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CARCASS STUDIES ON CROSSBRED PIGS SIRED BY HAMPSHIRE, LACOMBE, AND POLAND CHINA BOARS

by

DAVID TUPPER SPURR

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Carcass Studies on Crossbred Pigs Sired by Hampshire, Lacombe, and Poland China Boars" submitted by David Tupper Spurr, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Carcass characteristics of 136 pigs sired by six Hampshire, six Lacombe and five Poland China boars, and out of Yorkshire and Yorkshire crossbred dams, were studied to compare carcass traits from different breed groups and to study relationships between carcass traits and carcass value.

Females were significantly longer, had less backfat, larger loin eye areas, and yielded higher proportions of the four trimmed lean cuts (ham, loin, picnic shoulder, and Boston butt).

Lean cut index (ratio of weights of trimmed to weights of untrimmed lean cuts) was highly correlated to loin index (r=0.91), ham index (r=0.85), per cent primal cuts (r=0.83), per cent trimmed ham (r=0.80), total carcass backfat thickness (r=-.79), Record of Performance score (r=0.79), per cent trimmed ham plus loin (r=0.77), trimmed ham weight (r=-.73), specific gravity of the hot untrimmed ham (r=0.71), total backfat probe (r=-.71), belly grade (r=0.70), and carcass grade (r=0.68).

Wholesale cutout value was highly correlated with per cent primal cuts (r=0.98), per cent lean cuts (r=0.95), per cent trimmed ham plus loin (r=0.91), per cent trimmed ham (r=0.88), trimmed ham weight (r=0.82), lean cut index (r=0.84), ham index (r=0.77), loin index (r=0.77), Record of Performance score (r=0.71), belly grade (r=0.69), specific gravity of hot ham (r=0.68), total backfat probe (r=-.67), carcass grade (r=-.62), and total carcass backfat (r=-.62).

Specific gravity of the untrimmed ham immediately after the pigs were killed was more highly related to measures of carcass leanness than it was after the ham had been chilled. Specific gravity of the trimmed

ham was not highly related to measures of carcass merit but was related to the chemically determined proportions of moisture (r=0.50), protein (r=0.57), and fat (r=-.64).

The proportion of intra- and intermuscular fat did not appear to be related to the amount of subcutaneous fat, as the correlation between per cent ether extract in the boneless, trimmed ham and the ham index was low (r=-.21).

Progeny of the Hampshire boars were significantly shorter, had larger loin eye areas, higher proportions of trimmed ham and loin, higher ham and lean cut indices, and had a higher proportion of moisture in the trimmed ham that the Lacombe progeny. Wholesale cutout value per 100 pounds of carcass was higher for the Hampshire progeny. No significant differences between the Hampshire and Lacombe progeny were found in backfat thickness, Record of Performance score, per cent untrimmed ham, loin index, and in per cent fat, protein, and bone in the trimmed ham.

Progeny of the Poland China sires had significantly larger loin eye areas, Record of Performance scores, higher proportions of trimmed ham, and had more protein but less bone in the trimmed ham than the Lacombe progeny. They were significantly shorter than even the Hampshire progeny. No differences were found between the Poland China and Lacombe progeny in backfat thickness, proportions of untrimmed ham and loin or in trimmed loin, lean cuts, and primal cuts; ham, loin, and lean cut indices; and in the percentage of water and fat in the trimmed ham.

This study shows that individual boars can be selected from these United States breeds of hogs, especially the Hampshire, that when crossed with dams of Canadian breeds produce carcasses that meet Canadian grading and Record of Performance standards and yield higher proportions of trimmed ham and trimmed loin.

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INTRODUCTION

The objective of swine breeding research is to develop methods of selection and systems of mating which produce populations that will perform more economically and that will yield increased proportions of high-quality, edible products.

It is estimated that 50 to 80% of the hogs marketed in the United States are crosses between two or more breeds. In Canada, commercial hog production has been largely centered around the use of straightbred Yorkshires. In the past this has been in part due to the lack of suitable breeds for crossbreeding programs. However, in the last decade, the commercial industry has begun to utilize Lacombe and Landrace straightbreds and crosses which are superior to the Yorkshire in growth rate and produce carcasses of the quality required to meet Canadian grading standards. Because the Landrace is one of the parent breeds of the Lacombe, crosses involving both of these breeds would not be expected to give the highest degree of heterosis. Crosses involving more than two breeds would require the use of more genetically diverse breeds from other countries if maximum heterosis is to be achieved. Since grading standards were tailored to the Yorkshire breed and because of the lard-hog reputation of the United States swine industry, Canadian producers have avoided United States breeds of hogs during the past four decades. However, standards of quality in the Unites States have been changing rapidly since World War II and breeders have been trying to rid themselves of the lard-hog reputation and put more emphasis on the development of meat-type hogs.

Political and economic relationships have changed with time,

causing changes in markets which change the relative importance of or even the direction of emphasis on certain characteristics. The grading system, developed when the British Wiltshire side market was quite important, may not place the correct relative emphasis on the characteristics that are desirable for present market demands. In recent years there has been increasing emphasis on appraisal of carcass and meat quality in terms of the proportions of muscular, fatty, and skeletal tissue, and on the wholesale value of the uncured wholesale cuts. With the switch from the Wiltshire side market, the decreasing commercial value of lard and the necessity of trimming a large proportion of subcutaneous fat from pork carcasses to make them acceptable to the consumer, it is essential that composition be emphasized in evaluating carcass quality.

This study was carried out to examine some of the concepts of quality used in Canada and to see if it is possible to select boars from the more promising breeds used in the United States that will sire crossbred offspring equal, or superior, in carcass merit to some of the better Canadian-bred pigs.

LITERATURE REVIEW

I. Genetic Effects on Carcass Characteristics

A. Heritability

Heritability, in a narrow sense, is defined as that portion of the total phenotypic variance that is due to additive genetic effects. This is essentially the same as the average genetic progress made in the next generation when superior individuals are selected as parents. In a broad sense, it may be defined as that portion of the total phenotypic variance that is due to hereditary differences between individuals and includes variance due to additive effects, plus some of the effects of dominance, epistasis, and genetic-environmental interaction. In general, characters associated with reproductive fitness such as litter size, survival, longevity, and milk production have low heritabilities. Characters such as conformation, fat deposition, and many of the measures of carcass merit are more greatly affected by additive genetic effects. Natural and artificial selection has generally been in one direction for characteristics associated with reproductive fitness, while selection pressure has been mild or in opposite directions at different times for characteristics such as body conformation (Fredeen, 1957). Intense selection pressure in one direction for a number of generations will increase the degree of homozygosity in the traits selected and decrease the proportion of additive genetic variation in a population. However, selection for a trait such as litter size may have been toward intermediate levels, as natural selection will be towards the combinations and levels of various traits that give the highest reproductive efficiency.

Heritability estimates have been made for a number of performance and carcass characteristics and of certain live animal body measurements. A complete review of all heritability estimates is beyond the scope of this discussion but a summary of some of the heritability estimates found in the literature is presented in Table 1. All methods of estimating heritability are based on resemblance between relatives, and usually include some variance due to dominance, epistasis, and genetic-environmental interaction, the proportions depending on the technique used. Correlation and regression coefficients have been utilized for relationships between parents and progenies. Warner (1952) reviewed briefly the historical sequence of the development of methods for the study of hereditary and environmental contributions to phenotypic development.

B. Breed and sire effects

After World War I, Canadian producers found that, in spite of a surplus of hogs, they were losing the British market for bacon hogs to Denmark and other European countries because of the lack of uniformity of weight, type, and degree of finish of hogs being marketed in Canada. A grading system for live hogs based on visual appraisal of type, conformation, and finish was established. By a series of steps this changed to rail grading of hog carcasses based on weight class, length, backfat thickness, and visual appraisal of conformation (Maybee, 1962). Because Canadian hog producers have made little use of breeds other than the Yorkshire since the initiation of government grading in 1922, few breed comparisons have been made in Canada.

Hogan et al. (1922) carried out a study in the United States comparing protein and energy retention of eight lard-type pigs (Poland China) and eight bacon-type pigs (Yorkshire). The Yorkshire pigs were

Table 1. Heritability estimates of various conformation, performance, and carcass characteristics of swine[1]

	h^2 Range	h^2 Approx avg
Conformation measurements		
Body length	40 - 81	59
Leg length	51 - 75	65
Number of vertebrae	74	74
Conformation score	10 - 35	29
Performance measurements		
Litter size (farrowed)	0 - 24	15
Litter size (weaned)	0 - 32	12
Litter wt at weaning	3 - 37	17
Wt at 5 - 6 months	3 - 66	20
Growth rate	14 - 58	29
Economy of gain	8 - 72	31
Carcass measurements		
Length	40 - 81	59
Loin eye area	16 - 79	48
Backfat thickness	12 - 80	49
Belly thickness	39 - 72	52
Per cent ham	51 - 65	58
Per cent shoulder	38 - 56	47
Per cent fat cuts	52 - 69	63
Per cent lean cuts	14 - 76	31
Carcass score	35 - 67	46
Size and shape of ham (score)	61	61
Firmness of fat (score)	40	40

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[1] From Craft (1958) and Johansson and Korkman (1951).

found to be longer and taller, but essentially no difference was found in the proportions of fat and protein in the two breeds of pigs. Although the number of animals used in this study was quite small, breed differences in carcass composition were not as great as commonly believed and characteristics did not consistently favor either breed.

Berg (1958, 1959) reported results of crossbreeding experiments at the University of Alberta involving Yorkshire, Lacombe, Tamworth, and Landrace boars mated to Yorkshire and crossbred dams. Important differences due to mating system and to breed were found in a number of pre-weaning traits. Crossbred dams, for instance, tended to wean more and heavier pigs. Also, important breed and mating-system effects were reported for post-weaning performance traits. Progeny of Landrace and Lacombe boars tended to be more efficient in feed conversion than the progeny of Yorkshire and Tamworth sires. Progeny of Yorkshire sires tended to have lower average daily gain and required longer to reach market weight. Crossbred pigs ate more and gained faster but were no more efficient in feed conversion. However, crossbred pigs were better able to withstand the adverse effects of unbalanced rations. Differences between various measures of carcass merit were not as great as the differences between pre-weaning and post-weaning performance traits. Carcass length, backfat thickness, loin eye area, carcass grade, and Advanced Registry score were similar for the breeds and crosses studied. Sire differences within breeds were greater than differences between breeds, especially for the Tamworth and Landrace sires.

Bowland and Berg (1959a) reported a study of the influence of strain and sex on the relationship of protein to energy ratios in 120 pigs of four strains. Strains used in this study were the Yorkshire,

Lacombe x Yorkshire, Yorkshire x Lacombe-Yorkshire, and Tamworth x Lacombe-Yorkshire. Strain differences and strain x sex interactions were found in the rate of liveweight gain. The only significant difference found in carcass composition between the Yorkshire and single-cross pigs was a 1% higher dressing per cent in the Yorkshire pigs. Backcross pigs were found to excel the three-breed crossbred pigs in carcass length, thinness of backfat, per cent ham, belly score, and Record of Performance (ROP) score. Variation between sires within breed was found to be important in this study. Berg and Plank (1961), comparing offspring of two sires of each of three breeds (Yorkshire, Lacombe x Yorkshire, and Landrace x Yorkshire), found that under equalized feeding sire groups differed in loin area but did not differ in backfat thickness or ROP score. Under liberal feeding, sire groups differed in ROP score and backfat thickness but not in loin eye area.

II. Effect of Environmental Variables on Carcass Characteristics of Bacon Hogs

It has been well established that restriction of feed intake, especially for pigs over 100 lb., results in leaner carcasses. Tribble et al. (1956) reported that limited feeding of pigs produced carcasses with a larger area of ham muscle and less carcass backfat, but found no significant difference in loin eye area (cross-sectional area of the m. longissimus dorsi taken at the last rib). The discovery of thinner backfat agrees with research done by earlier workers (Ellis and Zeller, 1934; Crampton et al., 1954; Gregory and Dickerson, 1952). McMeekan (1940) produced pigs conforming to a predetermined growth curve by controlling the plane of nutrition. Growth of skeleton and muscle was encouraged by keeping pigs on a high plane of nutrition

early in the feeding period and then putting them on a low plane of nutrition. This caused the production of a bacon-type pig. Restriction of feed early in the feeding period and keeping the pigs on a high plane of nutrition later in the fattening period greatly increased the deposition of subcutaneous fat to produce a lard-type hog. Work at the University of Alberta (Berg and Bowland, 1958) has shown that restricting feed intake by only allowing the pigs to have access to feed for one or two 1-hour periods per day reduced the growth rate but improved feed efficiency and measures of carcass merit, such as backfat thickness, carcass grade, and Advanced Registry score. Crampton (1937) reported that self-fed pigs were 0.9 inches shorter in carcass length than pigs on restricted feeding. Days on feed were less, indicating that the shorter length was due to pigs reaching market weight at an earlier age. Salmela et al. (1963), using different breeds and three levels of feeding (liberal feeding, feed restricted to 85% of liberal feeding, and feed restricted by adding 20% roughage), noticed that restricted feeding had a significant, favorable influence on carcass length and in the proportion of the five trimmed primal cuts. Breed x treatment interactions were found in carcass length, ham weight, and loin eye area.

Season, year, location, and type of housing can also affect the composition of the carcass. Reddy et al. (1959) reported that pigs farrowed in the fall had an average of 0.43 mm more backfat but had a lower rate of liveweight gain than pigs farrowed in the spring. This was attributed to the increase in temperature and light causing a decrease in thyrotrophic hormone from the pituitary. This in turn caused lower thyroxine secretions and thus reduced basal metabolism allowing more subcutaneous and intramuscular deposition of fat for the

same energy intake. Reddy et al. also reported that pigs reared on pasture in the summer averaged 1.56 mm more in backfat thickness than those reared on dry lot. This does not agree with the work of Diggs et al. (1965) who reported that pigs on concrete had smaller loin eye area, more ham fat, a higher loin marbling score, and more soft, watery hams than pigs raised on pasture but no significant difference in backfat thickness or color of loins. Bowland and Berg (1958, 1959b) and Berg and Plank (1960) reported differences due to type of housing in pre- and post-weaning performance but found no major difference in measures of carcass merit between the pigs raised inside and pigs raised outside.

Johansson and Korkman (1951), in an analysis of data from Swedish progeny testing stations using 3036 Swedish Landrace and Large White litters, demonstrated significant ($P < 0.05$) and important station differences in age at slaughter and firmness of fat but not for other performance and carcass characteristics except for a barely significant ($P < 0.05$) difference in backfat thickness. Stothart (1938), using data from 81 litters of Canadian Yorkshires from seven Advanced Registry test stations, demonstrated important station differences in feed economy, length of carcass, and loin area. These could result from strain differences within the Yorkshire breed in Canada or from the varied climatic conditions found between stations. However, Fredeen (1964) found no evidence of strain formation in the Yorkshire breed in Canada. Station differences are likely caused by the large environmental differences between stations or by variations in pre-test environment as indicated by a wide variation in age of pigs starting test.

III. Effect of Sex on Carcass Composition of Bacon Hogs

Early work by Lacy (1932) and Warner et al. (1934) revealed a large sex effect on the carcass composition of the pig. Carcasses from barrows had a higher percentage of fat cuts and a lower percentage of ham and loin than carcasses from gilts. Lush (1936) found that sex had a small but significant influence on length and a highly significant influence on belly thickness and backfat. This agrees with the work of Hammond and Murray (1937) who found that for equal lengths of sides, gilt carcasses had thicker bellies and less backfat than barrow carcasses. Within sex, however, thicker bellies are generally associated with thicker backfat (Fredeen, 1953).

Research in Canada by Bennett and Coles (1946) on 281 Yorkshire pigs weighing 198 to 207 lb. live weight revealed that gilt carcasses averaged 0.34 inches more in carcass length, 0.78 square inches larger in loin eye area, and 0.15 inches less in average backfat depth. Per cent shoulder and ham were 0.5 and 0.4 more for gilts. This agrees with the work of Fredeen (1953) who analyzed data from 12,084 pigs raised at Canadian Advanced Registry test stations. Females required 5.4 days longer to reach market weight but produced carcasses that averaged 0.23 inches more in length, 0.11 inches less in shoulder fat, 0.12 inches less in backfat, and 0.11 inches less in loin fat. Loin eye area was 0.53 square inches larger and per cent ham and shoulder were 0.12 and 0.57 more, respectively. These measurements contributed to a sex difference of 8% in Advanced Registry score.

The superiority of carcasses from gilts over those from barrows, because of increased length, decreased backfat and greater loin eye area, has been confirmed by numerous other studies in Canada (Fredeen and

Lambroughton, 1956; Bowland and Berg, 1959; Berg and Plank, 1961; Plank, 1961; Fredeen and Plank, 1963; Bowland, 1963; Fredeen et al., 1964), in the United States (Reddy et al., 1959), in the United Kingdom (Buck et al., 1962), and in Sweden (Johansson and Korkman, 1951).

Chemical analysis and physical separation of hog carcasses have also shown a sex difference in carcass composition. McMeekan (1940) used physical separation of hog carcasses and found that barrows had less bone and muscle and more fat than gilts. Recent studies in the United Kingdom (Buck et al., 1962), on carcasses of 250 pigs made up of 161 Large Whites and 89 Landrace, revealed that the per cent separable lean in the half carcass varied more between sexes than it did between breeds. Adam and Smith (1964) compared dissection data from gilts and barrows marketed at 260 lb. and found significant differences in the per cent lean, per cent fat, and muscle/fat ratio but found no difference in muscle/bone ratio.

Fredeen and Plank (1963) reported an unexplained relationship between the number of pigs weaned and fat deposition. Among pigs from large litters, the sex difference in backfat thickness was greater than among pigs from small litters.

A few studies have been carried out to compare performance and carcass characteristics of boars with those of gilts and barrows although boars are seldom marketed for meat production in most countries. Hetzer et al. (1956) found that the rate of total fat deposition in boars and gilts was essentially the same, but barrows had a much faster rate of deposition of subcutaneous fat. Backfat thickness was greater in barrows than in boars at 175, 200, and 225 lb. but not at 150 lb. Gilts were found to have thicker backfat than boars at all four weights but had

thicker backfat than barrows only at 150 and 175 lb. This agrees with earlier work (Comstock et al., 1944) where not only a sex difference was noticed in rate of liveweight gain but a sex x breed interaction was also found. The early maturing Minnesota No. 1 line showed a greater sex difference than did the inbred lines of Poland China. This sex difference was attributed to the suppression of growth rate in the gilts due to the sexual activity at the onset of puberty which occurred at an earlier age in the No. 1 line.

IV. Methods of Estimating Composition of Live Hogs and Carcasses

A. Use of physical and chemical analysis

Whole-body analysis by physical separation into the various types of tissue and by chemical means is the most accurate way of determining the composition of the animal body. The use of these methods is limited because of the cost and labor involved and because the commercial value of the carcass is destroyed. Physical analysis was first reported by Lawes and Gilbert (1859) in a study of the composition of various animals used for human food. Physical separation and chemical analysis of carcasses have been used by a number of researchers since then to validate more indirect methods of determining body composition and to study physiological growth and age effects on composition (Murray, 1922; Moulton, 1923; Hogan et al., 1922; Morales et al., 1945; Pace and Rathbun, 1945; Doornenbal et al., 1962b; Wood and Groves, 1963).

B. Use of linear measurements in estimating carcass composition

Numerous attempts have been made to find a simple measurement or combination of measurements that accurately indicate the composition of the live hog or carcass. One of the most promising of these is split-

carcass backfat measurements and per cent lean cuts (ham, loin, and shoulder cuts), per cent primal cuts (lean cuts plus belly), or per cent fat cuts (belly plus fat trimmings) (Aunan and Winters, 1949; Hetzer et al., 1956; DePape and Whatley, 1956; Plank, 1961; Bowland et al., 1964). Buck et al. (1962) reported that the best combinations of two split carcass backfat measurements was the minimum mid-backfat and minimum loin fat thicknesses. Internal carcass measurements were reported to give an even better indication of per cent separable lean and per cent separable fat. The depth of subcutaneous fat over the middle of the m. longissimus dorsi, when the carcass was cut at right angles to the back of the head of the last rib, explained 61.9% of the variance in the proportion of lean as compared with 50.4% explained by the total of three split-carcass backfat measurements. This agrees with earlier work done by McMeekan (1941) who also reported that the depth of fat over the "eye" muscle (m. longissimus dorsi) was the single measurement most closely associated with carcass fatness. However, the major disadvantage in the use of this measurement is that it cannot be measured on the carcass that is split longitudinally.

Various methods have been devised for estimating the depth of subcutaneous fat in the live hog. Hazel and Kline (1952) developed a small ruler which is pushed through an incision in the animal's back and through the subcutaneous fat until the m. longissimus dorsi muscle is reached. Andrews and Whatley (1955) developed the electronic probe based on the principle that lean tissue presents more resistance to the flow of electrical current than does fat tissue. A description of this instrument was given by Plank (1961). Studies at the University of Alberta (Bowland et al., 1964) indicated that the average backfat probe

taken with a metal ruler gave a slightly better estimate of average carcass backfat (r=0.87) than did the average backfat thickness as measured with the electronic probe. In recent years ultrasonic techniques have been developed for measuring backfat thickness (Temple, 1956) and have been used for determining the loin eye area in pigs and cattle (Stauffer et al., 1961). Harrington (1958) discussed the use of probing devices on carcasses that are not split as in the heavy pork carcass trade in Britain. Bowman et al. (1962b) found that the electronic probe gave a more accurate indication of carcass fatness than did split-carcass backfat measurements. However, more skill is required in using the ruler, electronic probe, or ultrasonic techniques than in measuring split-carcass backfat.

The use of the cross-sectional area of the loin eye muscle taken at the last rib and its high relationship with carcass leanness was discussed by Harrington (1958). The loin eye area measured at the posterior side of the last thoracic vertebrae with the use of a planimeter is used in arriving at the ROP score in the progeny testing of pigs in Canada. Henry et al. (1963) reported a correlation of 0.63 between loin eye area and per cent lean cuts and 0.70 between loin eye area and per cent protein in the ham and loin. McMeekan (1941) reported a highly significant relationship between the product of length and depth of the loin eye muscle and the lean content of the carcass (r=0.84), but Aunan and Winters (1949) failed to find a significant correlation between these two measurements, probably because of the wide variation in weight in the latter study.

Per cent lean in the ham face has recently been shown to be highly associated with carcass leanness. Fredeen et al. (1964) reported

that this measurement accounted for 43% of the variance in per cent lean cuts as compared with 54% explained by a total of three split-carcass backfat measurements.

Carcass length is generally thought to be associated with carcass merit and is employed in grading systems in a number of countries for this reason. However, most studies do not confirm this popular belief. Bowman et al. (1962b) reported a low relationship (r^2=0.06) between carcass length and per cent separable lean in the carcass. Buck et al. (1962) reported that both carcass length and carcass depth were poor indicators of per cent separable lean and fat in the carcass. Fredeen et al. (1964) reported that carcass length accounts for only 9% of the total variance in per cent yield of trimmed cuts. It appears from these studies that the emphasis placed on length in the various progeny testing schemes and carcass grading systems in many countries, especially Canada, is not warranted and that such emphasis should be placed on more meaningful measures of carcass merit.

Evaluation of carcasses would be much simplified if measurements taken from one-half of the split carcass accurately indicated the composition or quality of the entire carcass. Bowman et al. (1962a) carried out a study to determine splitting and cutting errors using cross-sectional area, specific gravity, and physical separation data from 42 swine carcasses and found that loin eye area, carcass length, split-carcass backfat thickness, live animal fat probes, and specific gravity of the carcass and ham could all be accurately predicted from one side of the carcass. Fat and lean area measurements from cross-sectional tracings taken from eight different sites revealed that at the mid-region of the carcass, measurements were more accurate than at either

end of the carcass. It was also reported that splitting and cutting errors were largest in the per cent bone and least in the per cent lean in the carcass. Brungardt and Bray (1963) carried out a similar study with 35 steer carcasses and found that, of 26 measurements, only in per cent kidney and pelvic fat, side weight, and body wall thickness was there a significant difference between the left and right sides. Significant splitting and cutting errors in the fat portion of the carcass were reported by Lasley and Kline (1956) who found a significant difference in weight of primal cuts but not in weight of lean cuts between the left and right side. Earlier work (Kline and Hazel, 1955) indicated that loin area need only be measured from one side. These studies indicate that the extra labor involved in taking measurements from both sides of the carcass is generally not warranted.

C. Yield and composition of sample cuts

The use of per cent lean cuts (the loin, ham, and two shoulder cuts), per cent primal cuts, sometimes called preferred cuts, (lean cuts plus belly), and per cent fat cuts (belly plus cutting fat) as indices of carcass composition was discussed by Harrington (1958). The yield of fat cuts was highly related to the proportion of fat in the carcass (r=0.91) while the weight of belly and unskinned backfat was slightly inferior (r=0.84) as an index of carcass fatness. The trimmed ham and loin as a per cent of the carcass weight was inversely related to carcass fatness (r=-.77). A higher relationship reported between per cent lean cuts and carcass leanness than between per cent primal cuts and carcass leanness is due to the fact that the belly is a fat cut.

The per cent fat and per cent lean in the loin cut were highly correlated (r=0.80 and 0.82, respectively) with the same constituents in

the whole carcass (Harrington, 1958). Bowman et al. (1962b) reported that the weight of separable fat and lean in the ham was related to carcass leanness (R^2=0.92). McMeekan (1941) physically dissected 20 inbred Large White pigs and found that per cent bone, per cent muscle tissue, and per cent fat in the ham and loin were highly correlated (r=0.94, 0.98, and 0.98, respectively) to the same components in the whole carcass. Bowman et al. (1962b) reported that dissection of the ham gave a more accurate indication of carcass composition than did dissection of the middle and shoulder. From these studies it is evident that there is a strong relationship between the composition of the carcass and the composition of the loin and ham. Such measurements cannot be used in the evaluation of commercial carcasses, as these cuts are the most valuable and physical dissection would destroy their market value.

Fredeen et al. (1964) used the concept of the ratio of the trimmed cuts to the rough cuts which was called "per cent yield". Per cent yield of lean cuts was found to be highly correlated to per cent yield of ham (r=0.81) and per cent yield of loin (r=0.92). Pearson et al. (1958) referred to the ratio of the trimmed loin to the rough loin as the "loin index" which was found to be highly related to carcass cutout. In this thesis the terms per cent yield of ham, loin, picnic, butt, and lean cuts used by Fredeen et al. (1964) will be called ham index, loin index, picnic index, butt index, and lean cut index, respectively.

D. Densiometric measurements

Because the density of body fat is low in relation to that of muscle tissue and bone, it is reasonable to expect a relationship between

body density or specific gravity and body composition in terms of fat content. Density can be defined as the total body weight divided by the total body volume, expressed in the units in which volume and weight are measured. Specific gravity is the ratio of the density of the body over the density of the water at the temperatures of the body and water used. It has no units, thus temperatures at which the measurements are taken must be presented.

If there is a mixture of two substances of different densities, the density of the mixture will be dependent upon the proportions of the two substances in the mixture and the densities of the two substances. The relationship between the proportion of fat in a carcass or part of a carcass is illustrated in the following formula:

$$D = \frac{x + y}{\frac{x}{\alpha} + \frac{y}{\beta}}$$

D = density of the mixture
x = proportion of the fat-free body
y = proportion of fat where $x + y = 1$
α = density of the fat-free body
β = density of fat

By a series of algebraic manipulations, the following equation is obtained:

$$y = \frac{1}{D} \left(\frac{\alpha \beta}{\alpha - \beta}\right) - \left(\frac{\beta}{\alpha - \beta}\right)$$

Rathbun and Pace (1945) determined the specific gravity of the eviscerated carcasses of 50 guinea pigs ranging from 304 to 1000 g in weight. Fat content was found to be highly correlated with specific gravity (r=-.97).

The regression equation found was

$$\% \text{ fat} = 100\left(\frac{5.135}{\text{sp gr}}\right) - 4.694$$

Morales et al. (1945), using values for densities of the muscle, bone, and fat tissues determined by Rathbun and Pace, developed the following theoretical relationship:

$$\% \text{ fat} = 100\left(\frac{5.362}{\text{sp gr}}\right) - 5.031$$

The relationship between the composition of the carcass and the density or specific gravity should theoretically be hyperbolic. Many workers have therefore used the reciprocal of density or specific gravity in studying the relationship with carcass composition in order to change the hyperbolic relationship to a linear relationship. However, research with beef (Kraybill et al. 1952), mutton (Kirton and Barton, 1958), and pork carcasses (Holme et al., 1963; Adam and Smith, 1964) has shown that the use of the reciprocal does not increase the precision of regression equations. Kirton and Barton found that the relationship actually curved slightly in an opposite direction from that theoretically expected, with some data.

The relationship between specific gravity of swine carcasses and composition was first reported by Brown et al. (1951). Highly significant, positive correlations were found between specific gravity of the carcass and loin eye area (r=0.46), per cent primal cuts (r=0.68), per cent lean cuts (r=0.84), and carcass length (r=0.56) while highly significant, negative correlations were found between specific gravity and average backfat thickness (r=-.68), per cent fat cuts (r=-.78), and chilled

carcass weight (r=-.42). This relationship between carcass specific gravity was confirmed by Whiteman et al. (1953) who also reported high correlations of 0.95 and 0.94, in two populations, between carcass specific gravity and specific gravity of the ham. Pearson et al. (1956) investigated the specific gravity of various untrimmed cuts and found that the specific gravity of the ham was more highly related to carcass leanness than was the specific gravity of the loin or shoulder. More recently, workers with pigs (Bowman et al., 1962b; Buck et al., 1962; Doornenbal et al., 1962b; Holme et al., 1963; Adam and Smith, 1964; Fredeen et al., 1964) have all shown a high relationship between specific gravity of hog carcasses and various measures of carcass composition.

EXPERIMENTAL

I. Objectives

The purposes of the present study were to determine

1) if boars could be selected from the more promising United States' breeds of hogs to cross with Canadian straightbred and crossbred sows to produce offspring equal or superior in carcass characteristics to typical Canadian bacon hogs,

2) to assess the interrelationships between various performance and carcass characteristics, and

3) to find more useful and simple predictors of carcass value from carcass measurements.

II. The Data

A. Source of the data

Six Hampshire and six Poland China boars, approximately 6 to 7 months of age, were purchased from United States breeders using station testing and meat-type certification programs. These boars were purchased in two drafts; three of each breed to sire offspring for Trial 1 (Experiment 387) in 1963 and three of each breed to sire offspring for Trial 2 (Experiment 387B) in 1964.

Specifications for purchase were that boars meet importation health regulations, weigh at least 200 lb. at 154 days, and have an average backfat probe of not more than 1.10 inches at 200 lb. The purpose of the comparison was carefully explained in the initial contact with the breeders, with the expectation that they would offer only boars that were representative of desirable meat-type pigs. The herds from which the boars were secured had performed creditably in testing programs.

In Trial 1, Hampshire boars 2-6, 19-5, and 20-5 ranged from 0.9 to 1.1 inches average backfat probe. Progeny carcass tests were available on their sires. Poland China boars 6 and 9 averaged 1.1 and 1.0 inches backfat probe, respectively. Some progeny test data were available for the sire of boar no. 6. Boar 3-10 was a last-minute replacement for a canceled sale and no probe or weight records were available. His sire, however, was a "Certified Meat Sire" with the Poland China breed society. All purchases for Trial 1 were by correspondence.

In Trial 2, Hampshire boars 1-6 and 1-2 were selected on a visit to the herds and were outstanding boars in performance and probe among a large number offered. Boar 11-5 was selected by the breeder. Each of these three Hampshire boars averaged 0.8 inches backfat probe. Sire progeny data were available only on 11-5 whose sire was the first "Superior Meat Sire" recognized by the Hampshire breed society. Poland China sire 1-3 probed an average of 0.9 inches of backfat and was one of only three boars offered by the breeder. In appearance he was a short, "chuffy" pig but was purchased on the basis of his surprisingly low probe and the excellent carcass record of his full sibs and of his sire as a "Certified Meat Sire". Boars 12 and 18 were last-minute replacements for boars which failed to pass quarantine. No performance information of any kind was available on 12 and 18 although they were from the same herd as boars 6 and 9 in Trial 1. Boar 12 sired no progeny in time for Trial 2.

It was planned to use Lacombe boars with full sib ROP scores near the breed average of 76 to 78 points. If progeny of selected Hampshire and Poland China boars were not superior to average Canadian

crossbreds, there would then seem little value in more extensive tests of these US breeds. Conversely, if progeny of selected US sires were superior to average Canadian pigs, more extensive testing of the breeds would seem warranted to more accurately assess the potential merit of these US breeds.

The Lacombe boars were from the Agricultural Experimental Station at Lacombe, Alberta. The refusal of the highest ROP Lacombe boar to mate in Trial 1 made it necessary to use a replacement of a lower score. The three boars used ranged from 71 to 74 in ROP score, slightly below the breed average. In Trial 2, ROP scores ranged from 72 to 84. These three boars had also been probed. Two averaged 1.0 inches in backfat thickness, sire 432T was from a selected low-fat line and had an average probe of 0.6 inches, the lowest of all boars used.

Three sires of each breed each mated to a Yorkshire, a Yorkshire x Landrace, and a Yorkshire x Lacombe sow to produce offspring for Trial 1 and three sires of each breed were similarly mated for Trial 2. Available sows were composed of nine sets of three littermates, one from each set being randomly assigned to each breed of sire in Trial 1. The same sows, except for two substituted sets, were reassigned randomly for Trial 2. Two litters per sire were sampled, including all litters from the Yorkshire dams. Selection of the second litter was from the Yorkshire x Landrace where possible. In Trial 2 it was necessary to use two 3/4 Lacombe litters. Where possible two males and two females were selected from each litter and used in this study. The two litters from Poland China sire no. 9 both had unbalanced sex ratios so it was necessary to use three females and one male from one litter and one female and three males from the other litter.

B. Management and care of experimental animals

All pigs used in this study were creep fed and weaned at 21 days to the creep ration. The pigs were penned in litter groups of four and allowed access to dry, ground feed for three 1-hour periods per day. The pigs had access to water at all times except during the feeding periods. The test animals consumed approximately 10% less feed than littermates that were self-fed in nutrition studies at the University of Alberta. Pigs were weighed at weekly intervals and placed on test on the weekly weigh day at which they weighed approximately 50 lbs. The 20% crude protein creep ration was replaced with an 18% crude protein grower ration when the pigs were placed on test. On the first weekly weigh day in which the pigs weighed 110 lb. or more, the grower ration was replaced by a 16% crude protein finisher ration. Feed consumption for individual pigs was recorded on the weekly weigh days. The rations used are described in Table 2. The pigs were shipped to the packing plant, Swift Canadian Co. Ltd., Edmonton, Alberta, on the afternoon of the first weigh day at which they weighed 195 lb. or more.

Table 2. Rations used for the experimental animals[1]

Ingredient	Creep	Grower	Finisher
Wheat	68.35	40.0	20.0
Barley	-	44.1	44.35
Oats	-	-	25.0
Stabilized fat	2.0	-	-
Soybean meal	18.0	9.0	6.0
Fishmeal	5.0	2.0	-
Meat meal	5.0	3.0	3.0
Iodized salt	0.5	0.5	0.5
Ground limestone	0.6	0.8	0.8
Bonemeal	-	0.25	0.25
Aurofac-10[2]	0.1	0.1	-
TM-10[3]	0.1	0.05	0.05
$ZnSO_4$	0.05	0.05	0.05
Vitamin premix	0.2	0.1	-
Vitamin B_{12} (9 mg/lb.)	0.1	0.1	-
Dry vitamin A + D_2[4]	+	+	+
Total	100.0	100.0	100.0

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[1] Formulated by J. P. Bowland, Professor of Animal Nutrition, Department of Animal Science, University of Alberta.

[2] Aureomycin feed supplement with 10 g of antibiotic per pound.

[3] Terramycin feed supplement with 10 g of antibiotic per pound.

[4] 200,000 IU of vitamin A and 20,000 IU of vitamin D_2 per cwt in the creep ration and half this amount in the grower and finisher rations.

C. Description of traits studied

In this study the first 41 carcass characteristics listed were studied on 136 animals used in both trials. An additional 11 measurements were studied on the 64 pigs used in the second trial.

1) Market weight - the weight of the pigs on the weigh day at which they were shipped.
2) Hot carcass weight - official carcass weight with the viscera removed but with the head, leaf lard, and kidneys intact.
3) Dressing percentage - hot carcass weight as a percentage of the liveweight on the day shipped.
4) Carcass length - length of the side as measured from the anterior edge of the first rib to the anterior edge of the aitch bone.
5) Maximum shoulder fat - thickness of subcutaneous fat at the thickest point over the shoulder of the split carcass.
6) Minimum backfat - thickness of subcutaneous fat at the thinnest point over the mid-back.
7) Maximum loin fat - thickness of the subcutaneous fat at the thickest point over the loin, generally immediately anterior to the *m. gluteus medius* muscle.
8) Total carcass backfat - sum of the three above described split carcass backfat measurements.
9) Loin eye area - cross-sectional area of the *m. longissimus dorsi* muscle at the posterior side of the last thoracic vertebra.
10) Lean/fat ratio - ratio of the loin eye area to total carcass backfat.
11) Carcass grade - assigned by the Grading Service, Production and Marketing Branch, Canada Department of Agriculture, on the basis of chilled carcass measurements of length, backfat, and visual appraisal of conformation. The normal commercial practice in the larger

packing houses in Canada is to grade the hot carcass on the killing floor, but carcasses to be scored by ROP standards are generally graded after being chilled.

12) ROP score - Record of Performance score assigned by the Grading Service (100 points possible: based on length, 20; backfat thickness, 30; loin eye area, 30; and belly grade, 20).

13) Belly grade - assigned from standard photos by the Grading Service.

14) Rough ham weight - weight of the chilled, untrimmed commercial ham removed by making a cut approximately 3 inches anterior to the aitch bone and perpendicular to the leg but angling to leave most of the flank muscle on the belly.

15) Trimmed ham weight - weight of the trimmed ham after the skin and subcutaneous fat had been removed to leave about 1/8 inch of fat on the outside of the ham.

16) Rough loin weight - weight of the chilled, untrimmed loin with the fat, skin, and bone left intact.

17) Trimmed loin weight - weight of the loin with the bone in but with the skin and all but approximately 1/8 inch of the subcutaneous fat removed.

18) Rough picnic weight - weight of the chilled, untrimmed picnic shoulder with the skin on.

19) Trimmed picnic weight - weight of the picnic shoulder with the skin and fat trimmed from the top portion.

20) Rough butt weight - weight of the chilled, untrimmed Boston butt with the jowls removed.

21) Trimmed butt weight - weight of the square cut Boston butt with the skin and the major portion of fat removed.

22) Rough belly weight - weight of the chilled, untrimmed belly with the spareribs intact.

23) Trimmed belly weight - weight of the belly with the edges trimmed and the spareribs removed.

24) Per cent trimmed ham - weight of one trimmed ham x 2 as a percentage of the hot carcass weight.

25) Per cent trimmed loin - weight of one trimmed loin x 2 as a percentage of the hot carcass weight.

26) Per cent trimmed ham and loin - combined percentages of the trimmed ham and trimmed loin.

27) Per cent trimmed picnic - weight of the trimmed picnic x 2 as a percentage of the hot carcass weight.

28) Per cent trimmed butt - weight of the trimmed Boston butt x 2 as a percentage of the hot carcass weight.

29) Per cent lean cuts - combined percentages of the trimmed ham, loin, picnic, and butt.

30) Per cent trimmed belly - weight of the trimmed belly x 2 as a percentage of the hot carcass weight.

31) Per cent primal cuts - combined percentages of the trimmed lean cuts plus the trimmed belly.

32) Cutout value - value of trimmed primal cuts/cwt of hot carcass; value based on wholesale prices of $49.50/cwt, $37.75/cwt, $25.75/cwt, $32.75/cwt, and $29.25/cwt for ham, loin, picnic shoulder, Boston butt, and belly, respectively. Wholesale prices used in the calculations were based on prices prevalent at the time Trial 1 was carried out. It is assumed that relative differences in prices between cuts have been reasonably constant.

33) Ham index - weight of the trimmed ham as a percentage of the untrimmed ham weight.

34) Loin index - weight of the trimmed loin as a percentage of the untrimmed loin weight.

35) Picnic index - weight of the trimmed picnic shoulder as a percentage of the untrimmed picnic weight.

36) Butt index - weight of the trimmed Boston butt as a percentage of the untrimmed butt weight.

37) Lean cut index - combined weight of trimmed ham, loin, picnic, and butt as a percentage of the combined weight of these cuts before trimming. This measurement was referred to as percentage yield of lean cuts by Fredeen et al. (1964).

38) Per cent rough ham - weight of the untrimmed ham as a percentage of the hot carcass weight.

39) Per cent rough loin - weight of the untrimmed loin as a percentage of the hot carcass weight.

40) Per cent rough picnic - weight of the untrimmed picnic shoulder as a percentage of the hot carcass weight.

41) Per cent rough butt - weight of the untrimmed Boston butt as a percentage of the hot carcass weight.

42) Per cent ham bone - weight of the bone in the ham as a percentage of the trimmed ham weight.

43) Specific gravity of hot ham - specific gravity of the ham 1/2 to 1 hour after the carcass entered the cooler from the killing floor, taken by the procedure described on page 30.

44) Specific gravity of chilled rough ham - specific gravity of the rough ham after being in the cooler for a minimum of 24 hours.

45) Specific gravity of trimmed ham - specific gravity of the trimmed

ham after being in the cooler for 72 to 96 hours.

46) Per cent moisture in boneless, trimmed ham - weight of moisture as a percentage of the boneless, trimmed ham determined by the procedure outlined in Appendix B.

47) Per cent N x 6.25 in boneless, trimmed ham - protein in the boned, trimmed ham determined by the procedure described in Appendix B.

48) Per cent ether extract in boneless, trimmed ham - ether extract as determined by the procedure described in Appendix B.

49) Shoulder fat probe at market weight - metal ruler probe measurement taken immediately above the elbow joint and approximately 1 1/2 inches from the midline of the back.

50) Backfat probe at market weight - metal ruler probe measurement taken in the mid-back region 1 1/2 inches from the midline of the back.

51) Loin fat probe at market weight - metal ruler probe measurement taken 10 to 11 inches from the base of the tail and 1 1/2 inches from the midline of the back.

52) Total backfat probe - sum of three live-animal backfat probes.

III. Collection of Data and Experimental Procedures

A. Carcass data

In Trial 1, weekly weighings were done on Wednesday morning and the pigs were killed on Thursday morning. To accommodate an increased killing schedule at the packing plant, pigs in Trial 2 were weighed on Thursday and killed Friday morning. Government grades and Record of Performance measurements were taken on the chilled carcass on the first working day after slaughter, usually Friday in Trial 1 and the following Monday in Trial 2. Because of civic and national holidays, nine of the 64 pigs in Trial 2 were left in the cooler approximately 96 hours instead

of the usual 72 hours before carcass grades and measurements were taken. Weights of the rough and trimmed wholesale cuts were obtained to the nearest ounce after standard commercial cutting at the time the grade and ROP measurements were taken. In Trial 2, weights of the rough and trimmed ham were the weights when specific gravity readings were taken and converted from grams to pounds.

B. Specific gravity determinations of hams

Approximately 1/2 to 1 hour after the carcasses from Trial 2 left the killing floor and entered the cooler, the rough or untrimmed ham was removed from the right-hand side of the carcass by the standard commercial method of cutting. A cut was made about 3 inches anterior to the posterior edge of the aitch bone and perpendicular to the hind leg, and then angled to the rear to leave most of the flank muscle on the belly cut. The shank was removed with a saw immediately below the hock joint. Specific gravity determinations were made on the hot rough ham by weighing the ham in air and in water, to the nearest gram.

$$\text{Specific gravity} = \frac{\text{Weight in air}}{\text{Weight in air} - \text{weight in water}}$$

A triple beam balance was placed on a metal table in such a way that the pan extended over the end of the table. A 20-gal metal waste can was filled with tap water from the city water supply and placed under the pan of the balance. One side of a square metal frame was placed on the pan of the balance in such a way that the opposite lower side of the square was under the balance and above the level of the water. The weight of the ham in water was determined by hanging the ham from the iron square with cotton string so that the ham was completely immersed.

After specific gravity weighings were made, the hot rough ham was hung on the rail in the cooler with the remainder of the carcass until the first working day following slaughter.

After the carcasses had been in the cooler for at least 3 days, the left sides and the remainder of the right sides were utilized by the Production and Marketing Branch, Canada Department of Agriculture for determination of grade, ROP scores, and cutout data.

Determinations were made of specific gravity on the chilled ham in the same manner as described above. The hams were then skinned and trimmed to remove all but about 1/8 inch of subcutaneous fat from the outside, and virtually all of the fat from the inside surface of the ham. Specific gravity of the trimmed ham was then determined as described above. The temperature of the water was recorded as each ham was weighed in water. Means and standard deviations of the water temperature, when specific gravities of the hot ham, chilled ham, and trimmed ham were taken, were 24.5 C ± 1.54, 21.2 C ± 1.58, and 20.3 C ± 0.86, respectively.

After specific gravity determinations were taken on the trimmed hams, the hams were vacuum sealed in plastic bags and stored in the freezer room at 0 F until needed for chemical analysis. Storage time was approximately 6 months.

C. Chemical composition of hams

After the hams were stored in a freezer at the packing plant for approximately 6 months at 0 F, they were placed in a refrigerator for 36 ± 6 hours at approximately 38 F. The boneless trimmed ham and the ham bone were weighed to the nearest gram to determine the loss in weight while in storage. Loss in weight during storage exceeded 1% of the original weight in only 4 of the 63 hams and exceeded 2% in one case. Any

loss in weight during storage was assumed to have been due to evaporation of water. The boneless, trimmed ham was ground and moisture determinations were done on the ground ham. The ground ham was freeze-dried and ether extract and protein determinations were done on the freeze-dried material. Proportions of moisture, ether extract, and protein were calculated as percentages of the weight of the boneless ham before storage. A more complete description of the preparation of samples and determinations of moisture, ether extract, and protein is given in Appendix B.

D. Statistical methods

Means, standard deviations, simple and multiple regression equations, and phenotypic correlations among all traits studied were calculated on an IBM 7040 electronic computer at the University of Alberta utilizing the Department of Computing Science Library Program G2011. Multiple regression analyses were done by the method of least squares in a stepwise fashion; coefficients of determination, analyses of variance, t-values, and standard errors being computed after each independent variable was added into the regression equation.

Analyses of variance were done on the IBM 7040 using the Department of Computing Science Library Program BMD02V, a program designed for orthogonal factorial designs. Because the experimental design was hierarchal, it was necessary to add together the appropriate sums of squares and degrees of freedom in order to calculate the mean squares. To make the data orthogonal, all missing data were replaced by appropriate means and degrees of freedom were dropped accordingly. The two missing litters from Poland China sire 12 were added into the data by using the means of both sexes from the other two Poland China sires in

Trial 2. Degrees of freedom for sire within breed, litter within sire within breed, sex x sire within breed, and sex x litter within sire within breed were each reduced by one and the error degrees of freedom was reduced by four. The two litters from Poland China sire 9 in Trial 1 were unbalanced as to sex. The data from one individual were dropped at random from the sex having three individuals and were replaced by data identical to the littermate of the opposite sex. Each time this was done, error degrees of freedom was reduced by one.

Duncan's multiple-range test (Steel and Torrie, 1960) was used to test for significance between breed means. Numbers were rounded to the nearest even digit if the last digit dropped was five.

RESULTS AND DISCUSSION

I. Market Weight, Carcass Weight, and Dressing Per Cent

Sire and breed means for market weight, carcass weight, and dressing per cent are given in Table 3. Because hogs were marketed on the first weigh day on which they weighed 195 lb. or more, breed, sire, and sex should not affect market or carcass weight. Analysis of variance was therefore not carried out for liveweight or carcass weight. Generally, low but significant ($P < 0.05$) correlations (Appendix A) were found between both carcass weight and market weight and the weights of some of the individual cuts, but correlations with the weights of individual cuts taken as a percentage of the carcass weight were generally not significant. Carcass weight had low, significant, positive correlations with total carcass backfat ($r=0.24$) and per cent trimmed belly ($r=0.24$), and was negatively correlated with per cent trimmed ham ($r=-.16$) and per cent trimmed lean cuts ($r=-.17$). No significant relationships were found between market or carcass weights and per cent primal cuts, wholesale cutout value, or lean cut index.

Significant mean squares for dressing per cent (Table 4) were found for breed ($P < 0.01$), sire within breed ($P < 0.05$), and for litter within sire within breed ($P < 0.01$). Progeny of Poland China sires averaged 0.7% higher ($P < 0.05$) in dressing per cent than the progeny of the Lacombe and Hampshire sires. Progeny from Hampshire sire 1-6 and Lacombe sire 0442T had lower dressing per cents and graded higher than other sires within these two breeds. Average dressing per cent of sire groups ranged from 76.6 to 78.4%, 76.7 to 78.3%, and 77.7 to 78.9% for the Hampshire, Lacombe, and Poland China crosses, respectively.

Table 3. Sire and breed means for live and carcass weights and dressing per cent[1]

Breed of sire	Sire	Number of pigs	Market wt (lb.)	Carcass wt (lb.)	Dressing %
		Trial 1			
Hampshire	2-6	8	200	155	77.4
	20-5	8	200	157	78.3
	19-5	8	199	155	78.0
Lacombe	1761T	8	199	156	78.3
	2040T	8	200	155	77.7
	6031R	8	201	157	78.1
Poland China	6	8	202	159	78.7
	9	8	200	155	77.7
	3-10	8	199	156	78.5
		Trial 2			
Hampshire	11-5	8	201	158	78.4
	1-6	8	200	153	76.6
	1-2	8	200	156	78.0
Lacombe	595T	8	202	158	78.2
	432T	8	199	155	78.1
	0442T	8	198	152	76.7
Poland China	1-3	8	199	156	78.9
	18	8	202	159	78.9
Hampshire	mean	48	200	156	77.8^a
	SD		2.8	4.2	1.60
Lacombe	mean	48	200	156	77.8^a
	SD		3.6	3.8	1.28
Poland China	mean	40	200	157	78.5^b
	SD		4.2	3.7	1.36

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[1] All means having the same superscript were not significantly different from each other ($P < 0.05$). Unlabeled means were not tested.

Table 4. Mean squares for carcass traits and ROP score

Source of variation	df	Dressing %	Carcass length	Total backfat	Loin eye area	Lean/fat ratio	ROP score
Trial	1	0.002	3.2701**	3.0625**	0.0306	0.15867*	70.8
Breed	2	9.298**	12.6586**	0.2542	1.9008**	0.10664*	1333.2**
Sex	1	3.812	3.6417**	9.3025**	7.1556**	2.14134**	13904.3**
Trial x breed	2	3.814	1.6436	0.7289*	0.1900	0.09502*	1035.1**
Trial x sex	1	0.644	0.1667	0.0044	0.5751*	0.08507	390.1
Breed x sex	2	3.562	0.6436	0.0002	0.0034	0.00386	116.2
Trial x breed x sex	2	3.107	0.2303	0.0446	0.2986	0.02848	74.1
Sire/breed	11	3.210*	0.8334	0.5244**	0.2758**	0.05315*	485.8**
Litter/sire/breed	17	3.852**	0.6758	0.4103**	0.2648**	0.05792**	406.4*
Sex x sire/breed	11	2.053	0.2550	0.1621	0.1883	0.02744	243.7
Sex x litter/sire/breed	17	1.046	0.2846	0.1529	0.1677	0.03419	227.2
Error	66	1.563	0.4314	0.1574	0.1042	0.02376	185.8
Total	133						

*Significant at $P < 0.05$.

**Significant at $P < 0.01$.

Low but significant correlations were found between dressing per cent and total carcass backfat (r=0.29) and lean cut index (r=-.22). Church (1963) reported a similar relationship in cattle where it was found that fatter steers tended to have higher dressing percentages. This well-established relationship between dressing per cent and fatness probably explains the association of carcass weight with fatness.

II. Carcass Backfat Measurements and Backfat Probes

Sire and breed means for carcass backfat thickness (Table 5) and for backfat probes (Table 6) are presented. Mean squares for total carcass backfat (Table 4) and for total backfat probe (Table 7) were calculated. Total carcass backfat mean squares for trial, sex, sire within breed and litter within sire within breed were found to be highly significant ($P < 0.01$). A significant ($P < 0.05$) interaction between trial and breed was partially due to the differences between sires used in the 2 years. One Hampshire sire (19-5) and one Lacombe sire (2040T) in Trial 1 sired pigs that were much fatter than others of their respective breeds. Analysis of variance and Duncan's multiple range test both did not show significant breed differences in total backfat. Mean squares for total probe of the pigs used in Trial 2 revealed significant ($P < 0.01$) breed and sex differences and significant ($P < 0.05$) sire within breed effects, but no significant litter within sire within breed effects were found.

Negative and highly significant correlations between both carcass backfat and total backfat probe and various measures of carcass merit were found, although there were some differences between the two in relationship with various traits. Total carcass backfat was the more highly correlated ($P < 0.05$) with carcass grade (r=-.72 vs. r=-.50), ROP score (r=-.87 vs. r=-.65), and lean cut index (r=0.79 vs. r=0.64).

Table 5. Sire and breed means for certain carcass measurements[1]

Breed of sire	Sire	Number of pigs	Carcass length (in.)	Max shoulder fat (in.)	Min back fat (in.)	Max loin fat (in.)	Total backfat (in.)	Loin area (in.^{2})	Lean/fat ratio
Trial 1									
Hampshire	2-6	8	30.0	1.70	1.00	1.45	4.15	3.99	0.97
	20-5	8	30.7	1.61	0.95	1.44	4.00	4.20	1.09
	19-5	8	29.9	1.96	1.15	1.59	4.70	4.22	0.92
Lacombe	1761T	8	31.0	1.65	0.92	1.30	3.88	3.89	1.02
	2040T	8	30.4	1.86	1.05	1.60	4.51	3.98	0.90
	6031R	8	30.8	1.71	0.85	1.34	3.90	3.94	1.02
Poland China	6	8	30.3	1.70	1.04	1.45	4.19	4.18	1.02
	9	8	30.1	1.81	0.99	1.59	4.39	3.92	0.91
	3-10	8	29.8	1.64	0.96	1.42	4.02	4.52	1.13
Trial 2									
Hampshire	11-5	8	30.5	1.61	0.89	1.31	3.81	4.10	1.12
	1-6	8	30.0	1.51	0.84	1.25	3.60	4.13	1.16
	1-2	8	29.6	1.58	0.86	1.29	3.72	4.44	1.21
Lacombe	595T	8	30.9	1.74	0.89	1.41	4.04	3.65	0.93
	432T	8	30.7	1.61	0.78	1.31	3.70	4.01	1.11
	0442T	8	30.6	1.70	0.94	1.32	3.96	3.63	0.93
Poland China	1-3	8	29.3	1.61	0.94	1.40	3.95	4.21	1.08
	18	8	29.4	1.72	0.99	1.55	4.26	4.20	1.02
Hampshire	mean	48	30.1^{b}	1.66	0.95	1.39	4.00^{a}	4.18^{a}	1.08^{a}
	SD		0.76	0.248	0.220	0.217	0.642	0.427	0.238
Lacombe	mean	48	30.7^{a}	1.71	0.90	1.38	4.00^{a}	3.85^{b}	0.98^{b}
	SD		0.63	0.191	0.169	0.204	0.501	0.468	0.212
Poland China	mean	40	29.8^{c}	1.70	0.98	1.48	4.16^{a}	4.21^{a}	1.03^{ab}
	SD		0.73	0.196	0.158	0.186	0.483	0.470	0.211

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[1] All means having the same superscript were not significantly different from each other ($P < 0.05$). Unlabeled means were not tested.

Table 6. Sire and breed means for backfat probes

Breed of sire	Sire	Number of pigs	Shoulder probe	Back probe	Loin probe	Total probe
Hampshire	11-5	8	1.57	1.12	1.19	3.88
	1-6	8	1.35	1.02	1.13	3.50
	1-2	8	1.39	1.05	1.22	3.66
Lacombe	595T	8	1.64	1.09	1.29	4.01
	432T	8	1.49	1.05	1.12	3.66
	0442T	8	1.79	1.19	1.30	4.28
Poland China	1-3	8	1.67	1.12	1.34	4.13
	18	8	1.61	1.05	1.29	3.95
Hampshire	mean	24	1.44	1.06	1.18	3.68
	SD		0.239	0.190	0.146	0.487
Lacombe	mean	24	1.64	1.11	1.24	3.98
	SD		0.284	0.202	0.262	0.664
Poland China	mean	16	1.58	1.09	1.31	4.04
	SD		0.210	0.203	0.178	0.524

Table 7. Mean squares for total backfat probe

Source of variation	df	Mean square
Breed	2	0.8969**
Sex	1	6.5341**
Breed x sex	2	0.4204
Sire/breed	5	0.4500*
Litter/sire/breed	8	0.2801
Sex x sire/breed	5	0.1898
Sex x litter/sire/breed	8	0.2654
Error	32	0.1674
Total	63	

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*Significant at $P < 0.05$.

**Significant at $P < 0.01$.

Total backfat probe was slightly more highly correlated with per cent primal cuts (r=-.63 vs. r=-.60) and wholesale cutout value (r=-.67 vs. r=-.62), the latter differences between correlation coefficients not being significant. In both carcass backfat measurements and live probes, utility of measurements at the same location was similar. Mid-backfat probe and minimum mid-carcass backfat were less highly correlated with various measures of carcass merit than were measurements taken at the shoulder or loin, but differences in correlation coefficients were generally not significant. In predicting lean cut index from backfat measurements at the three locations, carcass fat thickness was the better when measured at the shoulder and loin fat was the better when measured at the loin. This could be due to inaccuracy in probing at the shoulder because of the presence of false lean or could be due to slight differences between the two methods in actual site of measurement of backfat thickness. The correlation between the shoulder probe and the maximum shoulder fat was lower than expected (r=0.47) indicating that inaccurate probes at the shoulder may have been an important factor. It was observed that the live-animal, loin probe was generally taken over the _m. gluteus medius_ muscle while the maximum loin fat thickness of the carcass was about 1 inch anterior to this point. The probing location remained unchanged throughout the experiment as some pigs had already been probed and marketed before the difference in site of probing was noticed. The loin probes may have been taken at a site where fat thickness was more highly associated with carcass fatness than was the site where the carcass loin fat thickness was measured. Buck et al. (1962) reported that minimum loin fat thickness was more highly associated with carcass fatness than was maximum loin fat thickness.

Simple and multiple regression equations relating various backfat measurements with per cent lean cuts, per cent primal cuts, wholesale cutout value, and lean cut index are given in Tables 8, 9, 10, and 11, respectively. The use of shoulder and loin fat measurements in multiple regression equations was found to give slightly more accurate predictions of per cent lean cuts, per cent primal cuts, cutout value, and lean cut index than the use of the sum of the three carcass backfat measurements in simple regression equations.

Within-breed regression equations were computed for the regression of the four major measures of carcass merit on total backfat thickness (Table 12). Covariance was used to test for homogeneity of regression coefficients (Steel and Torrie, 1960). Significant breed differences in regression coefficients were found for per cent lean cuts ($P < 0.05$), per cent primal cuts, and wholesale cutout value ($P < 0.01$). The lower regression coefficients for the progeny of the Hampshire boars indicates that better than average Hampshires would be discriminated against if prediction equations were calculated from data on Lacombe or Poland China pigs. Regression equations for predicting per cent lean cuts, per cent primal cuts, and cutout value from backfat thickness should therefore be calculated for each breed. No significant differences between breeds were found for regression coefficients of lean cut index on total backfat. This probably occurred because backfat is more of a direct measure of lean cut index than it is of the other three measures of carcass merit. The Y intercepts varied with breed, indicating that if total backfat thickness was used to establish market prices of hogs the bases should vary with the type of hogs used. Differences between constants were not tested statistically.

Table 8. Coefficients of determinations, constants, simple and multiple regression coefficients, and standard errors of the estimate for per cent lean cuts with different carcass backfat measurements

Independent variables	R^2 x 100	Constant	X_1 Maximum shoulder fat(in.)	X_2 Minimum back fat(in.)	X_3 Maximum loin fat(in.)	X_4 Total backfat (in.)	SE
X_1	41.6	61.84	-7.35				1.87
X_2	31.9	56.38		-7.38			2.02
X_3	37.3	59.58			-7.19		1.94
X_4	44.6	61.39				-2.96	1.83
X_1X_2	44.8	61.70	-5.52	-3.14			1.83
X_1X_3	45.9	62.64	-4.87		-3.54		1.81
X_2X_3	39.1	59.40		-2.86	-5.15		1.92
$X_1X_2X_3$	46.4	62.38	-4.60	-1.51	-2.66		1.81

Table 9. Coefficients of determination, constants, simple and multiple regression coefficients, and standard errors of the estimates for per cent primal cuts with different carcass backfat measurements

Independent variables	R^2 x 100	Constant	X_1 Maximum shoulder fat(in.)	X_2 Minimum back fat(in.)	X_3 Maximum loin fat(in.)	X_4 Total backfat (in.)	SE
X_1	32.8	72.73	-5.92				1.82
X_2	24.4	68.25		-5.85			1.94
X_3	32.7	71.36			-6.11		1.83
X_4	36.1	75.50				-2.42	1.78
X_1X_2	35.0	72.63	-4.53	-2.37			1.80
X_1X_3	38.0	73.53	-3.44		-3.53		1.76
X_2X_3	33.2	71.28		-1.33	-5.17		1.83
$X_1X_2X_3$	38.0	73.47	-3.38	-0.33	-3.34		1.77

Table 10. Coefficients of determination, constants, simple and multiple regression coefficients, and standard errors of the estimate for lean cut index with different carcass backfat measurements

Independent variables	R^2 x 100	Constant	X_1 Maximum shoulder fat(in.)	X_2 Minimum back fat(in.)	X_3 Maximum loin fat(in.)	X_4 Total backfat (in.)	SE
X_1	52.1	94.25	-10.68				2.21
X_2	49.4	87.46		-11.92			
X_3	54.0	92.10			-11.25		2.16
X_4	62.7	94.66				-4.56	1.95
X_1X_2	60.8	93.95	-6.73	-6.75			2.00
X_1X_3	61.5	95.79	-5.87		-6.81		1.98
X_2X_3	58.0	91.75		-5.50	-7.32		2.07
$X_1X_2X_3$	63.4	95.09	-5.16	-3.98	-4.53		1.94

Table 11. Coefficients of determination, constants, simple and multiple regression coefficients, and standard errors of the estimate for cutout value with different carcass backfat measurements

Independent variables	R^2 x 100	Constant	X_1 Maximum shoulder fat(in.)	X_2 Minimum back fat(in.)	X_3 Maximum loin fat(in.)	X_4 Total backfat (in.)	SE
X_1	36.0	27.25	-2.51				0.72
X_2	27.3	35.38		-2.51			0.77
X_3	34.3	26.59			-2.53		0.73
X_4	39.2	27.13				-1.02	0.70
X_1X_2	38.6	27.21	-1.90	-1.05			0.71
X_1X_3	40.8	27.56	-1.55		-1.37		0.70
X_2X_3	35.3	26.54		-0.76	-1.99		0.73
$X_1X_2X_3$	40.9	27.50	-1.49	-0.33	-1.18		0.70

Table 12. Within-breed regressions of measures of carcass merit on total backfat

Dependent variable	Breed of sire	Constant (a)	Regression coefficient (b)	r^2 x 100	SE	Homogeneity of regression (F)
% Lean cuts	Hampshire	59.31	-2.287	45.4	1.628	
	Lacombe	64.61	-3.970	57.9	1.713	3.75*
	Poland China	62.97	-3.280	45.6	1.754	
% Primal cuts	Hampshire	70.18	-1.732	31.2	1.668	
	Lacombe	74.48	-3.072	44.7	1.729	10.96**
	Poland China	76.15	-3.230	46.7	1.687	
Cutout value	Hampshire	26.25	-0.750	37.3	0.631	
	Lacombe	27.89	-1.289	47.9	0.680	18.95**
	Poland China	28.68	-1.355	51.2	0.647	
Lean cut index	Hampshire	94.95	-4.532	74.6	1.718	
	Lacombe	93.14	-4.353	51.7	2.129	0.66
	Poland China	97.38	-5.138	65.8	1.812	

*$P < 0.05$.

**$P < 0.01$.

III. Length, Loin Area, and Lean/Fat Ratio

Sire and breed means for carcass length, loin eye area, and lean/fat ratio are presented in Table 5, p. 38, and mean squares for the above-mentioned traits are presented in Table 4, p. 36.

Significant trial, breed, and sex effects ($P < 0.01$) were found for carcass length but sire and litter effects and interactions were not significant. The carcasses of pigs sired by Poland China boars were significantly ($P < 0.05$) shorter than Hampshire crossbred pigs which were significantly shorter than the Lacombe crosses. Poland China crossbred pigs in Trial 2 were especially short and in many cases were graded down because of length. Carcass length was lowly correlated with various measures of carcass merit such as total carcass backfat (r=-.32), per cent

trimmed loin (r=0.23), per cent trimmed butt (r=0.19), per cent lean cuts (r=0.26), per cent primal cuts (r=0.22), cutout value (r=0.22), and lean cut index (r=0.28). These correlations, although significant, are much lower than other measures of carcass merit and have little practical value.

Breed, sire, sire within breed, and litter within sire within breed caused highly significant ($P<0.01$) differences in loin eye area. The Lacombe progeny had an average loin eye area of 0.36 and 0.33 square inches smaller ($P<0.05$) than the Poland China and Hampshire progeny, respectively, but no significant difference was found between the Hampshire and Poland China progeny.

Significant trial, breed, sire within breed, trial x breed effects ($P<0.05$) and highly significant ($P<0.01$) sex and litter within sire within breed effects were found in lean/fat ratio. The Lacombe crosses were found to have an average lean/fat ratio 0.10 lower than the Hampshire crosses and 0.05 lower than the Poland China crosses. The only significant difference between breeds was between the Hampshire and Lacombe crosses ($P<0.05$). The trial and trial x breed differences were due largely to the sires used in the two years. The average of the total carcass backfat of the progeny from Hampshire sire 19-5 and Lacombe sire 2040T in Trial 1 was much higher than for other sires in these two breeds. Also, progeny from Poland China sire 3-10 used in Trial 1 had the largest loin eye areas of any sires used. The use of the ratio of loin eye area to the total of three backfat measurements was found to be positively correlated ($P<0.01$) with per cent lean cuts (r=0.70), per cent primal cuts (r=0.62), wholesale cutout value (r=0.67),and lean cut index (r=0.79). Although correlations between lean/fat ratio and the four above-mentioned

measures of carcass merit were higher than with total backfat or loin eye area, the differences between correlations were generally not significant. The correlation between lean cut index and loin eye area (r=0.53), however, was significantly lower than the correlation between lean cut index and lean/fat ratio.

V. Carcass Grade, Belly Grade, and ROP Score

Carcass grades were coded A = 4, B = 3, and C = 2. Belly grades were similarly coded A (Excellent) = 4, B (Good) = 3, C (Fair) = 2, and D (Poor) = 1. The numerical values, being in the form of small whole numbers, probably followed a Poisson distribution rather than a normal distribution (Steel and Torrie, 1960). Correlations between the assigned grades and all other carcass traits were calculated (Appendix A) but only mean squares for ROP scores were calculated (Table 4, p. 36). Sire and breed means are for carcass and belly grades, and ROP scores are presented in Table 13.

ROP score was slightly more highly correlated with per cent lean cuts (r=0.76), per cent primal cuts (r=0.68), lean cut index (r=0.79), and wholesale cutout value (r=0.71) than was carcass grade (r=0.64, 0.61, 0.68, and 0.62, respectively). The use of standard photos to grade the bellies into four categories appears to give a good indication of carcass leanness as correlation coefficients between the above-mentioned measures of carcass merit and belly grade were all intermediate to the correlation coefficients for carcass grade and ROP score. Differences between correlation coefficients for ROP score, carcass grade, and belly grade were not significant.

Significant differences in ROP score due to breed ($P < 0.01$), sex and sire within breed ($P < 0.01$), and litter within sire within breed ($P < 0.05$) were found.

Table 13. Sire and breed means for carcass and belly grades, and Record of Performance score[1]

Breed of sire	Sire	Number of pigs	Carcass grade[2]	Belly grade[3]	ROP score
		Trial 1			
Hampshire	2-6	8	3.4	3.2	66
	20-5	8	3.4	3.4	72
	19-5	8	2.6	2.5	52
Lacombe	1761T	8	3.8	3.4	79
	2040T	8	3.1	2.6	58
	6031T	8	3.8	3.2	76
Poland China	6	8	3.5	3.1	67
	9	8	3.1	2.5	53
	3-10	8	3.4	3.5	71
		Trial 2			
Hampshire	11-5	8	3.5	3.1	75
	1-6	8	3.8	3.2	77
	1-2	8	3.4	3.5	74
Lacombe	595T	8	3.4	2.9	66
	432T	8	3.4	3.1	79
	0442T	8	3.4	3.4	73
Poland China	1-3	8	3.1	3.0	61
	18	8	2.9	2.5	53
Hampshire	mean	48	3.3	3.1	69^a
	SD		0.63	0.87	19.2
Lacombe	mean	48	3.5	3.1	71^a
	SD		0.55	0.83	18.4
Poland China	mean	40	3.2	2.9	61^b
	SD		0.65	0.89	18.8

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[1] All means having the same superscript were not significantly different from each other ($P < 0.05$). Unlabeled means were not tested.

[2] Grade A = 4, B = 3, C = 2.

[3] A(excellent) = 4, B(good) = 3, C(fair) = 2, D(poor) = 1.

The higher ROP scores for the pigs sired by Lacombe and Hampshire boars and the lower scores for the Poland China crosses are largely a reflection of differences in length. Poland China and Hampshire crosses also had larger loin eye areas than did the Lacombe crosses but, under the ROP scoring system used, no additional credit was given for loin eye areas exceeding 4.2, 4.4, and 4.6 square inches, respectively, in the three ROP weight classes. The lower ROP scores for the Poland China crosses resulted from shorter length, slightly thicker backfat, fatter bellies, and also because no credit was given for exceptionally large loin eye areas. The sex difference in ROP score was largely because of the thicker backfat depth and smaller loin eye area in the barrow carcasses.

The highly significant trial x breed interaction ($P < 0.01$) is largely a reflection of the differences between sires used in the two years. The significant litter within sire difference ($P < 0.05$) may have been due in part to the dams used, as there were litters from one crossbred dam and one Yorkshire dam from most of the boars used.

As expected the ROP scored was related to carcass length ($r=0.49$), total backfat ($r=-.87$), loin area ($r=0.52$), and belly grade ($r=0.84$) because these four traits are used to establish the ROP score. ROP score was found to be more highly related to the proportions of the more valuable trimmed ham and trimmed loin ($r=0.66$ and 0.55, respectively) and to combined ham and loin ($r=0.71$) than to per cent trimmed picnic ($r=0.38$) and per cent trimmed butt ($r=0.37$). The correlation between ROP score and per cent trimmed belly ($r=-.36$) was low and negative. ROP score, however, was more highly correlated with per cent lean cuts ($r=0.76$), cutout value ($r=0.71$), and lean cut index ($r=0.79$) than it was with proportions of individual cuts.

V. Effect of Sex on Carcass Characteristics

Means and standard deviations for both sexes and for the combined data and the percentage of variance explained by grade and by sex are presented in Table 14 for all traits studied. Bowland (1963) and Fredeen et al. (1964) both presented evidence that a large amount of variation in carcass merit due to sex exists within carcass grade. Very little difference existed between the value of Grade A barrow carcasses and Grade B gilt carcasses.

A barrow advantage of 0.4% in dressing per cent, because of the fatter barrow carcasses, was non-significant. Highly significant ($P < 0.01$) sex differences were found in carcass length, loin eye area, and several measures of carcass fatness such as total carcass backfat, lean/fat ratio, total probe, ham index, loin index, butt index, and lean cut index. Gilt carcasses were 0.34 inches longer than barrow carcasses which is identical to the difference reported by Bennett and Coles (1946). A female advantage of 0.44 square inches in the loin eye area and 0.22 in the lean/fat ratio agrees with previous studies (Fredeen, 1953). The difference in length, carcass backfat, and loin eye area accounted for most of the 19% difference in ROP score.

No significant differences were found in the percentages of rough ham, rough picnic, or rough butt but a significant ($P < 0.05$) difference of 0.8% in favor of the females was found in per cent rough ham. Females were found to have a higher percentage of both individual and combined trimmed lean cuts, all sex differences being significant. Gilt advantages in per cent trimmed ham, per cent trimmed loin, per cent trimmed picnic, per cent trimmed butt, and per cent trimmed lean cuts were 1.1, 0.9, 0.1, 0.2, and 2.5%, respectively.

Table 14. Means, standard deviations (sexes separate and combined), and proportions of variance explained by grade and by sex for carcass measurements

	Significance of sex difference[1]	Females		Males		Combined		Per cent of total variance explained by	
		mean	SD	mean	SD	mean	SD	Sex	Grade
Number of pigs		68		68		136			
Market wt (lb.)	ND	200	4.0	200	3.6	200	3.8	0.0	2.0
Carcass wt (lb.)	ND	156	3.8	156	4.1	156	4.0	0.8	0.7
Dressing %	NS	77.8	1.38	78.2	1.49	78.0	1.45	1.6	7.1
Carcass length (in.)	**	30.4	0.76	30.1	0.82	30.2	0.80	4.4	21.6
Max shoulder fat (in.)	ND	1.61	0.200	1.77	0.199	1.69	0.215	14.0	38.7
Min backfat (in.)	ND	0.86	0.164	1.03	0.170	0.94	0.187	21.2	40.8
Max loin fat (in.)	ND	1.34	0.190	1.49	0.198	1.41	0.208	13.2	52.3
Total carcass backfat	**	3.81	0.503	4.28	0.495	4.06	0.551	18.8	52.1
Loin eye area (in.^{2})	**	4.29	0.417	3.85	0.440	4.07	0.480	20.8	12.5
Lean/fat ratio	**	1.13	0.210	0.91	0.162	1.03	0.223	28.4	40.6
ROP score	**	77	15.9	58	17.3	68	19.1	25.1	65.5
Rough ham wt (lb.)	ND	17.7	0.85	17.2	0.85	17.5	0.88	7.2	5.4
Trimmed ham wt (lb.)	ND	13.7	0.71	12.9	0.84	13.3	0.97	22.6	26.4
Rough loin wt (lb.)	ND	16.8	1.14	17.2	1.29	17.0	1.13	2.4	6.0
Trimmed loin wt (lb.)	ND	12.2	0.83	11.7	0.95	11.9	0.92	7.7	9.5

continued ......

Table 14 (continued)

	Significance of sex difference[1]	Females		Males		Combined		Per cent of total variance explained by	
		mean	SD	mean	SD	mean	SD	Sex	Grade
Rough picnic wt (lb.)	ND	8.6	0.49	8.6	0.65	8.7	0.58	0.3	8.0
Trimmed picnic wt (lb.)	ND	7.7	0.49	7.6	0.65	7.7	0.58	1.3	11.2
Rough butt wt (lb.)	ND	7.4	0.57	7.5	0.56	7.5	0.57	0.2	0.2
Trimmed butt wt (lb.)	ND	5.8	0.40	5.6	0.37	5.7	0.39	3.5	10.9
Rough belly wt (lb.)	ND	11.1	0.75	11.5	0.94	11.3	0.88	6.7	6.1
Trimmed belly wt (lb.)	ND	10.2	0.71	10.5	0.78	10.4	0.76	4.3	6.4
% Trimmed ham	**	17.6	0.91	16.5	1.00	17.1	1.11	26.7	30.7
% Trimmed loin	**	15.7	1.06	14.8	1.04	15.3	1.14	15.3	20.0
% Trimmed ham and loin	**	33.3	1.51	31.3	1.70	32.3	1.89	28.2	34.4
% Trimmed picnic	*	9.9	0.60	9.8	0.79	9.8	0.70	1.6	14.6
% Trimmed butt	**	7.4	0.51	7.2	0.47	7.3	0.50	5.6	13.2
% Trimmed lean cuts	**	50.7	1.89	48.2	2.30	49.4	2.44	26.6	40.9
% Trimmed belly	**	13.1	0.81	13.4	0.84	13.3	0.83	3.3	5.2
% Trimmed primal cuts	**	63.8	1.71	61.7	2.17	62.7	2.22	23.0	36.8
Cutout value ($/cwt)	**	23.47	0.681	22.54	0.850	23.01	0.897	26.9	38.7
Ham index (%)	**	77.53	2.808	74.75	2.380	76.15	3.172	19.2	29.4
Loin index (%)	**	72.53	4.116	67.37	4.139	69.95	4.859	28.4	46.0
Picnic index (%)		88.91	4.352	88.15	4.230	88.53	4.293	0.8	2.2

continued ......

Table 14 (continued)

	Significance of sex difference[1]	Females		Males		Combined		Per cent of total variance explained by	
		mean	SD	mean	SD	mean	SD	Sex	Grade
Butt index (%)	**	77.77	3.154	75.17	3.650	76.47	3.641	12.9	27.4
Lean cut index (%)	**	77.79	2.534	74.61	2.956	76.20	3.176	25.4	46.2
% Rough ham	NS	22.8	1.04	22.0	1.14	22.4	1.15	10.7	7.6
% Rough loin	*	21.6	1.31	22.0	1.54	21.8	1.44	1.8	5.5
% Rough picnic	NS	11.2	0.60	11.0	0.79	11.1	0.70	0.7	10.4
% Rough butt	NS	9.6	0.71	9.6	0.68	9.6	0.70	0.0	0.0
Number of pigs		31		32		63			
Shoulder probe (in.)	ND	1.44	0.207	1.68	0.263	1.57	0.264	20.8	17.9
Back probe (in.)	ND	0.99	0.142	1.18	0.194	1.09	0.195	25.8	13.4
Loin probe (in.)	ND	1.16	0.178	1.32	0.205	1.23	0.207	15.2	28.1
Total probe (in.)	**	3.59	0.440	4.18	0.555	3.89	0.581	26.7	25.4
Sp gr, hot ham	**	1.0430	0.00548	1.0357	0.00558	1.0393	0.00661	31.0	20.0
Sp gr, chilled ham	**	1.0607	0.00399	1.0571	0.00488	1.0589	0.00481	14.7	12.0
Sp gr, trimmed ham	**	1.0805	0.00279	1.0786	0.00341	1.0795	0.00325	8.6	1.0
% Ham bone	NS	13.2	0.85	13.8	1.46	13.5	1.23	6.1	0.7
% H_2O in ham	**	67.9	1.71	66.4	1.79	67.1	1.90	16.0	6.8
% N x 6.25	**	18.6	0.59	18.3	0.83	18.5	0.74	6.4	0.0
% Ether extract	**	11.4	1.88	13.1	2.22	12.2	2.22	15.2	5.2

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[1] $^{*}P < 0.05$, $^{**}P < 0.01$, NS - not significant, ND - not determined.

Barrow carcasses were 0.3% higher in per cent trimmed belly, the difference being highly significant ($P < 0.01$). The female advantage in all the proportions of the primal cuts except trimmed belly contributed to a 2.1% female advantage in per cent primal cuts and a difference of $0.93 in value of trimmed primal cuts per cwt of carcass.

Even after removing the skin and subcutaneous fat from the ham, significant sex differences were found in the chemical composition of the boneless, trimmed ham. Hams from females were higher in moisture and protein content and hams from barrows were higher in the proportion of fat.

Highly significant ($P < 0.01$) sex differences in the specific gravity of the hot, rough ham, chilled, rough ham, and in the chilled, trimmed ham also indicated that the gilt carcasses had a higher proportion of muscle tissue and a lower proportion of fat than the barrow carcasses.

VI. Weights of Untrimmed and Trimmed Wholesale Cuts

Sire and breed means for untrimmed or rough and trimmed weights of the five wholesale cuts are given in Table 15. Correlations of 0.22 to 0.57 were found between carcass weight and weights of each of the rough and trimmed cuts. Correlations between carcass weight and weights of rough cuts were higher than for weights of trimmed cuts except for belly weights. The differences between correlation coefficients were not significant.

Table 15. Sire and breed means for weights of rough and trimmed wholesale cuts

Breed of sire	Sire	Number of pigs	Rough ham	Trimmed ham	Rough loin	Trimmed loin	Rough picnic	Trimmed picnic	Rough butt	Trimmed butt	Rough belly	Trimmed belly
Trial 1												
Hampshire	2-6	8	17.4	13.4	17.9	12.6	8.8	7.8	7.6	5.8	11.1	10.4
	20-5	8	17.9	13.9	17.5	12.3	8.7	7.6	7.7	6.0	11.0	10.3
	19-5	8	17.3	13.1	18.1	11.7	8.0	7.1	7.7	5.7	11.1	10.4
Lacombe	1761T	8	17.4	13.3	17.0	11.9	8.9	7.9	7.5	5.9	11.5	10.7
	2040T	8	16.6	12.4	17.9	11.9	8.1	7.1	7.7	5.7	11.1	10.4
	6031R	8	17.0	13.3	17.4	12.3	8.6	7.6	8.0	6.1	11.3	10.6
Poland China	6	8	17.6	13.6	17.7	12.5	8.9	7.9	8.0	6.0	11.6	10.8
	9	8	17.5	13.1	17.7	11.6	8.4	7.2	7.6	5.6	10.6	10.0
	3-10	8	18.3	14.2	17.1	12.3	8.7	7.8	7.6	5.6	10.9	10.3
Trial 2												
Hampshire	11-5	8	17.9	13.7	16.9	12.1	8.8	8.1	7.0	5.6	11.4	10.2
	1-6	8	17.4	13.5	16.4	12.1	8.8	8.0	7.2	5.7	11.0	9.8
	1-2	8	16.9	13.0	16.8	12.3	8.8	7.3	7.4	5.7	11.4	10.0
Lacombe	595T	8	17.1	13.0	16.2	11.2	9.3	8.6	7.5	5.7	11.9	10.8
	432T	8	17.4	13.0	16.3	11.6	9.0	7.8	7.3	5.4	11.7	10.2
	0442T	8	17.4	12.6	16.2	11.0	8.4	7.5	7.3	5.4	10.8	9.5
Poland China	1-3	8	17.9	13.8	16.0	11.2	8.4	7.8	6.9	5.5	12.0	10.9
	18	8	18.2	13.3	16.7	11.6	8.8	7.5	7.2	5.5	12.0	10.7
Hampshire	mean	48	17.5	13.4	17.2	12.1	8.6	7.6	7.4	5.7	11.1	10.2
	SD		0.85	0.78	1.31	0.76	0.52	0.57	0.57	0.38	0.89	0.80
Lacombe	mean	48	17.1	12.9	16.8	11.7	8.7	7.7	7.6	5.7	11.4	10.4
	SD		0.78	0.89	1.21	0.91	0.69	0.66	0.46	0.36	0.88	0.77
Poland China	mean	40	17.9	13.6	17.0	12.0	8.6	7.6	7.4	5.6	11.4	10.5
	SD		0.85	0.84	1.14	1.06	0.50	0.48	0.67	0.44	0.85	0.65

Although the correlation between rough loin weight and total backfat ($r=0.51$) was highly significant ($P<0.01$) and positive, correlations of weights of trimmed ham and trimmed loin with various measures of carcass fatness were generally negative. The correlations ($P<0.01$) between total backfat and trimmed ham weight and trimmed loin weight were -.52 and -.24, respectively. Correlations between the lean cut index and the weights of the trimmed ham and loin were higher ($r=0.73$ and 0.31). Correlations ($P<0.01$) between total backfat and weights of the rough and trimmed picnic were -.36 and -.35, respectively.

Weights of all the lean cuts except rough butt weight and rough loin weight were positively associated with the lean/fat ratio ($r=0.21$ to 0.65) but the correlation between lean/fat ratio and weights of rough and trimmed belly were -.32 and -.36, respectively.

No significant relationship was found between rough loin weight and length ($r=0.03$) and loin eye area ($r=0.01$) which indicates that the weight of the rough loin is more dependent on the thickness of backfat ($r=0.51$) than on the length or size of the _m._ _longissimus_ _dorsi_ muscle.

VII. Percentages of Untrimmed Lean Cuts

Sire and breed means (Table 16) and mean squares (Table 17) were calculated for the weights of the untrimmed ham, loin, picnic, and butt as a percentage of the hot carcass weight.

Trial effects were found for per cent rough picnic ($P<0.05$), per cent rough loin, and per cent rough butt ($P<0.01$) but no trial effects were found in per cent rough ham. Significant ($P<0.05$) breed effects were found in per cent rough loin and per cent rough picnic

Table 16. Sire and breed means for per cent of untrimmed lean cuts[1]

Breed of sire	Sire	Number of pigs	% Rough ham	% Rough loin	% Rough picnic	% Rough butt
		Trial 1				
Hampshire	2-6	8	22.5	23.0	11.3	9.8
	20-5	8	22.9	22.3	11.1	9.8
	19-5	8	22.6	23.3	10.3	9.9
Lacombe	1761T	8	22.2	21.8	11.4	9.6
	2040T	8	21.4	23.0	10.5	9.9
	6031R	8	21.7	22.1	11.0	10.1
Poland China	6	8	22.2	22.3	11.8	10.1
	9	8	22.5	22.8	10.8	9.8
	3-10	8	23.4	21.9	11.1	9.3
		Trial 2				
Hampshire	11-5	8	22.8	21.5	11.2	9.0
	1-6	8	22.7	21.5	11.5	9.4
	1-2	8	21.7	21.5	11.3	9.5
Lacombe	595T	8	21.7	20.6	11.7	9.5
	432T	8	23.4	21.0	11.6	9.4
	0442T	8	22.8	21.3	11.0	9.6
Poland China	1-3	8	22.9	20.4	10.8	8.8
	18	8	22.9	21.0	11.0	9.0
Hampshire	mean	48	22.5^a	22.2^b	11.1^a	9.6^a
	SD		0.93	1.49	0.65	0.69
Lacombe	mean	48	22.0^a	21.6^a	11.2^a	9.7^a
	SD		1.28	1.42	0.82	0.60
Poland China	mean	40	22.8^a	21.7^a	11.0^a	9.4^a
	SD		1.08	1.35	0.57	0.79

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[1] All means having the same superscript were not significantly different from each other ($P < 0.05$). Unlabeled means were not tested.

Table 17. Mean squares for per cent of untrimmed wholesale cuts

Source of variation	df	% Rough ham	% Rough loin	% Rough picnic	% Rough butt
Trial	1	7.471	73.388**	2.1756*	11.9255**
Breed of sire	2	10.183	6.586*	0.7398	1.5668*
Sex	1	4.000	6.233*	0.6058	0.0009
Trial x breed	2	0.801	0.043	1.3548	0.4741
Trial x sex	1	2.879	7.272*	0.0720	0.6724
Breed x sex	2	1.334	0.483	0.3992	1.0051
Trial x breed x sex	2	6.730	2.521	0.0154	0.3253
Sire/breed	11	6.803	1.385	1.0796*	0.5305
Litter/sire/breed	17	4.939	1.642	0.2886	0.4322
Sex x sire	11	6.580	1.811	0.4779	0.1795
Sex x litter	17	4.570	0.944	0.2692	0.4593
Error	66	4.852	1.498	0.485	0.4102
Total	133				

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*Significant at $P<0.05$.

**Significant at $P<0.01$.

No sire within breed effects were present in the proportions of any of the rough lean cuts. The Lacombe crosses were 0.6 and 0.1% lower in per cent rough loin than the Hampshire and Poland China crosses respectively, the difference between the Lacombe and Poland China crosses not being significant. Although analysis of variance showed significant

breed effects in per cent rough butt, Duncan's multiple-range test did not show significant differences between breed means. Significant ($P < 0.05$) sex and trial x sex interaction effects were found in per cent rough loin.

Correlations between the proportions of various rough cuts and other traits were generally under 0.50 except with proportions of corresponding trimmed cuts. Proportions of rough cuts generally were found to be poor predictors of carcass merit except for per cent rough ham which was positively correlated with per cent lean cuts (r=0.51) and cutout value (r=0.53). Correlations between per cent rough ham and per cent primal cuts and lean cut index were 0.46 and 0.34, respectively. Correlations between per cent rough picnic and per cent lean cuts, per cent primal cuts, cutout value, and lean cut index were 0.37, 0.39, 0.33, and 0.38, respectively. No significant relationships were found between the proportion of rough loin or butt and per cent lean cuts, per cent primal cuts, and cutout value. Highly significant ($P < 0.01$) correlations between total carcass backfat and per cent rough ham (r=-.32) and per cent rough loin (r=0.47) indicate that fatter pigs tended to have heavier rough loins and lighter rough hams.

VIII. Wholesale Cutout Value and Trimmed Wholesale Cuts as a Percentage of Carcass Weight

Sire and breed means for the weights of the trimmed wholesale cuts as a percentage of the hot carcass weight and for the value of primal cuts per cwt of carcass are given in Table 18. Mean squares for per cent trimmed ham, loin, picnic, butt, and belly (Table 19) and for per cent ham plus loin, per cent lean cuts, per cent primal cuts, and wholesale cutout value (Table 20) were calculated.

Table 18. Sire and breed means for percentages of trimmed, wholesale cuts and value of trimmed primal cuts per 100 pounds of carcass[1]

Breed of sire	Sire	Number of pigs	% Trimmed ham	% Trimmed loin	% Trimmed ham & loin	% Trimmed picnic	% Trimmed butt	% Lean cuts	% Trimmed belly	% Primal cuts	Cutout value
					Trial 1						
Hampshire	2-6	8	17.3	16.2	33.5	10.0	7.4	50.9	13.0	64.2	23.58
	20-5	8	17.8	15.7	33.5	9.7	7.7	50.9	13.2	64.0	23.60
	19-5	8	16.9	15.1	32.0	9.1	7.3	48.4	13.4	61.8	22.73
Lacombe	1761T	8	17.1	15.3	32.4	10.1	7.5	50.0	13.8	63.8	23.32
	2040T	8	16.0	15.4	31.4	9.2	7.3	47.9	13.4	61.4	22.44
	6031R	8	16.9	15.6	32.6	9.6	7.7	49.9	13.5	63.4	23.22
Poland China	6	8	17.2	15.8	32.9	9.9	7.5	50.5	13.6	63.9	23.43
	9	8	16.9	15.0	31.9	9.3	7.2	48.4	12.9	61.3	22.55
	3-10	8	18.1	15.8	33.8	9.9	7.2	50.8	13.1	64.1	23.65
					Trial 2						
Hampshire	11-5	8	17.3	15.4	32.8	10.3	7.1	50.2	13.0	63.3	23.23
	1-6	8	17.7	15.7	33.4	10.4	7.4	51.2	12.9	64.1	23.58
	1-2	8	16.7	15.8	32.5	9.4	7.3	49.2	12.4	62.0	22.80
Lacombe	595T	8	16.5	14.2	30.6	10.9	7.2	48.8	13.6	62.4	22.66
	432T	8	16.8	15.0	31.8	10.0	7.0	48.8	13.1	62.0	22.70
	0442T	8	16.5	14.4	30.9	9.8	7.2	47.9	12.5	60.5	22.13
Poland China	1-3	8	17.7	14.4	32.0	10.0	7.0	49.0	14.0	63.1	23.14
	18	8	16.7	14.6	31.3	9.5	6.2	47.6	13.5	61.1	22.42
Hampshire	mean	48	17.3^{a}	15.6^{b}	33.0^{a}	9.8^{a}	7.4^{a}	50.2^{b}	13.1^{a}	63.2^{a}	23.25^{a}
	SD		1.01	0.91	1.60	0.70	0.48	2.18	0.89	1.99	0.788
Lacombe	mean	48	16.6^{b}	15.0^{a}	31.6^{b}	10.0^{a}	7.3^{a}	48.8^{a}	13.3^{a}	62.2^{b}	22.74^{b}
	SD		1.12	1.17	1.91	0.79	0.49	2.61	0.85	2.30	0.932
Poland China	mean	40	17.3^{a}	15.1^{a}	32.4^{a}	9.7^{a}	7.2^{b}	49.3^{a}	13.4^{a}	62.7^{ab}	23.04^{ab}
	SD		1.09	1.26	1.94	0.58	0.53	2.35	0.72	2.28	0.914

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[1] All means having the same superscript were not significantly different from each other ($P < 0.05$).

Table 19. Mean squares for percentages of individual trimmed wholesale cuts

Source of variation	df	% Trimmed ham	% Trimmed loin	% Trimmed picnic	% Trimmed butt	% Trimmed belly
Trial	1	0.3268	15.8344**	5.3361**	3.2972**	0.3335
Breed	2	7.0156**	7.1791**	0.5887	0.8447*	1.2654
Sex	1	46.1720**	26.4110**	1.4400*	2.2077**	3.6896*
Trial x breed	2	0.0678	3.3276	1.0803*	0.1680	4.8286**
Trial x sex	1	0.2070	6.4558**	0.0711	0.6574	3.8383*
Breed x sex	2	1.2916	0.1053	0.2982	0.4503	0.1374
Trial x breed x sex	2	0.7946	0.5665	0.0438	0.1803	0.1319
Sire/breed	11	2.1132**	1.1314	1.7562**	0.1850	0.9804
Litter/sire/breed	17	0.8211	0.9650	0.4067	0.3315	0.7543
Sex x sire/breed	11	0.4771	0.4620	0.4371	0.0657	0.4952
Sex x litter/sire/breed	17	0.6227	0.5941	0.3338	0.2784	0.6323
Error	66	0.7565	0.8498	0.3070	0.2047	0.5512
Total	133					

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*Significant at $P < 0.05$.

**Significant at $P < 0.01$.

Table 20. Mean squares for per cent ham and loin, per cent lean cuts, per cent primal cuts, and wholesale cutout value

Source of variation	df	% Trimmed ham & loin	% Lean cuts	% Primal cuts	Cutout value
Trial	1	21.129**	15.550*	25.637**	4.4803**
Breed	2	21.654**	25.192**	6.690	3.0768**
Sex	1	141.372**	236.750**	168.567**	31.8848**
Trial x breed	2	4.219	10.530*	1.859	0.5776
Trial x sex	1	8.801	1.497	0.027	0.0300
Breed x sex	2	1.768	7.322	3.662	0.6754
Trial x breed x sex	2	2.286	2.761	2.919	0.6146
Sire/breed	11	4.230*	10.899**	13.092**	1.6859**
Litter/sire/breed	17	2.390	6.869**	5.083**	0.7406**
Sex x sire/breed	11	1.057	3.218	5.222*	0.3465
Sex x litter/sire/breed	17	1.592	2.678	2.361	0.3387
Error	66	1.957	2.655	2.170	0.3734
Total	133				

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*Significant at $P < 0.05$.

**Significant at $P < 0.01$.

Highly significant ($P < 0.01$) breed, sex, and sire within breed effects were found in per cent trimmed ham. Gilt carcasses were 1.14% higher than barrow carcasses in per cent trimmed ham. Both Hampshire and Poland China crosses were 0.7% higher ($P < 0.05$) in per cent trimmed ham than the progeny of Lacombe sires. This is equal to about 1 lb. more of trimmed ham per 150 lb. carcass from the progeny of the US boars. The average per cent trimmed ham from sire groups ranged from 16.7 to 17.8%, 16.0 to 17.1%, and 16.7 to 18.1% for the Hampshire, Lacombe, and Poland China sires, respectively.

Highly significant ($P < 0.01$) trial, breed, sex, and trial x sex interaction effects were found in per cent trimmed loin. The larger proportion of loin in the pigs used in the first trial is probably a reflection of the choice of sires in the two trials. The progeny of Poland China sires used in Trial 1, with the exception of sire 3-10, were longer than the progeny of the other two Poland China sires in Trial 2. Also, the Hampshire crosses in Trial 1 had thicker carcass backfat which partly explains the trial effect. Hampshire crosses were 0.6% higher ($P < 0.05$) and Poland China crosses were 0.1% higher (NS) in per cent trimmed loin than the Lacombe crosses.

The larger proportion of trimmed loin in the Hampshire crosses and the larger proportion of trimmed ham in both the Hampshire and Poland China crosses caused highly significant ($P < 0.01$) breed differences in per cent ham plus loin. The larger loins from the carcasses in Trial 1 appeared as a highly significant trial effect. A significant ($P < 0.05$) sire within breed effect was found. The offspring from the Hampshire sires had heavier hams and loins and were less variable than the offspring from the Poland China and Lacombe sires. Because the

trimmed ham and loin are the most valuable cuts and because they comprise slightly more than half the trimmed primal cuts, any increase in the proportion of these cuts is highly desirable.

A lower proportion of trimmed picnic and higher proportion of trimmed butt were found in Trial 1. The averages for the combined per cent trimmed picnic and butt for Trials 1 and 2 were 17.08 and 17.11%, respectively, indicating that cutting errors may have caused the highly significant ($P<0.01$) trial effect in per cent trimmed picnic and per cent trimmed butt. Sex differences in the proportions of the shoulder cuts were discussed previously. No breed effect was found in per cent trimmed picnic, but a sire within breed effect ($P<0.01$) was found. A significant ($P<0.05$) breed effect was found in per cent trimmed butt. Hampshire crosses were 0.1% higher (NS) and Poland China crosses were 0.1% ($P<0.05$) lower than the Lacombe crosses.

No significant breed effects were found in per cent trimmed belly, but highly significant ($P<0.01$) trial x breed interaction and significant ($P<0.05$) sex and trial x sex interaction effects were found. The progeny of the Lacombe boars had a higher proportion of trimmed belly in Trial 1 and the progeny of Poland China sires had a higher proportion of trimmed belly in Trial 2.

Highly significant correlations were found between per cent trimmed ham and various measures of carcass merit such as per cent lean cuts ($r=0.84$), per cent trimmed primal cuts ($r=0.81$), cutout value ($r=0.88$), and lean cut index ($r=0.80$). Only per cent ham and loin ($r=0.91$) and per cent trimmed primal cuts ($r=0.98$) were more highly associated with wholesale cutout value than was per cent trimmed ham. Correlations between per cent trimmed loin and per cent lean cuts, per cent trimmed

primal cuts, cutout value, and lean cut index were 0.70, 0.60, 0.66, and 0.50, respectively. The relationships, although highly significant ($P < 0.01$), were lower than those with per cent trimmed ham.

Correlations between per cent trimmed picnic and butt and the four above-mentioned gross measures of carcass merit ($r=0.32$ to 0.54) were highly significant ($P < 0.01$) but lower than the correlations with per cent trimmed ham and with per cent trimmed loin.

Analysis of variance of per cent lean cuts revealed highly significant ($P < 0.01$) trial, breed of sire, sex, sire within breed, and litter within sire effects. The higher proportion of lean cuts from the carcasses studied in Trial 1 was largely due to a larger proportion of trimmed loin and, to some extent, trimmed ham. The gilt advantage in per cent lean cuts was discussed previously. The average proportion of lean cuts from the progeny of Lacombe sires was 1.4% lower ($P < 0.05$) than from the crosses and 0.5% lower (NS) than the Poland China crosses. Average per cent lean cuts for sire groups ranged from 48.4 to 51.2%, 47.9 to 50.0%, and 47.6 to 50.8% for the Hampshire, Lacombe, and Poland China sires, respectively.

Trial, sex, sire within breed, and litter within sire effects ($P < 0.01$) were found in per cent primal cuts. Progeny of the Hampshire sires had 1.0% more ($P < 0.05$) trimmed primal cuts than did the Lacombe crosses and 0.5% more than the Poland China crosses, most of this difference being due to the larger hams and loins rather than to difference in the proportion of the shoulder cuts or belly. They had, in fact, a lower proportion of trimmed belly than the Lacombe crosses but differences in per cent belly were not significant. The Poland China crosses had the highest proportion of trimmed belly, probably because of fatness as the

belly grades were lower for the Poland China crosses.

The higher proportion of primal cuts, particularly ham and loin, accounted for a Hampshire advantage over the Lacombe progeny of \$0.51 in wholesale value of primal cuts per cwt of carcass. The progeny of Poland China sires averaged \$0.30 more per cwt than the Lacombe progeny in cutout value.

IX. Indices — Ratios of Weights of Trimmed to Untrimmed Cuts

The proportion of muscular tissue is perhaps the most important factor in evaluation of hog carcasses so that relative price levels can be established for different qualities of hogs and hog carcass. Factors such as flavor, color, texture, and tenderness are difficult to measure objectively and are presently less important in determining the wholesale value of the carcass. For the past three decades, prices paid to producers in Canada have been based on hot carcass weight and carcass grade. Any method of establishing prices paid to the producer must be rapid, must fit into the routine used in the packing house, and must also establish returns to the producer that are highly correlated with returns to the processor. Under the grading system used in Canada, which is based on weight class, carcass length, backfat thickness and visual appraisal of conformation, a grader can grade up to 600 hogs per hour if he works at short intervals (Maybee, 1962). Approximately 40% of the weight of the carcass is made up of the head, feet, skin, and fat trimmings, all of which have little commercial value without further processing. Thus, any method of improving the accuracy of predicting the proportions of low and high-priced cuts is highly desirable.

Fredeen et al. (1964) used the term "per cent yield" for the ratio of the weight of the trimmed cuts to untrimmed cuts. Since the

terms "per cent yield of ham", "per cent yield of lean cuts", etc. may be confused with "per cent trimmed ham", "per cent lean cuts", etc. which are the ratios of the trimmed cuts to carcass weight, the terms "ham index" and "loin index" used by Pearson et al. (1958) and "picnic index", "butt index", and "lean cut index" are used here to avoid such confusion.

Highly significant ($P < 0.01$) trial effects were found for ham index, loin index, picnic index, and butt index, but no significant trial differences were found for lean cut index (Table 22, p. 68). The only explanations that can be given for trial effects are that sires used in the two years were different and that cutting and trimming errors may have existed, especially in the two shoulder cuts. Highly significant sex differences in ham index, loin index, butt index, and lean cut index and other indications that barrow carcasses tend to be fatter were discussed earlier.

Significant breed effects were found for ham index ($P < 0.01$) and lean cut index ($P < 0.05$) but not for loin index, picnic index, or butt index. Since no difference between breeds was found in per cent rough ham and since breed differences were found in per cent trimmed ham and ham index, differences in the proportion of fat trimming were evident. The average ham index of the Lacombe crosses was 1.54% lower ($P < 0.05$) than for the Hampshire crosses and 0.52% lower (NS) than for the Poland China crosses. Sire within breed effects ($P < 0.01$) in ham index were found, indicating that the sires selected within any breed was important. Ranges for the average ham index of sire groups ranged from 75.52 to 77.93%, 72.23 to 77.84%, and 72.94 and 77.36% for the Lacombe, Hampshire, and Poland China sires, respectively.

Table 21. Sire and breed means for ratios of weights of trimmed cuts to untrimmed cuts

Breed of sire	Sire	Number of pigs	Ham index	Loin index	Picnic index	Butt index	Lean cut index
Trial 1							
Hampshire	2-6	8	77.02	70.27	87.04	76.79	76.27
	20-5	8	77.56	70.75	87.44	77.94	77.26
	19-5	8	75.52	65.23	88.09	73.68	73.56
Lacombe	1761T	8	76.85	70.19	88.89	78.48	76.91
	2040T	8	74.82	66.91	87.74	74.17	73.96
	6031T	8	77.84	71.12	87.44	76.20	76.90
Poland China	6	8	77.36	70.74	88.78	74.28	76.57
	9	8	75.12	65.63	85.87	74.81	73.39
	3-10	8	77.34	71.90	89.42	77.45	77.57
Trial 2							
Hampshire	11-5	8	76.56	71.59	92.75	79.38	78.04
	1-6	8	77.93	73.39	90.87	78.61	78.81
	1-2	8	77.33	73.54	83.37	71.17	77.02
Lacombe	595T	8	75.90	68.95	92.84	76.02	76.80
	432T	8	75.05	72.37	85.43	75.30	75.87
	0442T	8	72.23	67.82	89.56	74.76	74.07
Poland China	1-3	8	77.08	70.21	93.41	79.89	78.00
	18	8	72.94	69.55	86.24	75.92	74.44
Hampshire	mean	48	76.99^{b}	70.80^{a}	88.25^{a}	77.26^{a}	76.83^{a}
	SD		3.233	5.258	5.034	3.974	3.371
Lacombe	mean	48	75.45^{a}	69.40^{a}	88.65^{a}	75.84^{b}	75.75^{b}
	SD		3.145	4.640	3.891	2.929	3.031
Poland China	mean	40	75.97^{a}	69.61^{a}	88.72^{a}	76.28^{ab}	75.99^{ab}
	SD		2.972	4.591	3.853	3.901	3.059

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[1] All means having the same superscript were not significantly different from each other ($P < 0.05$). Unlabeled means were not tested.

Table 22. Mean squares for trimming indices of ham, loin, picnic, butt, and lean cuts

Source of variation	df	Ham index	Loin index	Picnic index	Butt index	Lean cut index
Trial	1	41.990**	68.42*	76.42**	69.07**	17.654
Breed	2	30.353**	24.58	5.26	24.16	14.464*
Sex	1	277.833**	1040.92**	24.85	243.54**	386.188**
Trial x breed	2	25.176*	66.27**	0.46	47.05**	22.841**
Trial x sex	1	3.516	10.66	1.92	8.86	1.217
Breed x sex	2	5.988	2.75	24.39	6.59	1.808
Trial x breed x sex	2	1.588	11.86	0.41	0.08	1.150
Sire/breed	11	19.100**	37.87**	81.05**	28.12**	23.275**
Litter/sire/breed	17	13.824**	27.48**	16.63	12.06	10.458**
Sex x sire/breed	11	7.032	13.28	10.53	7.56	7.198
Sex x litter/sire/breed	17	2.656	10.80	20.59*	8.17	4.391
Error	66	5.261	10.65	10.57	9.39	4.540
Total	133					

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*Significant at $P < 0.05$.

**Significant at $P < 0.01$.

Trends for loin index were similar to those for ham index, as the loin index of the Lacombe crosses was 1.40% lower than for the Hampshire crosses and 0.21% lower than for the Poland China crosses. Both analysis of variance and Duncan's multiple-range test did not show any significant difference in loin index between breed groups. Sire within breed differences ($P<0.01$), however, were present.

No breed effects were found in the picnic index, but highly significant ($P<0.01$) differences due to sire within breed were present. No significant correlations were found between picnic index and ham or loin index. Less trimming on the wholesale cut probably contributes to the low relationship between measurements of the picnic and measures of carcass merit. Highly significant ($P<0.01$) breed effects were found, however, for the butt index with the Hampshire progeny having a higher ($P<0.05$), and the Lacombe having a lower (NS), butt index than the progeny of Poland China sires. The difference between the Lacombe and Poland China crosses was not significant.

Hampshire sires produced progeny with lean cut indices that averaged 1.08% more ($P<0.05$) than the Lacombe crosses, and Poland China crosses averaged 0.24% more (NS) than the Lacombe crosses. Sire within breed effects and litter within sire effects ($P<0.01$) were present, indicating that the sires and dams of the progeny contributed much of the variance in lean cut index.

Per cent lean cuts was highly correlated with ham index ($r=0.73$), loin index ($r=0.79$), and lean cut index ($r=0.84$). Picnic index ($r=0.28$) and butt index ($r=0.58$) were found to be related to per cent lean cuts but correlations were much lower than for the other indices. Correlations between per cent primal cuts and ham index ($r=0.74$), loin index ($r=0.73$),

picnic index (r=0.33), butt index (r=0.57), and lean cut index (r=0.83) were similar to those with per cent lean cuts. Cutout value was highly correlated ($P<0.01$) with ham index (r=0.77) and loin index (r=0.77). Lean cut index was more highly correlated with cutout value (r=0.84) than with all other variables studied except per cent trimmed ham (r=0.88), per cent ham plus loin (r=0.91), per cent lean cuts (r=0.95), and per cent primal cuts (r=0.98).

Low, positive correlations were found between length and ham index (r=0.29), loin index (r=0.23), lean cut index (r=0.28), and butt index (r=0.17). The above relationships with length, although present, account for less than 10% of the variance in the trimmed cut indices, again indicating that length is not highly related to carcass merit. Highly significant ($P<0.01$), negative correlations were found between total carcass backfat (r=-.59 to -.85) and total live probe (r=-.23 to -.80) and all indices except picnic index.

Loin area was found to be positively correlated with ham index, loin index, butt index, and lean cut index (r=0.51, 0.56, 0.39, and 0.53, respectively) but not with picnic index (r=-.03). Relationships between lean/fat ratio and ham index (r=0.67), loin index (r=0.85), butt index (r=0.61), and lean cut index (r=0.79) were found to be higher; some of the differences between correlation coefficients being significant ($P<0.05$).

Correlations between ROP score and all indices except picnic index were highly significant ($P<0.01$). The relationship between ROP score and loin index was especially high (r=0.82) because 60% of the possible points in ROP score were from backfat thickness and loin eye area, and because the loin index is highly related to the backfat thickness and muscle

development in the loin cut. Correlations between ROP score and ham index, butt index, and lean cut index were 0.65, 0.56, and 0.79, respectively.

X. Specific Gravity of the Hams

As outlined previously, specific gravities of the hams were taken soon after the pigs were killed, again after they had been in the cooler for at least 24 hours, and again after the skin and subcutaneous fat was removed. Sire and breed means (Table 23) and mean squares (Table 24) were calculated for all three readings.

Table 23. Sire and breed means for specific gravity of ham[1]

Breed of sire	Sire	Number of pigs	Sp gr, hot ham	Sp gr, chilled ham	Sp gr, trimmed ham
Hampshire	11-5	8	1.0412	1.0590	1.0790
	1-6	8	1.0402	1.0599	1.0782
	1-2	7	1.0453	1.0628	1.0828
Lacombe	595T	8	1.0376	1.0587	1.0792
	432T	8	1.0373	1.0571	1.0785
	0442T	8	1.0360	1.0572	1.0795
Poland China	1-3	8	1.0403	1.0591	1.0791
	18	8	1.0372	1.0577	1.0816
Hampshire	mean	23	1.0421^{b}	1.0605^{a}	1.0790
	SD		0.00705	0.00514	0.00402
Lacombe	mean	24	1.0370^{a}	1.0577^{b}	1.0799
	SD		0.00648	0.00488	0.00278
Poland China	mean	16	1.0387^{a}	1.0583^{ab}	1.0804
	SD		0.00466	0.00366	0.00232

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[1] All means having the same superscripts were not significantly different from each other ($P < 0.05$). Unlabeled means were not tested.

Table 24. Mean squares for specific gravity

Source of variation	df	Sp gr, hot ham	Sp gr, chilled ham	Sp gr, trimmed ham
Breed of sire	2	.000180**	.000060*	.000020
Sex	1	.000920**	.000240**	.000060**
Breed x sex	2	.000003	.000020	.000010
Sire/breed	5	.000032	.000100**	.000032**
Litter/sire/breed	8	.000031	.000024	.000006
Sex x sire/breed	5	.000030	.000038	.000002
Sex x litter/sire/breed	8	.000017	.000011	.000011
Error	31	.0000239	.0000174	.0000072
Total	62			

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[*] Significant at $P < 0.05$.

[**] Significant at $P < 0.01$.

Breed differences were found in the specific gravities of the hot ham ($P < 0.01$) and the chilled ham ($P < 0.05$), and sire within breed effects were present ($P < 0.01$) for the specific gravities of the chilled ham and trimmed ham. The specific gravities of both the hot ham and the chilled ham for the Lacombe crosses were significantly lower than the Hampshire crosses ($P < 0.05$) and lower than for Poland China crosses (NS). This trend is similar to that for per cent lean cuts, per cent primal cuts, cutout value, and lean cut index. The sire groups that had hams with higher specific gravities generally also had higher values for the above-mentioned measures of carcass merit.

Specific gravity of the hot ham was more highly associated with per cent trimmed ham plus loin ($r=0.75$), per cent lean cuts ($r=0.67$), per cent primal cuts ($r=0.62$), cutout value ($r=0.68$), and ham index ($r=0.76$) than was backfat thickness or loin eye area. Total backfat thickness was, however, more highly correlated with loin index ($r=-.85$) and lean cut index ($r=-.79$). Specific gravity of the untrimmed, chilled ham was inferior to total carcass backfat as an indicator of the above-mentioned measures of carcass merit. However, differences between correlation coefficients for total backfat and the two specific gravity readings with measures of carcass merit were not significant.

The reduction in relationship between measures of carcass leanness and specific gravity when the hams were chilled probably occurred because of unequal chilling time or because shrinkage reduced the variation in specific gravity. Shrinkage on chilling is not only a loss of moisture but also a loss in volume. It was observed that the chilled hams were lighter and that the weight of water displaced was also less. The reduction of the correlations may have occurred because of a loss

in variation in specific gravity caused by a greater reduction in volume of the fatter hams. Kline et al. (1955) reported that the correlations between measures of fatness and specific gravity of the hog carcass were maximal after 24 hours in the cooler and that the correlations with the specific gravity of the hot carcasses and the carcasses that had been chilled for 72 hours were essentially the same. In this study, nine of the 63 hams were in the cooler for approximately 92 hours before the second specific gravity reading was taken, while the remainder were chilled approximately 72 hours.

Removal of the skin and most of the subcutaneous fat in trimming removed the major variation in the proportions of fatty and lean tissues in the hams so that correlations between specific gravity of the trimmed ham and various measures of carcass leanness were not significant.

Positive correlations were found between the specific gravity of the trimmed ham and the moisture content of the boneless, trimmed ham ($r=0.51$), and between specific gravity and chemically determined protein ($r=0.57$; and a negative correlation was found between specific gravity and per cent ether extract ($r=-.64$). The regression equations computed for predicting composition of the boneless, trimmed ham from specific gravity of the trimmed ham are listed below.

1) % Water = -251.29 + 294.98 (specific gravity)
   $r^2 \times 100 = 25.58$
   Standard error of the estimate = 1.650

2) % N x 6.25 = -122.61 + 130.67 (specific gravity)
   $r^2 \times 100 = 32.85$
   Standard error of the estimate = 0.613

3) % Ether extract = 486.38 - 439.21 (specific gravity)

$r^2 \times 100 = 41.56$

Standard error of the estimate = 1.708

No significant relationships were found between the proportion of bone in the ham and the proportions of moisture or fat. A low but significant, negative correlation was found between the proportion of bone and the chemically determined protein in the ham (r=-.26). When the proportion of fat in a carcass or part of a carcass is estimated by measurement of specific gravity, it is necessary to assume a constant relationship among the remaining constituents. The relationship between the proportions of bone, which has a relatively high density, and of muscle must therefore be assumed to be constant.

Below are the multiple regression equations computed for predicting the proportions of moisture, fat, and protein from the specific gravity and proportion of bone in the trimmed ham.

1) % Water = -249.50 + 294.44 (specific gravity) - 0.090 (% ham bone)

$R^2 \times 100 = 25.92$

Standard error of the estimate = 1.660

2) % N x 6.25 = -119.64 + 129.79 (specific gravity - 0.149 (% ham bone)

$R^2 \times 100 = 38.99$

Standard error of the estimate = 0.589

3) % Ether extract = 482.36 - 438.02 (specific gravity) + 0.202 (% ham bone)

$R^2 \times 100 = 42.81$

Standard error of the estimate = 1.704

No significant decrease in the standard errors of the dependent variables were found by using both the percentage of bone and specific

gravity of the trimmed ham as compared to using the standard errors found when using only specific gravity. The t-values for the regression coefficients for per cent bone were non-significant. The lack of increase in accuracy of the regression equation by including the percentage of ham bone indicates that the proportion of bone in the ham has but a small influence in determining the density of the ham. This agrees with work done by Whiteman et al. (1953). Holme et al. (1963) reported that the percentage of muscle in the carcass and in the ham was more than three times as important in determining density as percentage bone.

Because the relationship between specific gravity and the proportion of fat in a carcass or part of a carcass theoretically should be hyperbolic, the inverse of the specific gravity should be more highly related to composition than specific gravity (Morales et al., 1945).

Below are the regression equations found for predicting composition of the ham reciprocal of specific gravity.

1) $\% \text{ Water} = 100 \left(3.831 - \frac{3.411}{\text{Sp gr}}\right)$

$r^2 \times 100 = 25.22$

Standard error of the estimate = 1.654

2) $\% \text{ N} \times 6.25 = 100 \left(1.589 - \frac{1.516}{\text{Sp gr}}\right)$

$r^2 \times 100 = 32.62$

Standard error of the estimate = 0.614

3) $\% \text{ Ether extract} = 100 \left(\frac{5.124}{\text{Sp gr}} - 4.622\right)$

$r^2 \times 100 = 41.68$

Standard error of the estimate = 1.706

From the standard errors of the dependent variables it can be concluded that there is no advantage in using the inverse of specific gravity in predicting composition of the ham.

XI. Chemical Composition of the Hams

Sire and breed means (Table 25) for per cent moisture, per cent ether extract, and per cent protein in the boneless, trimmed ham and the percentage of bone in the trimmed ham are presented.

Table 25. Sire and breed means for chemical composition of boneless, trimmed ham and per cent bone in ham[1]

Breed of sire	Sire	Number of pigs	% Water	% Ether extract	% N x 6.25	% Ham bone
Hampshire	11-5	8	66.3	13.3	17.9	12.9
	1-6	8	68.0	11.8	18.0	13.5
	1-2	7	68.9	10.4	18.7	14.0
Lacombe	595T	8	65.5	14.1	18.4	13.4
	432T	8	68.0	11.4	18.6	14.3
	0442T	8	66.5	12.9	18.3	13.5
Poland China	1-3	8	66.6	12.7	18.8	12.8
	18	8	67.6	11.2	19.1	13.3
Hampshire	mean	23	67.7^{a}	11.9^{a}	18.2^{a}	13.4^{ab}
	SD		1.96	2.30	0.77	1.24
Lacombe	mean	24	66.6^{b}	12.8^{a}	18.4^{a}	13.8^{a}
	SD		2.03	2.40	0.75	1.48
Poland China	mean	16	67.1^{ab}	12.0^{a}	19.0^{b}	13.1^{b}
	SD		1.44	1.69	0.40	0.52

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[1] All means having the same superscripts were not significantly different from each other ($P < 0.05$). Unlabeled means were not tested.

Highly significant sex effects (Table 26) in per cent moisture and per cent protein were discussed earlier. A significant ($P < 0.05$) breed effect was found in per cent moisture with the Lacombe crosses having a lower ($P < 0.05$) proportion than the Hampshire crosses but not significantly lower than the Poland China crosses. Murray (1922) stated that the proportion of water in the fat-free portion of the animal body is nearly constant for all species. Moulton (1923) found that after a certain age, which he called chemical maturity, the composition of the animal body on a fat-free basis approached constancy in terms of water, protein, and mineral matter. There has been some criticism of these statements (Harrington, 1958). The age at which the animal body approaches constancy is not well established. The presence of environmental variation, nutritional stress, and disease are factors that can lead to differences in composition of the animal body that are independent of physiological age.

Table 26. Mean squares for chemical composition and per cent ham bone

Source of variation	df	% Water, trimmed ham	% Nx6.25 trimmed ham	% Ether extract	% Ham bone
Breed of sire	2	8.142*	3.4745**	7.851	3.271
Sex	1	40.560**	2.2366**	52.292**	4.672
Breed x sex	2	1.649	0.5956	3.706	0.962
Sire/breed	5	1.192	0.7572*	16.618**	1.937
Litter/sire/breed	8	1.381	1.0063	2.190	2.752*
Sex x sire/breed	5	3.162	0.4308	4.639	1.563
Sex x litter/sire/breed	8	2.327	0.4458	4.001	0.562
Error	31	2.192	0.2831	2.865	1.192
Total	62				

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*Significant at $P < 0.05$.

**Significant at $P < 0.01$.

Highly significant ($P < 0.01$) breed effects and significant ($P < 0.05$) sire within breed effects were found in the proportion of chemically determined protein in the boneless, trimmed ham. The progeny of Poland China sires had a significantly higher ($P < 0.05$) proportion of protein than did the Hampshire or Lacombe crosses. The higher proportions of moisture and protein, and the higher specific gravities of the trimmed hams for the Poland China crosses, do not agree with specific gravities of the hot and chilled hams and ham index which indicates that the Poland China crosses tended to have more external or subcutaneous fat and less internal fat.

Significant breed effects were not found in the proportion of ether extract in the boneless, trimmed ham but highly significant ($P < 0.01$) sire within breed effects were found. Progeny from Hampshire sire 1-2 and Poland China sire 18 had the two lowest averages of proportions of fat in the boneless, trimmed ham while Lacombe sire 595T had the highest proportion of fat. This again does not agree with data on ham indices or specific gravity of the hot and chilled hams, as the progeny of Poland China sire 18 had ham indices that were among the lowest of all the sires used. Progeny of Hampshire sire 1-2 and Poland China sire 18 also had higher specific gravities of the trimmed ham than the progeny of other sires. The correlation between per cent ether extract and ham index ($r = -.21$) was not particularly high, again indicating that the proportion of subcutaneous fat is not highly related to intra- and intermuscular fat.

No sex, breed, or sire within breed effects were found in per cent bone in the trimmed ham, but an unexplained litter within sire within breed effect ($P < 0.05$) was found.

SUMMARY

Measurements of 41 different carcass traits were collected from 48 progeny of six Hampshire sires, 48 progeny of six Lacombe sires, and 40 progeny of five Poland China sires. All progeny were from straightbred Yorkshire and Yorkshire crossbred dams. Each sire group contained four males and four females. An additional 11 carcass traits were studied on three of the Hampshire, three of the Lacombe, and two of the Poland China sire groups. Relationships between the various carcass traits were studied to obtain a better understanding of the use of carcass characteristics in evaluation of carcass merit in terms of wholesale value and in terms of the proportions of muscular and fatty tissue in the carcass.

As the weights when the hogs were killed were within a narrow range, variations in liveweight at slaughter and hot carcass weight were not related to carcass merit. Dressing percentage, however, had low, positive correlations with measures of carcass fatness. Belly grades established from standard photos were as highly correlated with carcass leanness and wholesale cutout value as were carcass grades based on backfat thickness, conformation, and length.

Sex was found to have a major influence on measures of carcass merit. Gilt carcasses were significantly longer, had less backfat, higher proportions of the four trimmed lean cuts (ham, loin, picnic, and Boston butt), and therefore had higher wholesale cutout value per cwt of carcass. Because barrow carcasses were fatter they had lower lean cut indices.

Carcass backfat measurements were found to be highly associated

with the proportion of fat in the carcass, especially in the loin cut. Shoulder and loin fat thickness in multiple regression equations were found to be more accurate in predicting carcass merit than was the sum of the shoulder, back, and loin fat measurements. Live animal backfat probes were equal to or better than split carcass backfat measurements in predicting carcass fatness. The shoulder probe, however, was slightly inferior to split carcass shoulder fat thickness because of the difficulty in obtaining an accurate probe measurement at the shoulder.

Weights of all untrimmed wholesale cuts were poor predictors of carcass value and other measures of carcass merit, all correlations being below ±0.50. However, weights of trimmed wholesale cuts, especially trimmed ham and loin, were more highly related to carcass value.

The rough lean cuts as a percentage of carcass weight were generally not highly related to carcass merit. Negative correlations between per cent rough loin and measures of carcass merit indicated that the weight of the rough loin is largely influenced by the depth of subcutaneous fat over the back rather than by muscle development. Per cent rough ham, however, was positively associated with cutout value (r=0.53) and other measures of carcass merit. Weights of trimmed cuts as a percentage of the hot carcass weight were more highly related to carcass value than were untrimmed cuts. Per cent trimmed ham was more highly related to wholesale cutout value (r=0.85) than all other traits studied except per cent ham plus loin (r=0.91), per cent lean cuts (r=0.95), and per cent primal cuts (r=0.98).

The indices that were called "per cent yield" by Fredeen et al. (1964) were examined for their potential in evaluation of hog carcasses. The ham index, loin index, and lean cut index were found to give a good

indication of carcass leanness. No significant differences were found between correlation coefficients of wholesale cutout value with ham index (r=0.74), loin index (r=0.73), and lean cut index (r=0.83). These measurements were more highly related to wholesale cutout value than were grade (r=-.62) and ROP score (r=0.71) and can be easily obtained without destroying the commercial value of the wholesale cuts. Weights and proportions of the rough and trimmed shoulder cuts and shoulder cut indices were probably not highly correlated with measures of carcass merit or leanness because of the unidentified cutting errors or variation in trimming.

Specific gravity of the hot ham 1/2 to 1 hour after killing, was found to be as highly related to per cent lean cuts (r=0.67), cutout value (r=0.68), and ham index (r=0.76) as was total carcass backfat thickness (r=-.67, -.62, and -.59, respectively). Carcass backfat thickness, however, was more highly related to loin index (r=-.85) and lean cut index (r=-.79) and is more easily obtained. Specific gravity of the untrimmed, chilled ham, however, was slightly inferior to total carcass backfat thickness as an indication of carcass leanness. The specific gravity of the trimmed ham was not highly related to the lean cut index or wholesale cutout value in the carcass but was related to the composition of the trimmed ham. Specific gravity of the trimmed ham accounted for 25.6, 32.8, and 41.6% of the variation in per cent moisture, per cent N x 6.25, and per cent ether extract of the boneless, trimmed ham, respectively. Consideration of the proportion of bone in the trimmed ham in multiple regression equations did not increase the accuracy of predicting composition of the ham over that obtained by the use of specific gravity alone. The use of the reciprocal of specific

gravity in regression equations did not increase the accuracy of predicting composition so that it can be assumed that the relationship between specific gravity and the proportion of muscular tissue approaches linearity.

The use of boars selected from some of the more promising of the breeds of hogs used in the US, especially of the Hampshire breed, shows some promise in crossbreeding programs for commercial hog production in Canada. With the exception of one of the six Hampshires (sire 19-5), the progeny of Hampshire sires produced carcasses that compared favorably with the offspring of Lacombe sires in meeting Canadian carcass grade and ROP standards. Progeny of the Poland China sires generally had lower grades and ROP scores than the Hampshire or Lacombe crosses because of slightly greater backfat and significantly shorter carcass length. These factors and the fatter bellies also contributed to the lower ROP scores for the progeny of the Poland China boars.

The offspring of both of the US breeds possessed desirable characteristics that were not considered in the Canadian grading and ROP scoring procedures. The Lacombe crosses had loin eye areas that were 0.36 square inches smaller than the Poland China crosses ($P < 0.05$) and 0.33 square inches smaller than the Hampshire crosses. A significantly larger proportion of trimmed ham and trimmed loin in the Hampshire crosses resulted in a larger proportion of trimmed lean cuts and trimmed primal cuts. Higher ham and lean cut indices were also found in the Hampshire crosses. Poland China crosses had significantly larger proportions of trimmed ham, slightly higher proportions of lean cuts and primal cuts, and slightly higher lean cut indices. This meant that the trimmed primal cuts from the Hampshire crosses were worth $0.51 more to the packing house per cwt of hot carcass than the Lacombe

crosses but with essentially no difference in returns to the producer. The Poland China crosses were worth \$0.30 more per cwt to the packing house but less to the producer because of lower grades.

All US boars were from herds on Meat Type Certification programs. However, in retrospect, the Hampshire boars in Trial 1 were near the average of their respective herds when compared to those used in Trial 2 and all those in Trial 1 would have been rejected had they been offered for Trial 2. The Hampshire boars in Trial 2 were from among the lowest probing boars of a large number offered and were the most highly selected group of boars used. Because the three Poland China boars which were the most select on the basis of probe and sire-progeny tests inadvertently had to be replaced by unprobed boars, the Poland China boars in both trials probably more nearly represented a cross-section of their respective herds than was intended. They ranged from one of the outstanding sires (3-10 in Trial 1) to one of the poorest (18 in Trial 2). The average ROP score of 71 for Lacombe progeny in both trials was below breed average. However, carcass grades were near the Alberta average in Trial 2 and decidedly superior in Trial 1. There is no strong evidence against accepting the Lacombe crossbreds as typical of Canadian bacon pigs using the generally accepted standards of carcass grade and ROP score.

Further testing should be done to compare a broader selection of Hampshire, Poland China, and other promising US breeds of hogs with typical Canadian bacon hogs. From this study it is obvious that boars can be selected from the Hampshire and Poland China breeds, especially from the Hampshire, that will sire offspring capable of meeting Canadian grading standards and that will yield higher proportions of trimmed ham

and loin than average Canadian bacon-type crossbred pigs. Although wholesale carcass value was significantly higher in the Hampshire crosses, the present standards of grading would not reflect this to the producer.

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APPENDIX A. Phenotypic correlations*, breeds and sexes combined (134 df)

	Carcass wt	Dress-ing %	Length	Max shoulder fat	Min back fat	Max loin fat	Total fat	Loin area	Lean/fat ratio	Grade	ROP score	Belly grade	Rough ham wt	Trimmed ham wt
Market wt	.70	-.05	.24	.01	.03	.03	.03	.03	.01	.14	.00	.00	.29	.26
Carcass wt		.66	.07	.18	.24	.25	.24	.09	-.11	-.08	-.19	-.16	.37	.23
Dressing %			-.18	.22	.29	.29	.29	.09	-.15	-.26	-.26	-.23	.20	.05
Length				-.26	-.34	-.27	-.32	-.12	.16	.46	.49	.31	-.02	.17
Max shoulder fat					.67	.73	.89	-.39	-.78	-.62	-.74	-.60	-.23	-.51
Min back fat						.79	.89	-.30	-.74	-.64	-.76	-.62	-.14	-.44
Max loin fat							.93	-.34	-.78	-.72	-.87	-.64	-.17	-.46
Total fat								-.38	-.85	-.72	-.87	-.68	-.19	-.52
Loin area									.78	.35	.52	.57	.36	.59
Lean/fat ratio										.64	.83	.72	.30	.64
Grade											.81	.73	.23	.51
ROP score												.84	.23	.58
Belly grade													.28	.58
Rough ham wt														.78

*r=0.16 significant at $P < 0.05$

r=0.22 significant at $P < 0.01$

APPENDIX A. Phenotypic correlations*, breeds and sexes combined (134 df)

	Rough loin wt	Trimmed loin wt	Rough picnic wt	Trimmed picnic wt	Rough butt wt	Trimmed butt wt	Rough belly wt	Trimmed belly wt	% Trimmed ham	% Trimmed loin	% Ham and loin	% Trimmed picnic	% Trimmed butt
Market wt	.18	.16	.31	.29	.31	.32	.27	.32	-.01	-.05	-.03	.06	.08
Carcass wt	.41	.22	.35	.29	.30	.24	.49	.57	-.16	-.11	-.15	-.03	-.13
Dressing %	.35	.10	.17	.12	.08	-.01	.44	.49	-.21	-.14	-.20	-.09	-.28
Length	.03	.19	.10	.17	.07	.20	-.16	-.11	.14	.23	.22	.13	.19
Max shoulder fat	.38	-.28	-.29	-.31	.22	-.18	.24	.31	-.59	-.39	-.59	-.38	-.26
Min back fat	.50	-.20	-.34	-.28	.22	-.12	.21	.33	-.54	-.32	-.51	-.37	-.20
Max loin fat	.51	-.16	-.35	-.36	.16	-.19	.20	.31	-.57	-.32	-.53	-.46	-.30
Total fat	.51	-.24	-.36	-.35	.22	-.18	.24	.35	-.62	-.38	-.60	-.44	-.28
Loin area	.01	.45	.08	.05	-.04	.23	-.28	-.22	.56	.53	.64	.00	.22
Lean/fat ratio	-.32	.40	.25	.21	-.18	.22	-.32	-.36	.70	.53	.73	.24	.28
Grade	-.24	.31	.28	.34	-.04	.33	-.25	-.25	.55	.45	.59	.38	.36
ROP score	-.31	.36	.27	.32	-.10	.28	-.36	-.39	.66	.54	.71	.38	.37
Belly grade	-.18	.41	.23	.26	-.09	.27	-.41	-.42	.64	.59	.73	.33	.33
Rough ham wt	-.05	.18	.27	.36	-.07	.13	-.03	-.01	.64	.09	.43	.23	.05

*r=0.16 significant at $P < 0.05$

r=0.22 significant at $P < 0.01$

APPENDIX A. Phenotypic correlations*, breeds and sexes combined (134 df)

	% Lean cuts	% Trimmed belly	% Primal cuts	Cutout value	Ham index	Loin index	Picnic index	Butt index	Lean cut index	% Rough ham	% Rough loin	% Rough picnic	% Rough butt
Market wt	.01	.08	.04	.02	.06	.01	.04	-.05	.03	-.05	-.06	.05	.08
Carcass wt	-.17	.24	-.08	-.11	-.08	-.18	-.01	-.14	-.14	-.12	.07	-.03	-.04
Dressing %	-.26	.28	-.15	-.18	-.15	-.26	-.03	-.14	-.22	-.12	.13	-.08	-.16
Length	.26	-.13	.22	.22	.29	.23	.11	.17	.28	-.07	.01	.06	.07
Max shoulder fat	-.64	.27	-.57	-.60	-.54	-.75	-.09	-.60	-.72	-.32	.35	-.37	.15
Min back fat	-.56	.29	-.49	-.52	-.54	-.77	.02	-.52	-.70	-.27	.46	-.44	.15
Max loin fat	-.61	.25	-.57	-.58	-.54	-.78	-.10	-.53	-.74	-.30	.46	-.47	.07
Total fat	-.67	.29	-.60	-.62	-.59	-.85	-.06	-.61	-.79	-.32	.46	-.47	.13
Loin area	.54	-.30	.50	.56	.51	.56	-.03	.39	.53	.34	-.02	.04	-.06
Lean/fat ratio	.70	-.37	.62	.68	.67	.85	.00	.61	.79	.36	-.30	.30	-.14
Grade	.64	-.23	.61	.62	.54	.68	.15	.52	.68	.28	-.23	.32	.00
ROP score	.76	-.36	.68	.71	.65	.82	.13	.56	.79	.32	-.26	.35	-.02
Belly grade	.74	-.42	.64	.69	.58	.73	.07	.55	.70	.37	-.13	.30	-.03
Rough ham wt	.40	-.16	.39	.45	.04	.27	.21	.29	.26	.83	-.19	.13	-.17

*$r=0.16$ significant at $P < 0.05$
$r=0.22$ significant at $P < 0.01$

APPENDIX A. Phenotypic correlations*, breeds and sexes combined (61 df)

	Shoulder probe	Back probe	Loin probe	Total probe	Sp gr, hot ham	Sp gr, chilled ham	Sp gr, trimmed ham	% Ham bone	% H_2O in ham	% Nx6.25 in ham	% Ether extract
Market wt	.07	-.01	-.08	.00	.08	.11	.08	-.17	-.03	.15	.00
Carcass wt	.12	.11	.05	.11	.00	-.04	.13	-.28	-.08	.26	.00
Dressing %	.11	.22	.18	.19	-.07	-.13	.10	-.23	-.11	.23	.03
Length	-.03	-.01	-.15	-.07	.14	.14	.01	.02	-.07	-.04	.05
Max shoulder fat	.47	.40	.41	.49	-.61	-.58	-.34	.01	-.37	-.18	.36
Min back fat	.66	.63	.57	.71	-.52	-.49	-.23	-.16	-.31	-.02	.27
Max loin fat	.61	.49	.64	.67	-.50	-.41	-.17	-.12	-.24	.09	.19
Total fat	.66	.56	.61	.71	-.62	-.56	-.29	-.11	-.35	-.04	.31
Loin area	-.48	-.34	-.44	-.49	.70	.49	.45	-.28	.62	.42	-.64
Lean/fat ratio	-.65	-.55	-.61	-.70	.78	.62	.44	-.09	.56	.27	-.55
Grade	-.42	-.37	-.53	-.50	.45	.35	.10	-.08	.26	.02	-.23
ROP score	-.59	-.48	-.62	-.65	.67	.50	.29	.01	.41	.07	-.39
Belly grade	-.39	-.40	-.42	-.46	.67	.46	.29	.03	.51	.19	-.49
Rough ham wt	-.09	-.10	-.27	-.17	.11	.07	.17	-.48	.13	.32	-.19

*r=0.25 significant at $P < 0.05$
r=0.32 significant at $P < 0.01$

APPENDIX A. Phenotypic correlations*, breeds and sexes combined (134 df)

	Rough loin wt	Trimmed loin wt	Rough picnic wt	Trimmed picnic wt	Rough butt wt	Trimmed butt wt	Rough belly wt	Trimmed belly wt	% Trimmed ham	% Trimmed loin	% Ham and loin	% Trimmed picnic	% Trimmed butt
Trimmed ham wt	-.15	.36	.34	.46	-.08	.28	-.20	-.11	.92	.41	.78	.36	.26
Rough loin wt		.53	-.28	-.30	.29	.10	-.12	.07	-.31	.41	.06	-.46	-.04
Trimmed loin wt			.04	-.02	.12	.28	-.38	-.26	.28	.81	.65	-.10	.20
Rough picnic wt				.78	.07	.17	.30	.21	.20	-.04	.10	.71	.02
Trimmed picnic wt					.00	.20	.23	.22	.35	-.05	.18	.93	.09
Rough butt wt						.80	.06	.16	-.20	-.02	-.12	-.08	.67
Trimmed butt wt							-.03	.06	.19	.20	.24	.13	.90
Rough belly wt								.90	-.39	-.55	-.55	.10	-.24
Trimmed belly wt									-.34	-.45	-.46	.04	-.16
% Trimmed ham										.45	.85	.38	.31
% Trimmed loin											.85	-.03	.26
% Ham and loin												.21	.34
% Trimmed picnic													.12

*r=0.16 significant at $P < 0.05$
r=0.22 significant at $P < 0.01$

APPENDIX A. Phenotypic correlations*, breeds and sexes combined (134 df)

	% Lean cuts	% Trimmed belly	% Primal cuts	Cutout value	Ham index	Loin index	Picnic index	Butt index	Lean cut index	% Rough ham	% Rough loin	% Rough picnic	% Rough butt
Trimmed ham wt	.76	-.21	.77	.82	.66	.65	.26	.53	.73	.69	-.24	.25	-.12
Rough loin wt	-.12	-.08	-.14	-.12	-.18	-.46	-.12	-.31	-.42	-.24	.94	-.45	.16
Trimmed loin wt	.50	-.40	.42	.47	.34	.38	-.13	.25	.31	.08	.50	-.05	.04
Rough picnic wt	.29	.08	.35	.29	.21	.36	-.12	.11	.32	.13	-.43	.92	-.06
Trimmed picnic wt	.45	.13	.53	.44	.30	.35	.50	.25	.50	.23	-.44	.71	-.09
Rough butt wt	.02	.06	.04	.00	-.05	-.22	-.10	-.47	-.23	-.18	.21	-.04	.92
Trimmed butt wt	.42	-.03	.44	.40	.28	.20	.06	.14	.25	.04	.02	.09	.75
Rough belly wt	-.46	.83	-.18	-.30	-.28	-.29	-.01	-.16	-.25	-.28	-.32	.12	-.12
Trimmed belly wt	-.39	.91	-.07	-.18	-.16	-.34	.08	-.19	-.24	-.30	-.14	-.01	-.03
% Trimmed ham	.84	-.31	.81	.88	.70	.73	.26	.59	.80	.75	-.28	.26	-.11
% Trimmed loin	.70	-.46	.60	.66	.54	.56	-.07	.36	.50	.15	.49	.00	.03
% Ham and loin	.91	-.45	.83	.91	.72	.77	.12	.57	.77	.52	.12	.16	-.04
% Trimmed picnic	.49	.04	.54	.46	.29	.42	.48	.29	.54	.27	-.49	.78	-.09

*r=0.16 significant at $P < 0.05$
r=0.22 significant at $P < 0.01$

APPENDIX A. Phenotypic correlations[*], breeds and sexes combined (134 df)

	% Lean cuts	% Trimmed belly	% Primal cuts	Cutout value	Ham index	Loin index	Picnic index	Butt index	Lean cut index	% Rough ham	% Rough loin	% Rough picnic	% Rough butt
% Trimmed butt	.52	-.10	.52	.50	.35	.28	.11	.20	.32	.14	.00	.06	.78
% Lean cuts		-.36	.92	.95	.73	.79	.28	.58	.84	.51	-.06	.37	.11
% Trimmed belly			-.03	-.15	-.15	-.32	.11	-.16	-.21	-.28	-.18	-.01	.00
% Primal cuts				.98	.74	.73	.33	.57	.83	.46	-.12	.39	.11
Cutout value					.77	.77	.29	.59	.84	.53	-.09	.33	.08
Ham index						.71	.15	.50	.85	.11	-.17	.24	.00
Loin index							.04	.65	.91	.36	-.43	.44	-.15
Picnic index								.19	.34	.20	-.12	-.13	-.07
Butt index									.73	.35	-.28	.17	-.42
Lean cut index										.34	-.40	.38	-.17
% Rough ham											-.22	.18	-.12
% Rough loin												-.48	.20
% Rough picnic													-.05

[*] r=0.16 significant at $P < 0.05$
r=0.22 significant at $P < 0.01$

APPENDIX A. Phenotypic correlations*, breeds and sexes combined (61 df)

	Shoulder probe	Back probe	Loin probe	Total probe	Sp gr, hot ham	Sp gr, chilled ham	Sp gr, trimmed ham	% Ham bone	% H_2O in ham	% Nx6.25 in ham	% Ether extract
Trimmed ham wt	-.48	-.40	-.54	-.54	.57	.50	.28	-.47	.26	.24	-.28
Rough loin wt	.17	.19	.20	.21	.12	-.13	.18	.01	.22	.15	-.27
Trimmed loin wt	-.39	-.37	-.34	-.42	.64	.37	.39	.04	.56	.22	-.55
Rough picnic wt	-.27	-.23	-.30	-.30	.01	.25	.02	.06	-.06	-.02	.10
Trimmed picnic wt	-.11	-.12	-.26	-.19	.09	.17	-.27	-.22	-.28	-.20	.36
Rough butt wt	-.04	-.04	-.08	-.06	-.08	-.11	.02	.12	-.03	.03	.05
Trimmed butt wt	-.18	-.14	-.22	-.20	.16	.06	.05	-.04	.05	.07	-.03
Rough belly wt	.19	.32	.21	.27	-.40	-.27	-.23	-.10	-.29	.01	.27
Trimmed belly wt	.23	.30	.22	.28	-.34	-.26	-.28	-.24	-.32	.04	.30
% Trimmed ham	-.53	-.44	-.57	-.60	.57	.52	.23	-.36	.30	.13	-.28
% Trimmed loin	-.46	-.40	-.39	-.48	.67	.41	.37	.06	.59	.15	-.57
% Ham and loin	-.59	-.50	-.57	-.64	.75	.56	.36	-.17	.54	.17	-.52
% Trimmed picnic	-.11	-.13	-.25	-.18	.03	.13	-.37	.02	-.29	-.34	.41

*r=0.25 significant at $P < 0.05$
r=0.32 significant at $P < 0.01$

APPENDIX A. Phenotypic correlations*, breeds and sexes combined (61 df)

	Shoulder probe	Back probe	Loin probe	Total probe	Sp gr, hot ham	Sp gr, chilled ham	Sp gr, trimmed ham	% Ham bone	% H_2O in ham	% Nx6.25 in ham	% Ether extract
% Trimmed butt	-.30	-.18	-.35	-.32	.27	.18	.09	-.15	.14	.06	-.12
% Lean cuts	-.58	-.50	-.61	-.65	.67	.53	.20	-.17	.38	.05	-.32
% Trimmed belly	.19	.32	.19	.26	-.34	-.23	-.33	-.29	-.31	-.02	.31
% Primal cuts	-.58	-.43	-.62	-.63	.62	.50	.07	-.33	.29	.05	-.22
Cutout value	-.62	-.47	-.64	-.67	.68	.54	.17	-.33	.37	.10	-.32
Ham index	-.64	-.49	-.52	-.64	.76	.70	.23	-.17	.26	.00	-.21
Loin index	-.71	-.68	-.68	-.80	.72	.62	.33	-.03	.51	.13	-.46
Picnic index	.14	.09	-.03	.08	.10	-.07	-.38	-.34	-.30	-.25	-.35
Butt index	-.23	-.16	-.21	-.23	.42	.29	.03	-.28	.12	.07	-.13
Lean cut index	-.58	-.52	-.57	-.64	.71	.60	.12	-.20	.25	-.02	-.18
% Rough ham	-.16	-.17	-.32	-.24	.12	.10	.12	.36	.18	.20	-.21
% Rough loin	.12	.15	.18	.18	.15	-.10	.15	.11	.28	.06	-.30
% Rough picnic	-.28	-.26	-.29	-.32	-.03	.25	-.04	.24	-.06	-.14	.13

*
r=0.25 significant at P 0.05
r=0.32 significant at P 0.01

APPENDIX A. Phenotypic correlations*, breeds and sexes combined (61 df)

	Shoulder probe	Back probe	Loin probe	Total probe	Sp gr, hot ham	Sp gr, chilled ham	Sp gr, trimmed ham	% Ham bone	% H_2O in ham	% Nx6.25 in ham	% Ether extract
% Rough butt	.14	-.07	-.18	.15	.02	-.03	.03	.05	.03	-.02	.00
Shoulder probe		.66	.69	.92	-.57	-.52	-.31	.00	-.40	-.09	.36
Back probe			.52	.82	-.44	-.39	-.23	-.13	-.31	-.16	.27
Loin probe				.85	-.51	-.36	-.16	.19	-.36	-.03	.32
Total probe					-.59	-.50	-.28	.03	-.41	-.11	.37
Sp gr, hot ham						.80	.61	-.16	.60	.26	-.60
Sp gr, chilled ham							.70	-.11	.45	.36	-.47
Sp gr, trimmed ham								-.02	.50	.57	-.64
% Ham bone									-.07	-.26	.12
% H_2O in ham										.38	-.95
% N x 6.25 in ham											-.56

*r=0.25 significant at $P < 0.05$
r=0.32 significant at $P < 0.01$

APPENDIX B. Laboratory Procedures

A. Preparation of samples of ground ham

The packaged hams were removed from the freezer at the packing plant and placed in a walk-in refrigerator for 36 ± 6 hours at 38 F. Thawing was not complete but was sufficient for easy grinding. Before grinding the hams from any of the experimental pigs, other hams were ground with variable thawing time. Insufficient thawing was found to make the passage of the meat through the grinder somewhat difficult while over-thawing of the ham resulted in some separation of fibrous tissues from the fat in the grinder, causing the grinder to plug. All hams were sawed into pieces 1 to 1 1/2 inches square and 4 to 10 inches long with an electric bandsaw before grinding. After the strips of ham were ground in a 2 hp electric meat grinder using a plate with 1/8 inch holes, the samples were thoroughly mixed by hand and the ground ham was put through the grinder again. The ground ham was then mixed by hand and patted into a semi-spherical mound. Two slices about 1 inch thick were taken from the mound at right angles to each other and placed in a plastic bag. The samples were then placed in a freezer at 0 to 10 F until needed.

Because of sampling errors encountered in analyzing the samples of ground ham for protein and ether extract, samples were freeze-dried before further analyses was done. The samples of ground ham were removed from the freezer and kept in the refrigerator for 24 hours to allow them to thaw before freeze-drying. Any ice crystals inside the package thus became thawed and were thoroughly mixed with the ground ham samples. Approximately 200 g of ground ham and approximately 150 ml of

water were placed in a homogenizer and homogenized for about 10 min. The homogenized samples were then frozen to the inside of 1000-ml, freeze-drying flasks until the flasks no longer felt cool. The crusts of freeze-dried material were then broken with a small hand meat grinder and placed in glass sample jars with metal lids. They were then stored in the refrigerator until analyzed for ether extract and protein.

B. Moisture determination of ground ham

When the ground ham samples were freeze-dried, duplicate 120 ± 20 g samples of ground ham were placed in a 4 x 6 x 1 inch aluminum pans and flattened by hand until they were approximately 1/8 inch thick. The tared pan and ground meat sample were then weighed on a torsion balance to the nearest 0.1 g and placed in a mechanical convection oven set at 60 C until the samples dried to a constant weight[1]. Samples were weighed every 24 hours and, in nearly all cases, 48 hours were required to reach a constant weight. For any duplicate samples that differed by more than 2% of the larger percentage of moisture, a second duplicate determination was made.

C. Ether extract analysis of ground ham

The procedure used for ether extract determination of the boneless, trimmed ham was a modification of the official AOAC (1955) method.

Duplicate 2 ± 0.2 g samples of freeze-dried, ground ham were weighed onto tared filter paper (Whatman no. 41). The filter paper was folder around the sample and another filter was then folded around the first. The wrapped samples were then placed in aluminum sample holders and placed in a Goldfisch extraction apparatus. Approximately 30 ml of petroleum ether (bp 30-60) were placed in a tared beaker and the beaker attached to the Goldfisch apparatus. An 8-hour extraction period followed.

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[1] R. O. A. Renner, Associate Professor of Household Economics. University of Alberta. Private communication. 1965.

The beakers were then removed from the extraction apparatus and placed on a steambath until the petroleum ether evaporated. The beakers were then dried in a mechanical convection oven for 1 hour at 100 C, cooled in a desiccator, and weighed. The weight of the ether extract was calculated as a percentage of the weight of the original sample weight of the ground ham, corrected for per cent moisture. For any duplicates that differed by more than 2% of the larger value, a second duplicate determination was done.

D. Protein determination of ground ham

The nitrogen in the boneless, ground ham was determined by the Kjeldahl method using duplicate 1.5-g samples of freeze-dried, ground ham. Per cent nitrogen x 6.25 was calculated as a percentage of the chilled, boneless, trimmed ham. For any duplicate determinations that differed by more than 2% of the larger value, a second set of duplicate determinations were done.