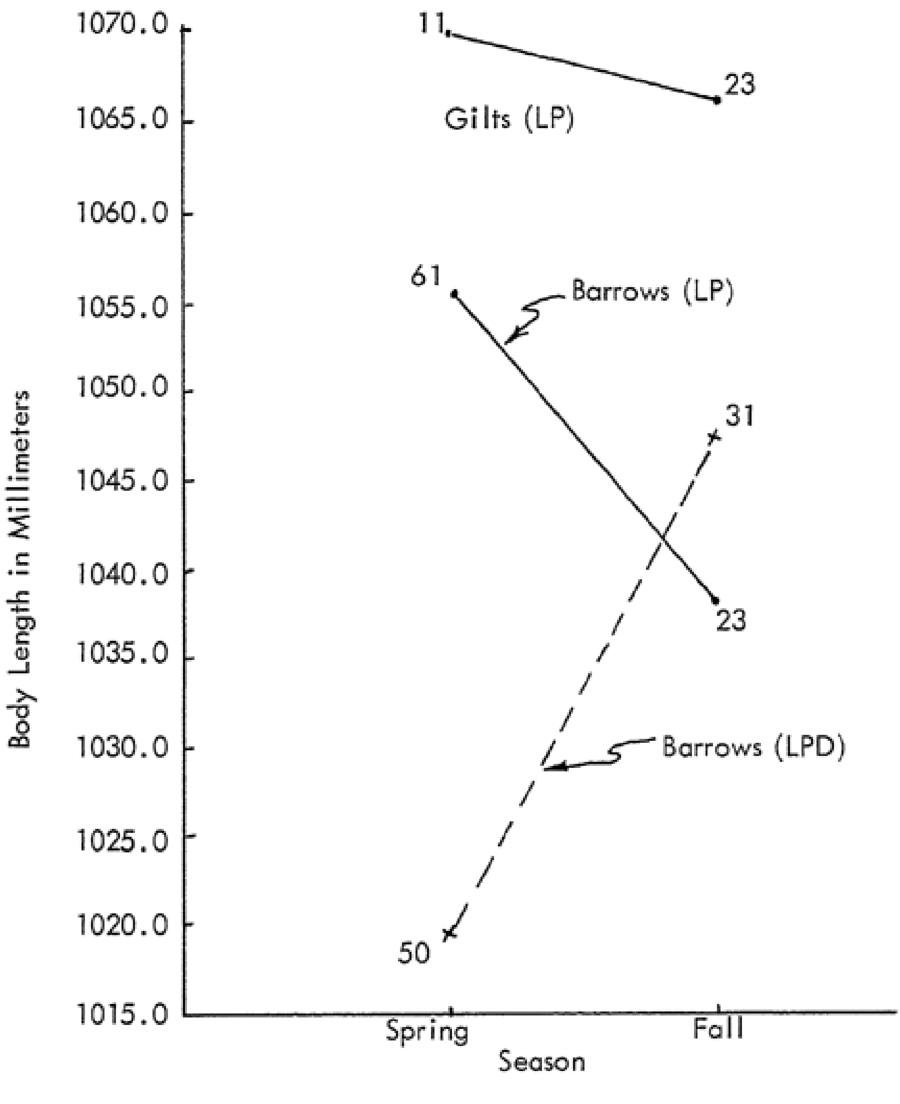
F_{breed} = 17.19**

F_{season} = 2.28

$F_{interaction}$ = .55

Figure 9. Mean Millimeters Body Length Classified by Season, Sex, and Breed-Cross

Figures indicate number of animals comprising mean.



Within LP Breed-Cross:

F_{sex} = 8.50**

F_{season} = 2.01

$F_{interaction}$ = .83

Within Male Sex:

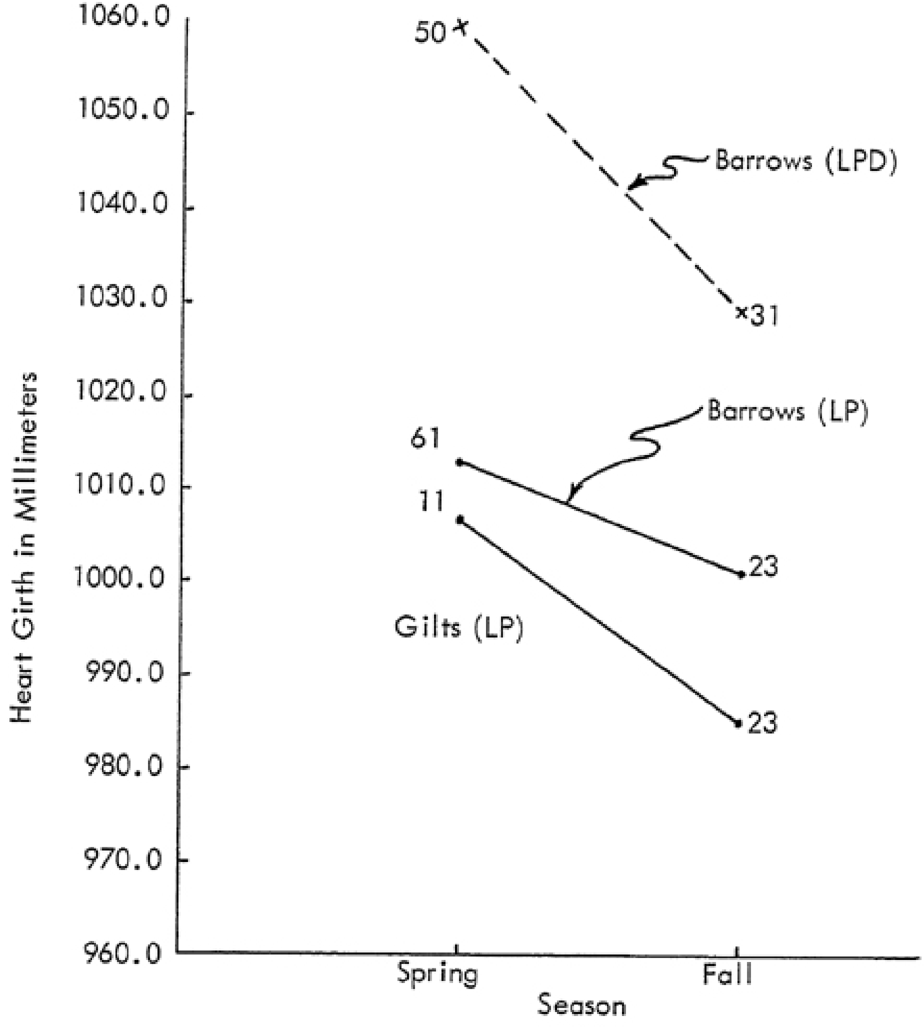
F_{breed} = 4.87*

F_{season} = .88

$F_{interaction}$ = 14.63**

Figure 10. Mean Millimeters Heart Girth Classified by Season, Sex, and Breed-Cross

Figures indicate number of animals comprising mean.



Within LP Breed-Cross:

$F_{sex} = 5.26^*$

$F_{season} = 9.34^{**}$

$F_{interaction} = .73$

Within Male Sex:

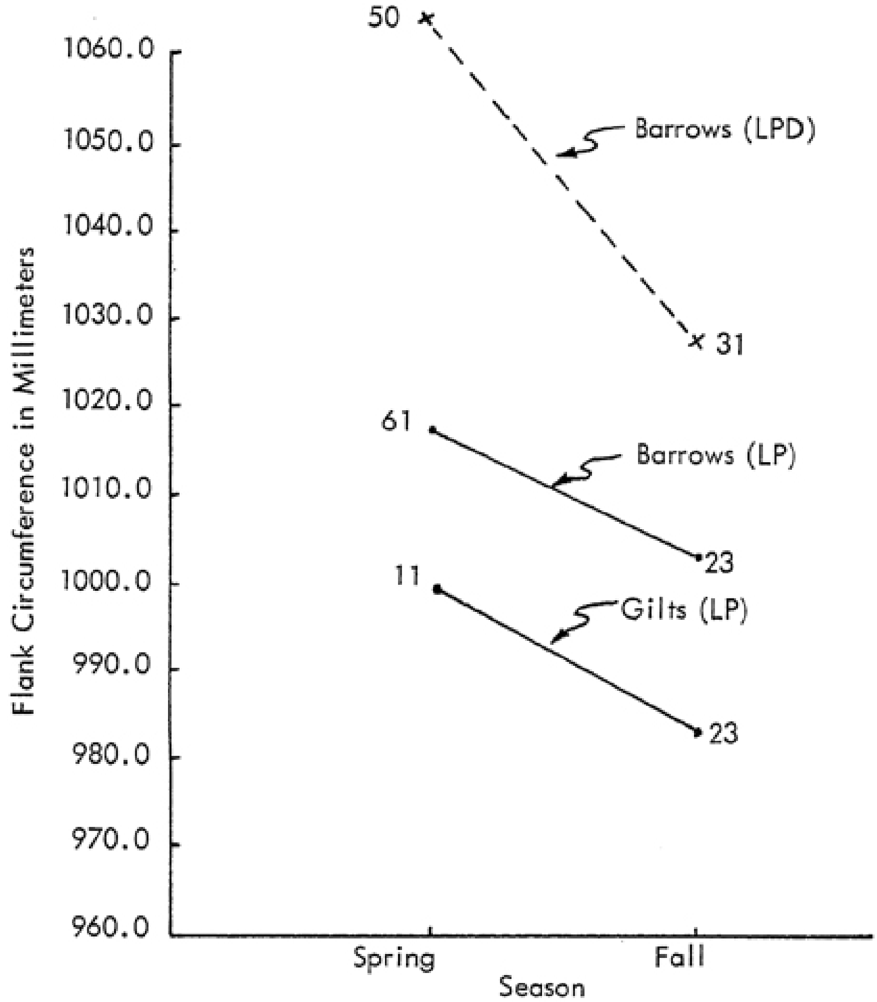
$F_{breed} = 67.95^{**}$

$F_{season} = 23.69^{**}$

$F_{interaction} = 4.31^*$

Figure 11. Mean Millimeters Flank Circumference Classified by Season, Sex, and Breed-Cross

Figures indicate number of animals comprising mean



Within LP Breed-Cross:

$F_{sex} = 4.97$*
$F_{season} = 4.46$*
$F_{interaction} = .04$

Within Male Sex:

$F_{breed} = 28.72$**
$F_{season} = 13.40$**
$F_{interaction} = 2.59$

In 1953, spring and fall pigs were sired by different boars (Tables 1 and 3), while in 1954 the same boars sired both spring and fall pigs in approximately equal numbers (Tables 5 and 7), enabling the disregarding of sire attributable variance in that year. No sire variance analysis was attempted in 1953 due to season-sire confounding.

Effect of Sex

Figures 1 through 11 indicate that significant differences existed between barrows and gilts for all characteristics studied, with the exception of dressing percentage. Gilts in general produced a greater percentage of lean meat, had less fat, were considerably longer in body length, and smaller in heart girth and flank circumference. The magnitude of the sex differences may be appraised by noting the "F" values for sex within-breed, given at the bottom of each figure.

Effect of Breed-Cross

Breed-cross differences were observable in percentage of total fat and depth of fat at the shoulder probe with the Landrace x Poland x Duroc exceeding the Landrace x Poland cross. Inasmuch as the weighted average of backfat (Figure 8) is relatively more dependent on the shoulder backfat probe, it followed that a significantly larger value was also obtained for the three-breed cross.

$$\text{Weight average} = \frac{2(\text{shoulder probe}) + \text{hip probe} + \text{ham probe}}{4}$$

The higher dressing percentage of the Landrace x Poland x Duroc cross is undoubtedly attributable in part to the greater amount of fat observed in that breed-cross. An interesting observation was noted concerning body length, hearth girth, and flank circumference. Figure 9 shows not only a breed difference in body length but a significant season x breed interaction. Whereas the two-breed cross was longer in the spring, the three-breed cross was longer in the fall, and vice versa. A significant season-breed interaction also existed for heart girth, although it is not as discernible from the diagrammatic presentation. Generally speaking, however, it is a reverse of that noted for body length, with the Landrace x Poland x Duroc being longer in the spring. Undoubtedly, the breed cross relationships here are not as great as for body length due to the backfat which contributed to these diameter measurements.

Effect of Season

The effects of season are probably the most interesting features of this study. In the two-breed cross, both barrows and gilts had a significantly higher dressing percentage in the fall, although no difference was noted for the barrows of the three-breed cross. In both crosses, the heart girth and flank circumference were greater in the spring than in the fall.

A Comparison of Dry Lot vs. Pasture Feeding

Throughout the previous discussion, spring and fall-farrowed pigs were compared. However, it was realized that spring litters were subject to different management practices, and the influence of this factor was questioned. Table 10 compares effects of pasture and dry lot feeding on the carcass composition and live-hog measurements of barrows from both breed crosses. From this table, it may be concluded that the pasture fed hogs generally possessed a more desirable meat-type carcass, although the superiority was not great. Significant differences were noted in the Landrace x Poland x Duroc cross but not in the Landrace x Poland cross, although the trends were similar. The effect of these differences on the mean values of Figures 1 through 11, had only dry lot fed spring pigs been studied, would generally have been to increase the seasonal differences of the characteristics studied.

TABLE 10-COMPARISON OF DRY LOT VERSUS PASTURE FEEDING ON CARCASS COMPOSITION AND BODY MEASUREMENTS FOR SPRING-FARROWED BARROWS

Characteristic	LPD (1953)		LP (1954)	
	Dry Lot	Pasture	Dry Lot	Pasture
Number of pigs	28	22	31	30
Adjusted loin equivalent	49.33	50.95**	49.96	50.61
Five primal cuts	47.37	48.55**	47.57	47.73
Fat	17.56*	16.21	16.17	15.68
Dressing per cent	76.31	76.59	75.23	75.22
Backfat at shoulder	51.61	48.59	47.02	44.86
Backfat at hip	35.64	33.95	34.27	32.18
Backfat at ham	33.75	31.50	34.03	33.65
Backfat (weighted average)	43.14*	40.50	40.65	38.89
Body length	1018.53	1021.59	1055.16	1055.67
Heart girth	1066.18*	1050.18	1008.71	1019.33
Flank circumference	1073.39*	1048.23	1023.74	1009.67

*Mean is significantly greater at 0.05 percent level than that of the animals fed in the alternative manner in the L-P-D cross.
**Mean is significantly greater at 0.01 percent level.

Effectiveness of Scores

Table 11 presents the mean live-hog scores for the five characteristics evaluated with classification made on the same bases used in classifying absolute measures, i.e. carcass composition and live-hog measurements reported in Figures 1 through 11. Analyses of variance were conducted within each score to determine if the mean values differed significantly with the "F" ratios given at the bottom of each column. In all cases, the mean values for each classification were different, as indicated by highly significant "F" ratio, although the exact source of the difference was not discernible from this type of analysis.

TABLE 11-MEAN LIVE-HOG SCORES CLASSIFIED BY SEASON, SEX, AND BREED-CROSS

Season Breed-Cross and Sex	No. of Pigs	Body Length		Meatiness		Quality		Finish		Conformation	
		Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
Landrace x Poland x Duroc											
Spring Barrows	50	6.28	.62	6.58	.39	6.51	.37	7.03	.40	5.97	.69
Fall Barrows	31	6.11	.51	5.98	.56	5.84	.44	6.21	.66	5.82	.49
Landrace x Poland											
Spring Barrows	61	7.33	.53	7.34	.57	6.79	.52	7.11	.64	6.43	.73
Spring Gilts	11	7.68	.31	8.04	.17	7.50	.20	6.73	.11	7.41	.39
Fall Barrows	23	6.11	.50	6.50	.59	6.04	.75	5.59	.90	5.76	.75
Fall Gilts	23	6.56	.46	6.91	.40	6.30	.45	5.17	.67	6.20	.47
Total	199	6.67	.83	6.86	.51	6.47	.63	6.53	1.13	6.16	.78
F-Ratio		23.40**		2.98*		14.91**		31.09**		9.87**	

* $P < .05$
** $P < .01$

The apparent similarity of all mean scores in Table 11 indicates that all hogs scored were comparatively alike (or that the scores did not sufficiently reflect the actual differences). The differences noted were very small when consideration is made of the fact that a score of 1 to 9 was possible for each trait.

Scores for body length reflect a difference between spring and fall barrows in both breed crosses and for gilts in the Landrace x Poland cross, with higher scores recorded in all instances in the spring. Comparing these scores with the actual body length measurements recorded (Figure 9), shows contradictory results for the three-breed cross, although agreement does exist in the Landrace x Poland cross.

A specific score which was directly comparable to an absolute measure was that for finish. Here it was shown that higher scores were recorded for finish in all cases for the spring-farrowed animals, with barrows receiving slightly higher average scores than gilts. Figure 3 does not entirely substantiate this conclusion in that, in general, the opposite season differences appeared true, with fall pigs being fatter in the Landrace x Poland cross and almost no season differences existing in the Landrace x Poland x Duroc cross. However, as the scores indicated, barrows were fatter than gilts in both seasons.

Scores for meatiness and quality favored the gilts, a result which is actually substantiated on the basis of carcass cut-out values for primal cuts and adjusted loin equivalent.

It might be concluded that the scores used in this study did indicate major differences which were actually shown to exist on the basis of actual measurements. Undoubtedly, scores for any characteristic are markedly influenced by other proportional parts of the animal. In other words, in comparison of animals much alike in their over-all conformation, an illusion of greater length might be obtained in the animal possessing a small heart girth. It also appeared that the differences in the animals scored were not separated sufficiently by the judges, as reflected in the scores given.

The Effectiveness of Live-hog Subjective Scores, Body Measurements, and Backfat Probes in Estimating Carcass Yields and Composition.

Live-hog measurements, backfat probes, and scores, along with carcass data, were available on eighty-one Landrace x Poland x Duroc crossbred spring and fall-farrowed barrows in 1953, and 118 Landrace x Poland crossbred barrows and gilts farrowed in the spring and fall of 1954. Appendix I presents the original sum of squares and means classified by season, sex, and breed-cross.

Due to the unavailabality of data on gilts in the Landrace x Poland x Duroc cross, complete analyses were not possible for each sex individually within the two breed-crosses studied. The breed-cross differences in the various items were significant in most instances, as has been previously shown. For this reason, analyses of interrelationships among the various items were made separately for each breed-cross.

The means of the various items studied, classified by breed-cross, are shown in Table 11. No significant differences existed between the breed-crosses for adjusted loin equivalent or percent of five primal cuts. However, the Landrace x Poland x Duroc cross produced carcasses with 1.08 percent more fat, a difference which was highly significant. Shoulder probe, hip probe, heart girth, and flank circumference were all significantly ($P < .01$) greater in the Landrace x Poland x Duroc cross, while the Landrace x Poland hogs had significantly ($P < .01$) longer bodies. Dressing percentage was higher in the Landrace x Poland x Duroc hogs by .81 percent, a difference which was also statistically significant.

Table 12 presents the mean values for the live-hog scores for the two crosses studied. The Landrace x Poland hogs were scored significantly higher in body

TABLE 12-MEANS OF LIVE-HOG MEASUREMENTS AND CARCASS YIELDS FOR LANDRACE X POLAND X DUROC AND LANDRACE X POLAND HOGS

Body Measurements in Millimeters and Carcass Yields as Per Cent of Adjusted Live-Weight	LPD (N = 81)		LP (N = 118)	
	Mean	Variance	Mean	Variance
Per Cent Adjusted Loin Equivalent	50.39	4.72	50.74	3.39
Per Cent of Five Primal Cuts	48.11	2.62	47.96	1.84
Per Cent Fat	16.94**	4.19	15.86	3.01
Dressing Percentage	76.37**	2.72	75.56	1.49
Shoulder Probe	50.20**	44.56	44.67	40.78
Hip Probe	35.51**	28.18	33.36	25.30
Ham Probe	33.32	21.25	32.92	21.28
Body Length	1030.60	1043.32	1055.51**	1177.94
Heart Girth	1047.49	945.63	1005.25	676.44
Flank Circumference	1049.15**	2185.78	1006.18	1160.87

*Mean is significantly greater at .05 percent level.
**Mean is significantly greater at .01 percent level.

TABLE 13-MEAN LIVE-HOG SCORES FOR LANDRACE X POLAND X DUROC AND LANDRACE X POLAND HOGS

Live-Hog Score	LPD (N = 81)		LP (N = 118)	
	Mean	Variance	Mean	Variance
Body Length	6.22	.58	7.05**	.82
Meatiness	6.35	.53	7.28**	.66
Quality	6.25	.50	6.69**	.71
Finish	6.71	.65	6.64	1.56
Conformation	5.91	.61	6.43**	.82

**Mean is significantly greater at .01 per cent level.

length which is similar to the results shown in the previous table for body length measurements. However, the Landrace x Poland cross also received higher scores for meatiness, quality, and conformation, which is not consistent with the actual carcass cutout values, as indicated in the previous table. In other words, no significant differences were noted between the two crosses in percent of five primal cuts or adjusted loin equivalent, and yet the Landrace x Poland cross received the higher scores for meatiness and quality. The mean scores for finish were not significantly different, even though the carcass studied indicated 1.08 percent more fat.

Table 14 shows the zero order correlation coefficients between the various body measurements, backfat probes, and carcass yield. All backfat probes were significantly ($P < .01$) correlated with yield of adjusted loin equivalent, percent of five primal cuts, and percent of fat in both crosses, with correlations of greater magnitude observed between all probes and percentage of carcass fat. These correlations are larger than those reported by previous workers, which may be due to the analyses being made on each breedcross individually, whereas all other workers have reported correlations on intra-breed bases. When intra-breed-cross correlations were calculated, values were obtained proportionately between those of each breed calculated separately. These intra-breed-cross correlations are shown in parentheses in the table and were calculated for percent of five primal cuts and percent of fat only. Body length showed no significant correlations with the dependent variable in the Landrace x Polad x Duroc cross, but did show significant positive correlations between adjusted loin equivalent and primal cuts and a significant negative correlation with percent of fat in the Landrace x Poland cross. In both crosses significant negative correlations were observed between heart girth and flank circumference and adjusted loin equivalent and primal cuts; whereas, positive relationships existed between these same two variables and percentage of fat. The lower half of the table presents the interrelationships existing between the various probes and live-hog measurements. As would be expected, the correlations between the three backfat probes are quite high and positive. All backfat probes were negatively correlated with body length and positively correlated with heart girth and flank circumference.

In Table 15 the zero order correlations are summarized between the live-animal scores and carcass yields. The notable lack of significance is of special interest in view of the fact that considerable time and effort is annually spent appraising carcass merit in just this manner. The only score which was of any value was that for finish. Here, however, these correlations are approximately one half of those obtained by any one of the three backfat probes. Negative correlations existed between all other scores and percent fat, but were in no manner of any value in evaluating the carcass yields they were taken to determine. One exception was noted in the Landrace x Poland cross in that a very low but significant positive correlation (.18) was observed between conformation and adjusted loin equivalent.

Body length score was less accurate in estimating actual carcass length than was body length measure, as shown in Table 16. Correlations of 0.53 and 0.56 were noted between body length measurement and carcass length, while 0.44 and 0.57 was shown between body length score and carcass length of the three-breed and two-breed crosses, respectively. This table also shows the coefficient of correlation between hind leg length and carcass length to be about 0.55, and between body length measurement and body length score about 0.50.

TABLE 14-ZERO ORDER CORRELATION COEFFICIENTS BETWEEN LIVE-HOG MEASUREMENTS AND CARCASS YIELDS FOR LANDRACE X POLAND X DUROC AND LANDRACE X POLAND HOGS*
(INTRA-BREED-CROSS CORRELATIONS SHOWN IN PARENTHESES)

Body Measurements in mm. and Carcass Yields as Percentage of Live-Weight	Breed-Cross	Backfat Probes: Shoulder Probe	Hip Probe	Ham Probe	Body Length	Heart Girth	Flank Circumference
Per Cent Adjusted Loin Equivalent	LPD(N=81)	-.33	-.38	-.34	.08	-.31	-.21
	LP (N=118)	-.45	-.38	-.49	.26	-.19	-.27
Per Cent Five Primal Cuts	LPD	-.33 (-.42)	-.35 (-.39)	-.31 (-.40)	.00 (.11)	-.41 (-.28)	-.22 (-.24)
Cuts	LP	-.50	-.42	-.48	.20	-.22	-.26
Per Cent Fat	LPD	.63 (.67)	.55 (.63)	.56 (.59)	-.14 (-.17)	.45 (.28)	.40 (.40)
	LP	.71	.70	.62	-.19	.26	.40
Shoulder Probe	LPD		.61	.65	-.31	.35	.41
	LP		.78	.63	-.18	.42	.39
Hip Probe	LPD			.67	-.53	.28	.29
	LP			.70	-.22	.28	.27
Ham Probe	LPD				-.26	.20	.16
	LP				-.16	.44	.42
Body Length	LPD					-.27	-.25
	LP					-.09	.02
Heart Girth	LPD						.63
	LP						.56

*LPD--Correlations of 0.22 are significant at the 5 percent level and 0.28 at the 1 percent level.
LP---Correlations of 0.18 are significant at the 5 percent level and 0.24 at the 1 percent level.

TABLE 15-ZERO-ORDER CORRELATION COEFFICIENTS BETWEEN LIVE-HOG SCORES AND CARCASS YIELDS FOR LANDRACE X POLAND X DUROC AND LANDRACE X POLAND HOGS

		Live-Hog Scores				
Carcass Yields	Breed-cross	Body Length	Meatiness	Quality	Finish	Conformation
Adjusted Loin Equivalent	LPD (N=81)	.12	.02	-.19	-.24*	-.10
	LP (N = 118)	.04	.10	.11	-.24**	.18*
Per Cent Five Primal Cuts	LPD	.12	.00	-.04	-.22*	-.14
	LP	.01	.06	.06	-.19*	-.14
Per Cent Fat	LPD	-.13	-.09	.08	.24*	.01
	LP	-.26**	-.34**	-.22*	.18*	-.28**

*Statistically significant at .05 level.
**Highly statistically significant at .01 level.

TABLE 16-ZERO-ORDER CORRELATION COEFFICIENTS BETWEEN BODY LENGTH SCORE, BODY LENGTH MEASUREMENT, CARCASS, AND LEG LENGTH MEASUREMENTS FOR LANDRACE X POLAND X DUROC AND LANDRACE X PLLAND HOGS*

	Breed-Cross	Carcass Length	Body Length Score
Body Length Measurement	LPD (N = 81)	.53	.49
	LP (N = 118)	.56	.51
Body Length Score	LPD	.44	
	LP	.57	
Hind Leg Length (Carcass)	LPD	.53	
	LP	.57	

*All values are highly statistically significant at the .01 level.

The relative importance of each of the three body measurements and three backfat probes in explaining variance in the adjusted loin equivalent, percentage of five primal cuts, and percentage of fat when used in multiple correlation studies is shown in Tables 17, 18, and 19. These three tables present the stand-

TABLE 17-BETAS USED FOR DETERMINATION OF DIRECT AND INDIRECT EFFECTS OF SIX BODY MEASUREMENTS ON THE VARIANCE IN THE ADJUSTED LOIN EQUIVALENT (X_1)

	LPD (N = 81)		LP (N = 118)	
Items	Betas	Squared Betas		Squared Betas
Shoulder Probe (X_2)	-.058	.003	-.321	.103
Hip Probe (X_3)	-.198(-.310)	.039(.096)	.177	.032
Ham Probe (X_4)	-.129	.017	-.392(-.455)	.153(.207)
Body Length (X_5)	-.043	.002	.188(.183)	.035(.034)
Heart Girth (X_6)	-.297(-.258)	.088(.066)	.133	.018
Flank Circumference (X_7)	.067	.004	-.110	.012
Sum of Direct Effects		.153(.162)		.353(.241)
Sum of Indirect Effects		.061(.046)		-.034(-.013)
R^2		.214(.208)		.319(.228)
R		.463(.456)**		.565(.477)**

Estimating equation for LPD:

$X_1 = 77.542 - .019X_2 - .081X_3 - .061X_4 - .002X_5 - .021X_6 + .003X_7$

$S_{1.2..7} = 1.902$

$X_1 = 73.978 - .127X_3 - .018X_6 \quad S_{1.36} = 1.921$

Estimating equation for LP:

$X_1 = 32.180 - .092X_2 + .065X_3 - .156X_4 + .010X_5 + .009X_6 - .006X_7$

$S_{1.2..7} = 1.520$

$X_1 = 46.367 - .182X_4 + .010X_5 \quad S_{1.45} = 1.567$

**Highly significant at .01 level.

TABLE 18-BETAS USED FOR DETERMINATION OF DIRECT AND INDIRECT EFFECTS OF SIX BODY MEASUREMENTS ON THE VARIANCE IN THE PERCENTAGE OF FIVE PRIMAL CUTS (X_1)

	LPD (N = 81)		LP (N = 118)	
Items	Betas	Squared Betas	Betas	Squared Betas
Shoulder Probe (X_2)	-.126	.016	-.375(-.476)	.141(.226)
Hip Probe (X_3)	-.101	.010	.109	.012
Ham Probe (X_4)	-.136	.019	-.306	.094
Body Length (X_5)	-.165(-.099)	.027(.010)	.140(.113)	.020(.013)
Heart Girth (X_6)	-.405(-.380)	.164(.144)	.091	.008
Flank Circumference (X_7)	.085	.007	-.066	.004
Sum of Direct Effects		.243(.154)		.279(.239)
Sum of Indirect Effects		.006(.010)		.036(.010)
R^2		.249(.164)		.315(.249)
R		.499(.405)**		.561(.499)**

Estimating equation for LPD:
$X_1 = 79.011 - .031X_2 - .031X_3 - .048X_4 - .007X_5 - .021X_6 + .003X_7$
$S_{1.2..7} = 1.381.$
$X_1 = 73.498 - .004X_5 = .020X_6$ $S_{1.56} = 1.481$
Estimating equation for LP:
$X_1 = 39.100 - .080X_2 + .029X_3 - .090X_4 + .006X_5 + .005X_6 - .003X_7$
$S_{1.2..7} = 1.123$
$X_1 = 47.761 - .101X_2 + .004X_5$ $S_{1.25} = 1.164$

** Highly statistically significant at a .01 level.

ard partial (net) or beta coefficients and terms for the direct and indirect effects of each independent variable on the variance in the dependent variables studied. By comparing the magnitude of the squared beta coefficients, the relative importance of each associated variable can be ascertained. The beta coefficients have been obtained by reducing the coefficients of regression to comparable terms by expressing the dependent and independent variables in units of their respective standard deviations.

$$\beta 12.3...7 = b_{12.3...7} \frac{\sigma_2}{\sigma_1}$$

Table 17 shows the relative effect of each independent variable on the variance in the adjusted loin equivalent for each breed-cross analyzed separately. In the Landrace x Poland x Duroc cross, the betas were all negative, except for flank circumference; whereas, negative betas were obtained for shoulder and ham probes in addition to flank circumference in the Landrace x Poland cross. The positive beta for hip probe in the two-breed cross may be indicative of a different fattening pattern in the three-breed cross. Thus, in the Landrace x Po-

TABLE 19-BETAS USED FOR DETERMINATION OF DIRECT AND INDIRECT EFFECTS OF SIX BODY MEASUREMENTS ON THE VARIANCE IN THE PERCENTAGE OF FAT (X_1)

	LPD (N = 81)		LP (N = 118)	
Items	Betas	Squared Betas	Betas	Squared Betas
Shoulder Probe (X_2)	.335(.542)	.112(.294)	.357(.696)	.127(.484)
Hip Probe (X_3)	.102	.011	.229	.052
Ham Probe (X_4)	.240	.058	.184	.034
Body Length (X_5)	.118	.014	-.248(-.068)	.062(.005)
Heart Girth (X_6)	.243(.260)	.059(.068)	-.159	.025
Flank Circumference (X_7)	.074	.005	.199	.040
Sum of Direct Effects		.259(.362)		.340).489)
Sum of Indirect Effects		.255(.050)		.322(.008)
R^2		.514(.412)		.662(.497)
R		.718(.642)**		.814(.705)**

Estimating equation for LPD:

$X_1 = -20.124 + .103X_2 + .040X_3 + .107X_4 + .006X_5 + .016X_6 + .003X_7$

$S_{1.2..7} = 1.389$

$X_1 = -9.55 + .166X_2 + .017X_6 \quad S_{1.26} = 1.491$

Estimating equation for LP:

$X_1 = 21.350 + .097X_2 + .079X_3 + 069X_4 - .013X_5 - .011X_6 + .010X_7$

$S_{1.2..7} = 1.010$

$X_1 = 11.018 + .189X_2 - .003X_5 \quad S_{1.25} = 1.213$

**Highly statistically significant at .01 level.

land cross, the fat at the ham probe is indicative of maturity, whereas in the Landrace x Poland x Duroc cross, the fat thickness at the hip probe is indicative of maturity.

The squared betas in Table 17 indicate that heart girth had the greatest predictive influence, followed by the hip and ham probes in the Landrace x Poland x Duroc hogs. These three independent variables account for 66 percent of the associated variance. All six of the variables acting together explained about 21 percent of the total variance in the adjusted loin equivalent. A greater amount of the variation was explained by the six measures in the Landrace x Poland cross as indicated by a coefficient of multiple determination of .319 with the ham and shoulder probes alone accounting for approximately 80 percent of this value. Nonetheless, about 68 percent of the variance in the adjusted loin equivalent was not explained or associated with the measurements studied.

The multiple correlation coefficients were highly significant for both breed crosses.

$$t = \frac{R1.2...n \sqrt{n-m}}{\sqrt{1-R^2_{1.2...n}}}$$

The regression equations given at the bottom of the table apply within the limits of these data only. For example, the first regression equation is read: for each increase of 1 millimeter in shoulder probe there is a decrease of 0.019 in the adjusted loin equivalent. It should be realized, in appraising the value of the beta and net regression coefficients in Tables 17, 18, and 19 that the values are subject to random variation, as are all statistics.

Since some of the measurements had a low predictive influence on the yield of the adjusted loin equivalent, the betas were recalculated, using the two most important variables, i.e., hip probe and heart girth in the Landrace x Poland x Duroc cross and ham probe and body length in the Landrace x Poland cross. These recalculated betas are given in parentheses, with the corresponding estimating equations at the bottom of the table. In the two-breed cross, it will be noted that the beta coefficient for shoulder probe was greater than that for body lengh. However, by referring to Table 14 it is seen that a correlation of 0.63 existed between these two variables; whereas, –0.16 was the correlation between ham probe and body length. Since a high correlation between two independent variables lessens the importance of one of them in a multiple correlation study, it appeared desirable to use two variables which were less correlated and still had considerable predictive value; hence, ham probe and body length were used. The bases of selecting two independent variables in Tables 17 and 19 were also decided upon similar consideration.

Associated variance was reduced from 0.214 and 0.319 to 0.208 and 0.228 in the Landrace x Poland x Duroc and the Landrace x Poland crosses by the omission of four less valuable independent variables. Apparently, the combination of hip probe and heart girth in the case of the two-breed cross, and of the ham probe and body length in the three-breed cross was nearly as valuable in estimating the adjusted loin equivalent as all six measurements considered together.

Table 17 shows the relative effect of each independent variable on variance in percent of five primal cuts. The betas were all negative except for flank circumference, in the Landrace x Poland x Duroc cross, whereas negative betas were obtained for only the shoulder probe, ham probe, and flank circumference in the Landrace x Poland cross. This pattern is similar to that in Table 17 where the same independent variables were correlated with the adjusted loin equivalent. As shown in the lower part of Table 18, the six measurements account for approximately 25 and 32 percent of the variation in the percentage of five primal cuts for the two- and three-breed crosses, respectively. In the Landrace x Poland x Duroc, heart girth had the greatest predictive influence on five primal cuts, as was the case for the adjusted loin equivalent. However, body length was relatively more important, with backfat probes about equal in value. Heart girth and body length accounted for about 75 percent of the associated variance when all six variables were used. By using these two variables alone, the associated variance was lowered from 0.249 to 0.164. In the two-breed cross, the rank of predictive influence was similar to that of Table 17 with the exception of shoulder and ham probes. However, this difference might well be within the realm of random variation. By using the two most important measures in each cross and recalculating the betas, coefficients of determination of 0.164 and 0.249 were obtained in the Landrace x Poland x Duroc and Landrace x Poland cross, respectively.

Negative betas were observed for body length and heart girth in the Landrace x Poland cross. As was the case in the three-breed cross, shoulder probe had the greatest predictive influence. In this cross, however, a more equal distribution of associated variance was noted between the remaining five variables. Recalculation of the multiple correlation coefficient using only shoulder probe and body length yielded a value of 0.705. The estimating equation shows that each millimeter increase in shoulder probe increases the total fat 0.189 percent; whereas, each millimeter increase in body length is associated with a 0.003 percent decrease in total fat.

The effect of the six body measurements and backfat probes on the variance in the percentage of fat is shown in Table 19. All betas are positive in the Landrace x Poland x Duroc cross, with the shoulder probe having the greatest predictive influence, followed by heart girth and ham probe. The direct effects of these three variables accounted for 44 percent of the explained variance in percentage of fat; whereas, the use of all six variables accounted directly for about 50 percent. However, the indirect or joint effects were equally as great, and together with the direct effects of the six variables, explained about 51 percent of the total variance. When the multiple correlation was recalculated using only shoulder probe and heart girth, the coefficient of multiple determination was reduced to 0.412. The recalculated estimating equation reads: for each increase of 1 millimeter in shoulder probe, total carcass fat increases 0.166 percent, while each millimeter increase in heart girth increases the total fat in the carcass 0.017 percent.

In consideration of the differences existing between the two-breed crosses studied, it becomes apparent that notable differences in relative importance of specific variables exist between the crosses. Whereas, body length had a rather high predictive influence on the percentage of fat in the Landrace x Poland cross, the opposite situation existed in the Landrace x Poland x Duroc hogs. Theorization on the reason underlying this phenomenon may indicate that differences in "age of maturity" exist within breed (genetic) groups. Assuming that the Landrace x Poland x Duroc crossbreds mature at an earlier age, it follows that they will have reached a greater percentage of their protential total length at a given weight, say 200 pounds. Thus, as growth rate decreases, lipogenesis increases and predominates. In the Landrace x Poland cross, however, growth is relatively greater at 200 pounds live-weight, and a greater percentage of intermediate metabolites is directed toward tissue and bone development than toward lipogenesis. Body length variation in the Landrace x Poland cross indicates that the growth-rate plateau has not yet been reached at slaughter weight, thus accounting for the negative relationship between body length and percentage of fat.

Relationships Between Growth Rate and Carcass Characteristics.

Correlations were studied between carcass yields and growth rate as indicated by average daily gain from birth to slaughter on 165 of the animals previously described. Spring-farrowed barrows of the Landrace x Poland x Duroc cross, and spring- and fall-farrowed barrows and gilts of the Landrace x Poland cross were used. The Landrace x Poland x Duroc barrows farrowed in the fall of 1953 were not included in the correlation studies, due to the possible influence of various management practices used in that season (see Table 3). Correlations were made for each breed, sex, and season, individually, along with the mean daily gains for each sub-class (Table 20).

MEAN DAILY GAINS AND ZERO-ORDER CORRELATION COEFFICIENTS WITH CARCASS YIELDS

	Average Daily Gain from Birth to Slaughter				
	LPD	LP	LP	LP	LP
	Spring Barrows (N = 50)	Spring Barrows (N = 61)	Fall Barrows (N = 23)	Spring Gilts (N = 11)	Fall Gilts (N = 23)
	Mean	Mean	Mean	Mean	Mean
Carcass Yields	1.21 + .09	1.17 + .07	1.20 + .08	1.10 + .09	1.15 + .08
Adjusted Loin Equivalent	-.27***	-.13	-.45*	.75**	.24
Percentage Five Primal Cuts	-.37*	-.16	-.17	.63*	.34
Percentage Fat	.28***	.20	-.12	-.40	-.30

* Statistically significant at .05 level.
** Statistically significant at .01 level.
*** A correlation of .282 would be significant at .05 level.

The barrows of the Landrace x Poland x Duroc cross had a slightly higher daily gain than those of Landrace x Poland breeding, with fall-farrowed barrows outgaining spring-farrowed by 0.03 pound per day in the two-breed cross. Regardless of season, barrows outgained gilts an average of 0.05 pound per day. (Average daily gain from birth to slaughter for all Landrace x Poland barrows was 1.18 compared to 1.13 for all gilts of the same breed cross.)

In all instances, barrows exhibited negative correlations between rate of gain and adjusted loin equivalent and percentage of five primal cuts; whereas, positive correlations were shown between rate of gain and percentage of fat. In the Landrace x Poland x Duroc cross, these correlations were nearly significant at the 0.05 level; whereas, in the Landrace x Poland cross, relationships were generally not statistically significant and were of low magnitude, with the exception of that existing with adjusted loin equivalent for fall-farrowed barrows.

An interesting relationship was exhibited in gilts which showed relationships exactly opposite those found in barrows. In other words, positive correlations were shown between adjusted loin equivalent and percentage of five primal cuts and rate of gain, while a negative relationship existed between rate of gain and percentage of fat. These values were rather low in magnitude but definitely indicated trends. The high relationship noted in the spring-farrowed gilts cannot be counted too highly, due to the unusually small size of this sub-class (N = 11).

In Figures 12 and 13, regression equations for percentage of fat and five primal cuts on daily rate of gain are plotted for the Landrace x Poland x Duroc barrows. For percentage of fat on average daily gain, it is noted that the regression coefficient was extremely small and barely approached significance at the 0.05 level. The graph for percentage of fat reads: for each unit increase in average daily gain, the percentage of fat will increase 5.698 percent. Figure 13 reads: for each 1 pound increase in average daily gain, the percentage of five primal cuts would decrease 6.256 percent. No regression equations were calculated for the two-breed cross, due to the low and, in most cases, nonsignificant correlation, which indicates that the corresponding regression coefficients would also be below the levels of significance.

Results of this study seem consistent with those of other workers, in that rather low correlations are reported between rate of gain and carcass yields and composition. However, sex differences are shown to exist, which may account for the partial discrepancy (for gilts) between these findings and those of Dickerson (1947), Blunn, and Blunn and Baker (1947) who reported a positive correlation between fatness and rate of gain. Nonsignificant correlations or correlations of very low significance were reported by Cummings and Winters (1951) between growth rate factors and yield of five primal cuts and index of fat cuts, even after adjustments were made for weight differences and breed groups. No mention was made concerning the sexes studied and it appears, in view of the results reported herein, that the opposite correlations existing between the sexes in growth rate and carcass yields would tend to reduce the numerical magnitude of any correlation studies in which both sexes constituted the sample. The effect of correlation studies made on an intra-sex basis would seem to be unsound, since they would merely tend to mask the fundamental underlying relationships.

To observe the value of gross correlations in which both sexes appeared in equal numbers, trial correlations were calculated on fall-farrowed pigs (both barrows and gilts included) of the Landrace x Poland cross. The total correlation between average daily gain and adjusted loin equivalent was -0.25 with -0.10 obtained between average daily gain and percent fat. When intra-sex correlations were run on the same individuals for the same two variables, values of -0.14 and -0.19 were observed for the relationship between adjusted loin equivalent and percent of fat with average daily gain.

Figure 12. Regression of Percentage of Fat on Average Daily Gain for Landrace X Poland X Duroc Spring Farrowed Barrows

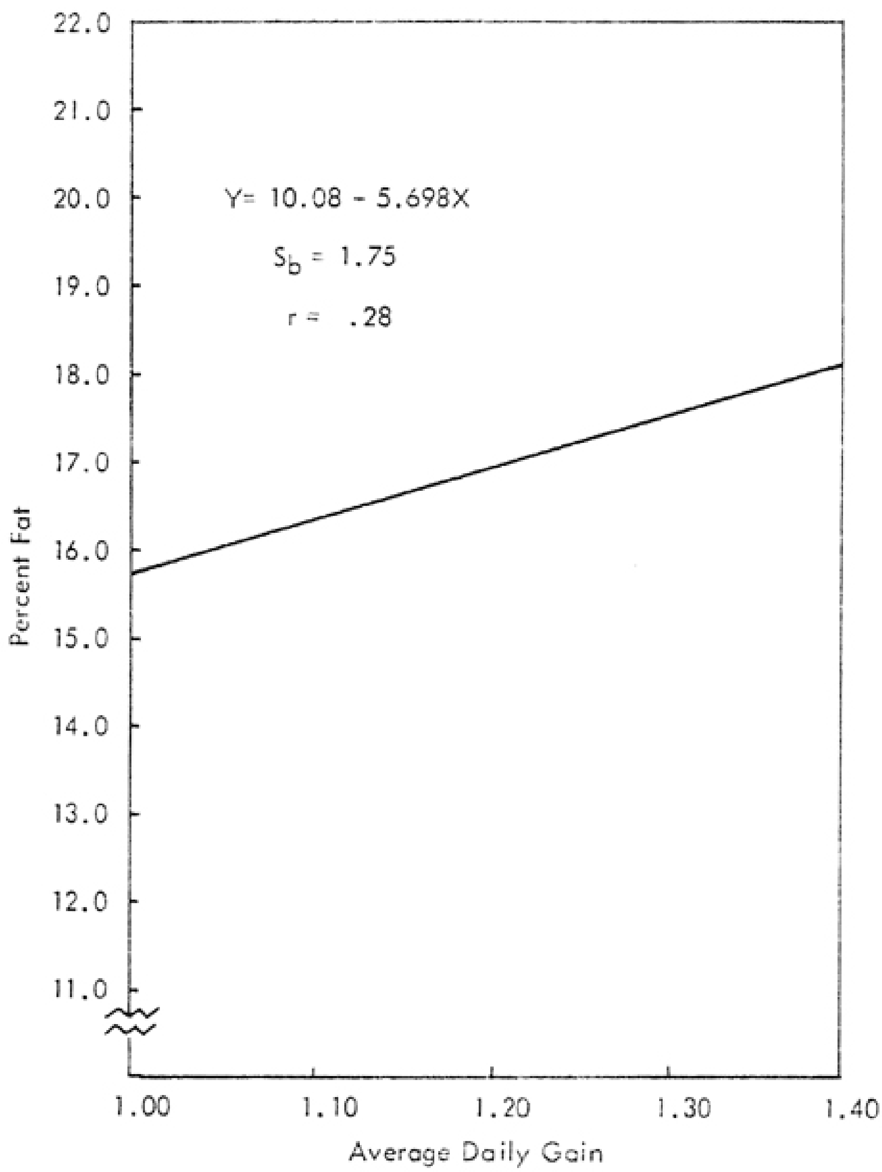
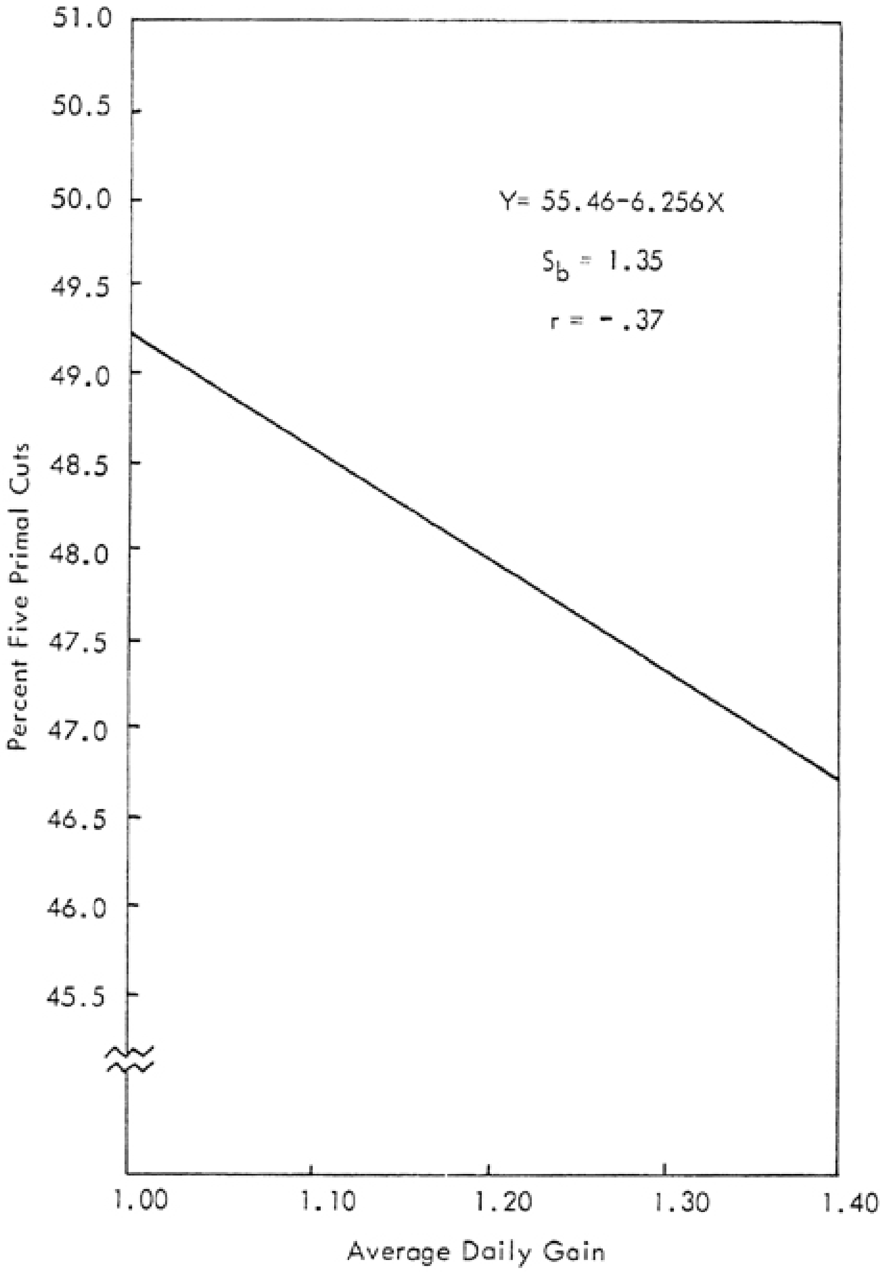


Figure 13. Regression of Percentage of Five Primal Cuts on Average Daily Gain for Landrace X Poland X Duroc Spring Farrowed Barrows



The theory underlying these observed results may be derived and shown as follows:

When separate correlations are calculated for each sex,

$$\frac{\Sigma x_a y_a}{\sqrt{(\Sigma x^2{}_a)\ (\Sigma y^2{}_a)}} = r_a \text{ and}$$

$$\frac{-\Sigma x_b y_b}{\sqrt{(\Sigma x^2{}_b)\ (\Sigma y^2{}_b)}} = -r_b.$$

a = gilts
b = barrows
x = rate of gain
y = adjusted loin equivalent

The total (gross) correlation in which both sexes were included would be:

$$\frac{\Sigma x_{a+b}\ y_{a+b}}{\sqrt{(\Sigma x^2{}_{a+b})\ (\Sigma y^2{}_{a+b})}} = \pm\ r_{a+b}$$

where

$$\Sigma x_{a+b}\ y_{a+b} = [\Sigma x_a y_a - \frac{(\Sigma x_a)\ (\Sigma y_a)}{N_a}] + [\Sigma x_b y_b - \frac{(\Sigma x_b)\ (\Sigma y_b)}{N_b}]$$

When the signs of r_a and r_b are unlike, as shown above where r_a is positive and r_b is negative, the numerical value of the numerator is decreased, giving rise to a lower numerical gross correlation.

The within sex correlation is as follows:

$$\frac{(\Sigma x_{a+b}\ y_{a+b})_G - (\Sigma x_{a+b}\ y_{a+b})_B}{\sqrt{[\Sigma x^2{}_{a+b})_G - (\Sigma x^2{}_{a+b})_B] \cdot [(\Sigma y_{a+b})_G - (\Sigma y^2{}_{a+b})_B]}} = \pm\ r_{a+bW}$$

G = gross
B = between sexes
W = within sexes.

In instances where the algebraic signs of r_a and r_b are unlike, $(\Sigma x_{a+b}\ y_{a+b})_B$ will be negative, thereby decreasing the numerical value of the numerator and subsequently lowering the numerical magnitude of $\pm r_{a+bW}$ which is the intra-sex correlation when $(\Sigma x_{a+b}\ y_{a+b})_G$ is negative, as in the foregoing example.

The results of this work seem to indicate that sex is one of the more important factors influencing the relationship between rate of gain and carcass composition. The hormonal influences on growth are apparently involved in this phenomenon. Since it has been shown that the estrogenic hormones exert a stimulus on growth, it has been hypothesized that the action of estrogen is on the growth hormone. In gilts, this hormonal action expresses itself in an increase in protein catabolism and an inhibition of lipogenesis, both of which are partially controlled by the anterior pituitary's growth hormone. Therefore, those females having the higher levels of growth and/or the estrogenic hormones make the most rapid growth and convert a larger portion of the nutrient intake to protein tissue; hence, explaining the positive relationship existing between growth rate and the percentage of primal cuts and negative correlations shown with carcass total fat.

In the case of barrows, where the major source of the androgens has been removed, lipogenesis is relatively more predominant, giving rise to a higher percentage of fat at slaughter weights. The reason why positive correlations exist between growth rate and fatness is not as apparent, although the level of thyroid activity might well be a contributing factor, with barrows that have an optimum metabolic activity making the most rapid growth and carrying on lipogenesis at a higher rate.

This philosophizing does not pretend to answer this observed phenomenon in a conclusive manner, but merely points out some of the possibilities. Undoubtedly, selection can be effective in altering this make up. It can also have a small effect on the reassorting and recombining of the genetic bases responsible for these visible differences. However, in the samples generally studied in research work, a greater degree of homogeneity exists than is normal to the total population, thereby rendering the isolation of related phenomena difficult. This fact, coupled with the extensive use of various statistical techniques, often produces misleading conclusions. There is no doubt that statistical control and/or removal of sources of variation is a valuable tool; nevertheless, it is also possible that these same techniques may lead to false conclusions.

SUMMARY AND CONCLUSIONS

Live-hog descriptive scores, body measurements, backfat probes and carcass data were studied on 199 crossbred hogs; 81 were barrows of Landrace x Poland x Duroc breeding farrowed in the spring and fall of 1953, and 118 were barrows and gilts of Landrace x Poland breeding farrowed in the spring and fall of 1954.

The influence of breed-cross, season, and sex on live-hog probes and body measurements and measures of gross carcass evaluation was studied by means of statistical techniques modified to fit these particular data.

In the breed-crosses studied, no significant differences were noted in the adjusted loin equivalent or percentage of primal cuts, although animals of Landrace x Poland x Duroc breeding had a greater amount of total fat and a higher dressing percentage. In this research, all evaluations of carcass worth were expressed in terms of the adjusted live weight which was obtained by adjusting all animals at slaughter weights to an equal fill, thereby eliminating a source of variation. Backfat probes were greater in the Landrace x Poland x Duroc cross, as were heart girth and flank circumference measurements; whereas, the Landrace x Poland pigs had greater body length. These findings indicate that differences in growth patterns existed between the two breed-crosses studied.

Seasonal differences in backfat probes, body measurements, and carcass yields were noted. Although they were not, in most instances, statistically significant, they do indicate that environmental factors influence growth and development in the hog.

Sex differences were very pronounced and highly significant, with gilts having a higher adjusted loin equivalent and percentage of primal cuts and lower total fat. It is interesting that even though the gilts had less total fat, they had approximately the same dressing percentage as barrows. This seems to indicate that the sex hormones influence true growth to a marked extent. This was further substantiated by significantly longer bodies in the gilts.

Two-way interactions were statistically significant between breed-crosses and season for body length and heart girth. Whereas the Landrace x Poland pigs tended to have longer bodies in the spring than the Landrace x Poland x Duroc hogs, they were shorter bodied in the fall compared to the three-breed cross. This shows that a specific genetic constitution may be expressed as a different phenotype under varying environmental conditions.

Pasture influenced carcass development to a small extent. Pasture-fed pigs generally exhibited a slightly more desirable meat-type carcass than dry lot fed pigs.

When live-hog scores were compared with carcass cutout values, general similarities were shown which indicated that the judges were able in most cases to rank carcass merit groupings by live-hog scoring. However, sufficient differentiation was not made between the groups when they were classified by sex, season, and breed-cross.

Correlation studies concerned with predicting carcass worth from live-hog measurements and backfat probes were calculated for each breed-cross separately. Live-hog measurements and backfat probes showed higher relationships with carcass merit than did any of the subjective scores studied. Most correlations between carcass yields and live hog scores were nonsignificant, with the exception of the score for finish. Scores for body length, meatiness, quality, and conformation all exhibited significant negative correlations with total carcass fat in the Landrace x Poland cross, although none of those same correlations were significant in the Landrace x Poland x Duroc cross.

Since absolute live hog measurement and backfat probes had considerably greater predictive influence on carcass yields than scores, they were used in multiple correlation studies. When the three probes and three live-hog measurements were combined into one multiple correlation study, a value of multiple correlation equal to 0.463 was obtained with adjusted loin equivalent in the Landrace x Poland x Duroc cross with values of 0.499 and 0.718 shown with percentage of five primal cuts and percentage of total fat, respectively. Coefficients of multiple correlation equal to 0.565, 0.561, and 0.814 were obtained between the six measurements and the adjusted loin equivalent, percentage of primal cuts, and percentage total fat, respectively, in the Landrace x Poland cross.

The recalculation of the multiple correlation coefficient using only the two most important independent variables (heart girth and hip probe with adjusted loin equivalent; heart girth and body length with primal cuts; and shoulder probe and heart girth with percentage of total fat in the Landrace x Poland x Duroc cross and ham probe and body length with adjusted loin equivalent; shoulder probe and body length with percentage of primal cuts; and shoulder probe and body length on percentage of fat in the Landrace x Poland cross) gave values of 0.456, 0.405, and 0.642 for adjusted loin equivalent, percentage primal cuts, and percentage total fat in the Landrace x Poland x Duroc cross. In the Landrace x Poland cross the figures were 0.477, 0.499, and 0.705 for adjusted loin equivalent, percentage of primal cuts, and percentage total fat.

The estimating equations derived for predictive purposes in the Landrace x Poland x Duroc breed-cross were as follows:

Adjusted loin equivalent $= 73.978 - .127^{\text{hip}}_{\text{probe}} - .018^{\text{heart}}_{\text{girth}}$
Percent five primal cuts $= 73.498 - .004^{\text{body}}_{\text{length}} - .020^{\text{heart}}_{\text{girth}}$
Percent fat $= -9.550 + .166^{\text{shoulder}}_{\text{probe}} + .017^{\text{heart}}_{\text{girth}}$

In the Landrace x Poland breed-cross, equations were developed as shown below:

Adjusted loin equivalent $= 46.367 - .182^{\text{ham}}_{\text{probe}} + .010^{\text{body}}_{\text{length}}$
Percent five primal cuts $= 47.761 - .010^{\text{shoulder}}_{\text{probe}} + .004^{\text{body}}_{\text{length}}$
Percent fat $= 11.018 + .189^{\text{shoulder}}_{\text{probe}} - .003^{\text{body}}_{\text{length}}$

Shoulder backfat probe was the most valuable single measurement in estimating the percentage of total carcass fat in both crosses. Body measurements and backfat probes used in this study were of greater value in explaining variance in the percentage of fat than in the adjusted loin equivalent or percentage of primal cuts. Backfat probes had a greater predictive influence on the adjusted loin equivalent than percentage of primal cuts.

This work shows that certain body measurements, in addition to backfat probes, are of value in estimating carcass yields. However, breed differences in growth pattern should be recognized along with sex differences necessitating separate correlation studies being made for genetic groups and sexes. It would appear that intra-sex-genetic group correlations are not of great value in uncovering underlying fundamental relationships.

Growth rate in terms of average daily gain from birth to slaughter was correlated with the three measures of gross carcass merit used throughout this research, i.e., adjusted loin equivalent, percentage of primal cuts, and percentage of total fat. Each breed-cross, season, and sex was studied separately.

No conclusive statistically significant relationships were found, although obvious trends in sex differences were observable. For barrows of both breed-crosses, average daily gain was negatively correlated with the adjusted loin equivalent and percentage of primal cuts, while an opposite relationship was indicated between daily gain and percentage of fat. Correlations for gilts between rate of gain and adjusted loin equivalent and primal cuts were positive, while those between average daily gain and percentage of fat were negative. In a situation where subgroups exhibit a different relationship (such was the case here) the effects of oft-used statistical techniques on interpretation were shown to be unreliable.

The apparent low correlations existing between rate of gain and carcass yields are indicative of independent, genetically controlled physiological bases of these two economically desirable traits, and make possible the assortment and recombination of genetic determiners for both characteristics into a single breeding group.

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APPENDIX I

SUMMARY OF DATA ON GROWTH RATE, CARCASS YIELDS AND MEASUREMENTS, AND LIVE-HOG MEASUREMENTS AND SCORES CLASSIFIED BY SEASON, SEX, AND BREED-CROSS

SUM OF SQUARES AND MEANS FOR 50 LANDRACE X POLAND X DUROC BARROWS FARROWED IN THE SPRING OF 1953

	X^2	X	$\overline{X}$
Age in days at slaughter	1,233,127.00	7,835.00	156.70
Adjusted live weight	1,795,861.78	9,475.20	189.50
Chilled carcass weight	1,049, 809.88	7,241.80	144.84
Dressing per cent	292,231.57	3,821.76	76.43
Average daily gain[1]	74.17	60.72	1.21
Percentage of Five Primal Cuts[2]	114,783.85	2,394.41	47.89
Adjusted Loin[2] Equivalent	125,415.31	2,502.04	50.04
Percentage Fat[2]	14,569.24	848.28	16.97
Carcass Length[3]	26,962,562.00	36,772.00	735.44
Hind Leg Length[3]	13,964,421.00	26,411.00	528.22

[1]From birth to slaughter
[2]Expressed in terms of adjusted live weight
[3]Measured in millimeters

SUM OF SQUARES AND MEANS FOR 50 LANDRACE X POLAND X DUROC BARROWS FARROWED IN THE SPRING OF 1953

	X^2	X	$\overline{X}$
Live-hog probes:[1]			
Shoulder	128,120.00	2,514.00	50.28
Hip	62,071.00	1,745.00	34.90
Ham	54,784.00	1,638.00	32.76
Weighted Average	89,703.92	2,104.40	42.09
Body measurements:[1]			
Body length	52,063,960.00	50,994.00	1019.88
Heart girth	56,126,759.00	52,957.00	1059.14
Flank circumference	56,491,196.00	53,116.00	1062.32
Live-hog scores:[2]			
Body length	2,005.04	314.20	6.28
Meatiness	2,183.72	329.00	6.58
Quality	2,137.09	325.50	6.51
Finish	2,487.67	351.30	7.03
Conformation	1,813.67	298.30	5.97

[1]All live-hog probes and body measurements are in millimeters.
[2]Scoring system used had limits of 1 to 9.

SUM OF SQUARES AND MEANS FOR 31 LANDRACE X POLAND X DUROC BARROWS FARROWED IN THE FALL OF 1953

	X^2	X	$\overline{X}$
Age in days at slaughter	707,266.00	4,980.00	160.64
Adjusted live weight	1,291,528.25	6,323.50	203.98
Chilled carcass weight	751,846.45	4,827.10	155.71
Dressing per cent	180,770.61	2,366.60	76.34
Average daily gain	51.49	39.72	1.28
Percentage of five primal cuts	72,906.43	1,502.50	48.47
Adjusted loin equivalent	80,674.65	1,579.96	50.97
Percentage fat	9,014.50	524.00	16.90
Carcass length	15,966,616.00	22,926.00	739.55
Hind leg length	8,823,486.00	16,528.00	533.16

SUM OF SQUARES AND MEANS FOR 31 LANDRACE X POLAND X DUROC BARROWS FARROWED IN THE FALL OF 1953

	X^2	X	$\overline{X}$
Live-hog probes:			
Shoulder	79,468.00	1,552.00	50.06
Hip	42,299.00	1,131.00	36.48
Ham	36,849.00	1,061.00	34.23
Weighted average	57,627.17	1,324.90	42.75
Body measurements:			
Body length	34,082,175.00	32,485.00	1,047.90
Heart girth	32,825,600.00	31,890.00	1,028.71
Flank circumference	32,841,325.00	31,865.00	1,027.90
Live-hog scores:			
Body length	1,173.75	189.50	6.11
Meatiness	1,126.75	185.50	5.98
Quality	1,070.00	181.00	5.84
Finish	1,215.25	192.50	6.21
Conformation	1,065.75	180.50	5.82

SUM OF SQUARES AND MEANS FOR 61 LANDRACE X POLAND BARROWS FARROWED IN THE SPRING OF 1954

	X^2	X	$\overline{X}$
Age in days at slaughter	1,655,435.00	10,033.00	164.48
Adjusted live weight	2,262.362.44	11,740.80	192.47
Chilled carcass weight	1,282,523.51	8,836.90	144.87
Dressing per cent	345,266.88	4,588.77	75.23
Average daily gain	84.21	71.53	1.17
Percentage of five primal cuts	138,608.13	2,906.59	47.65
Adjusted loin equivalent	154,386.34	3,066.87	50.28
Percentage fat	15,681.63	971.64	15.93
Carcass length	34,303,975.00	45,727.00	749.62
Hind leg length	17,600,976.00	32,754.00	536.95

SUM OF SQUARES AND MEANS FOR 61 LANDRACE X POLAND BARROWS FARROWED IN THE SPRING OF 1954

	X^2	X	$\overline{X}$
Live-hog probes:			
Shoulder	131,557.94	2,803.20	45.95
Hip	69.002.00	2,028.00	33.25
Ham	71,167.86	2,064.60	33.85
Weighted average	98,272.07	2,426.87	39.78
Body measurements:			
Body length	68,006,875.00	64,375.00	1,055.33
Heart girth	62,752,220.00	61,850.00	1,013.93
Flank circumference	63,143,330.00	62,026.00	1,016.82
Live-hog scores:			
Body length	3,307.50	447.00	7.33
Meatiness	3,346.75	449.50	7.34
Quality	2,841.00	414.00	6.79
Finish	3,126.50	434.00	7.11
Conformation	2,563.00	392.00	6.43

SUM OF SQUARES AND MEANS FOR 23 LANDRACE X POLAND BARROWS FARROWED IN THE FALL OF 1954

	X^2	X	$\overline{X}$
Age in days at slaughter	639,492.00	3,826.00	166.35
Adjusted live weight	899,996.25	4,572.50	198.80
Chilled carcass weight	526.117.19	3,476.70	151.16
Dressing per cent	133,060.55	1,749.06	76.05
Average daily gain	33.26	27.59	1.20
Percentage of five primal cuts	52,876.47	1,102.42	47.93
Adjusted loin equivalent	58,305.11	1,157.52	50.33
Percentage fat	6,238.93	376.86	16.38
Carcass length	12,354,014.00	16,852.00	732.70
Hind leg length	6,358,658.00	12,090.00	525.65

SUM OF SQUARES AND MEANS FOR 23 LANDRACE X POLAND BARROWS FARROWED IN THE FALL OF 1954

	X^2	X	$\overline{X}$
Live-hog probes:			
Shoulder	47,569.00	1,036.00	45.04
Hip	29,394.25	814.50	35.41
Ham	26,337.25	772.50	33.59
Weighted average	36,960.36	914.80	39.77
Body measurements:			
Body length	23,822,150.00	23,880.00	1,038.26
Heart girth	23,091,600.00	23,040.00	1,001.74
Flank circumference	23,177,816.00	23,080.00	1,003.48
Live-hog scores:			
Body length	869.25	140.50	6.11
Meatiness	984.75	149.50	6.50
Quality	856.50	139.00	6.04
Finish	737.75	128.50	5.59
Conformation	779.75	132.50	5.76

SUM OF SQUARES AND MEANS FOR 11 LANDRACE X POLAND GILTS FARROWED IN THE SPRING OF 1954

	X^2	X	$\overline{X}$
Age in days at slaughter	334,864.00	1,914.00	174.00
Adjusted live weight	397,702.90	2,090.80	190.07
Chilled carcass weight	226,251.97	1,576.70	143.34
Dressing per cent	62,550.31	829.42	75.40
Average daily gain	13.34	12.07	1.10
Percentage of five primal cuts	25,753.13	532.04	48.37
Adjusted loin equivalent	29,459.53	568.78	51.71
Percentage fat	2,495.40	164.62	14.96
Carcass length	6,289,275.00	8,315.00	755.91
Hind leg length	3,103,735.00	5,841.00	531.00

SUM OF SQUARES AND MEANS FOR 11 LANDRACE X POLAND GILTS FARROWED IN THE SPRING OF 1954

	X^2	X	$\overline{X}$
Live-hog probes:			
Shoulder	20,391.75	467.50	42.50
Hip	10,221.25	331.50	30.14
Ham	12,278.00	363.00	33.00
Weighted average	15,411.81	407.37	37.03
Body measurements:			
Body length	12,597,150.00	11,770.00	1,070.00
Heart girth	11,146,268.00	11,070.00	1,006.36
Flank circumference	11,004,848.00	10,998.00	999.82
Live-hog scores:			
Body length	652.25	84.50	7.68
Meatiness	713.75	88.50	8.04
Quality	620.75	82.50	7.50
Finish	509.00	74.00	6.73
Conformation	607.75	81.50	7.41

SUM OF SQUARES AND MEANS FOR 23 LANDRACE X POLAND GILTS FARROWED IN THE FALL OF 1954

	X^2	X	$\overline{X}$
Age in days at slaughter	680,418.00	3,948.00	171.65
Adjusted live weight	893,235.53	4,530.90	197.00
Chilled carcass weight	516.314.58	3,444.80	149.77
Dressing per cent	132,996.73	1,748.84	76.04
Average daily gain	30.62	26.48	1.15
Percentage of five primal cuts	54,370.25	1,117.95	48.61
Adjusted loin equivalent	62,055.35	1,194.28	51.92
Percentage fat	5,637.20	358.95	15.61
Carcass length	12,712,425.00	17,095.00	743.26
Hind leg length	6,409,199.00	12,137.00	527.70

TESTING FOR INTERACTION

Sex	k_1	Spring $\bar{x}_1$	k_2	Fall $\bar{x}_2$	$\frac{k_1 k_2}{k_1+k_2}$ W	$=\bar{x}_1-\bar{x}_2=$ D	WD	WD^2
Barrows	61	50.28	23	50.33	16.70	-.05	-.80	.04
Gilts	11	51.71	23	51.93	7.44	-.22	-1.64	.36
					24.14		-2.44	.40

Sum of Squares for Interaction = $SWD^2 - \frac{(SWD)^2}{SW} = .15$

$F = \frac{.15}{2.95} = .05$ = no significant interaction.

Since the correction term, $(SWD)^2$, is an unbiased estimate of the mean square between the column means, a correction for disproportion is calculated as follows:

$$(\text{Sum of Squares for Season}) - \frac{(SWD)^2}{SW} = 10.92$$

PRELIMINARY ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	164	232,331.12		
Subclasses	3	36,469.32	12,156.44	9.99**
Individuals	161	195,861.88	1,216.53	

**Probability of chance occurrence less than .01 per cent. Therefore, subclasses are significantly different.

Note: In the completed analysis of variance, the recalculated mean square for individuals (3.04) is used for testing season and sex significance. The use of the original mean square for individuals (2.95) would also be acceptable. Another theoretically debatable practice would be the addition of the sum of squares for interaction to those of individuals since interaction is not significant, thereby deriving a slightly higher value for individuals mean square to be used in testing season and sex significance.

Computations for a 2 x 2 table with disproportionate sub-class numbers. Data are body length of two breed crosses and two seasons. Diagrammatic presentation given in Figure 9. Interaction present.

TESTING FOR INTERACTION

Breed Cross	k_1	Spring $\bar{x}_1$	k_2	Fall $\bar{x}_2$	$\frac{k_1 k_2}{k_1+k_2}$ W	$= x_1 - x_2 =$ D	WD	WD^2
LPD	50	1019.88	31	1047.90	19.14	-28.02	-536.30	15,027.13
LP	61	1055.33	23	1038.26	16.43	17.07	280.46	4,607.96
					35.57		-255.84	19,635.09

Sum of Squares for Interaction = $SWD^2 - \frac{(SWD)^2}{SW} = 17,794.73$

$F = \frac{17,794.73}{1,216.53} = 14.63$ = significant interaction between two breed-crosses studied and season in regard to body length.

Note: Up to this point the analysis proceeds along the same lines as when no interaction is present. However, from this point (interaction shown to exist) the analysis differs.

Harmonic mean of subclass numbers calculated.

$$\frac{1}{k_o} = \frac{1}{4}\quad \frac{1}{50} + \frac{1}{31} + \frac{1}{61} + \frac{1}{23} \quad =$$

$$\frac{1}{.0281} = 35.59 = \text{Harmonic mean}$$

MEAN BODY LENGTH IN 4 GROUPS OF HOGS TAKEN FROM PRECEDING TABLE*

	Spring	Fall	Sum	Mean
LPD	1,019.88	1,047.90	2,067.78	1,033.89
LP	1,055.33	1,038.26	2,093.59	1,046.79
Sum	2,075.21	2,086.16	4,161.37	
Mean	1,037.60	1,043.08		1,040.34

*Note that from this point on, analysis is made on means of groups.

Mean Square:

Breeds $\dfrac{(2093.59 - 2067.78)^2}{4} = 166.54$

Season $\dfrac{(2086.16 - 2075.21)^2}{4} = 29.98$

COMPLETED ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Mean Square	F
Total	164		
Breed	1	166.54(35.59) = 5927.16	4.87*
Season	1	29.98(35.59) = 1066.99	.88
Interaction	1	17,794.73	14.63**
Individuals	161	1,216.53	

*Probability of chance occurrence less than .05 percent.
** Probability of chance occurrence less than .01 percent.

It should be noted that the mean squares for breed and season in the completed analysis of variance table are "estimates" of the variance if original observations were used instead of the means. These estimates were derived by multiplication of the mean squares of means by the harmonic mean of subclass numbers.

It may be said in passing, that some statisticians would prefer to divide the individuals' mean square by the harmonic mean instead of multiplication of the mean square for breed and season by harmonic mean before derivation of F ratios.