MUSCLE DEVELOPMENT IN TWO GENETIC GROUPS OF SWINE AS INFLUENCED BY THE AMOUNT OF FEED AND LENGTH OF FEEDING

by

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A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subject: Animal Breeding

Approved:

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1958

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INTRODUCTION

Knowledge concerning factors which influence the composition of the pork carcass is important for several reasons. The price differential between lard and the lean cuts has increased for the past several decades as shown in Figure 1. Also, people associated with the swine industry desire that pork attain a better competitive position with other meats at a time when consumers are preferring leaner cuts of meat.

The composition of the pork carcass is the result of the growth and development of each tissue (skeleton, muscle, fat, etc.) and each region (hindquarters, loin, etc.) of the body during the pig's lifetime. Therefore many variables interplay to determine the final composition of the carcass. The individual growth rates of the various tissues and parts are affected by the age of the animal, the environmental conditions with which it is confronted, and its genetic potential.

Various studies have demonstrated that the maximum rate of growth is attained early in life for bone, later for muscle, and much later for fat. Restriction of feed intake has a more pronounced effect on the later developing tissues and parts than on those which develop earlier. Thus limited feeding affects the growth of fat more severely than it affects the growth of lean. Whether, under mildly

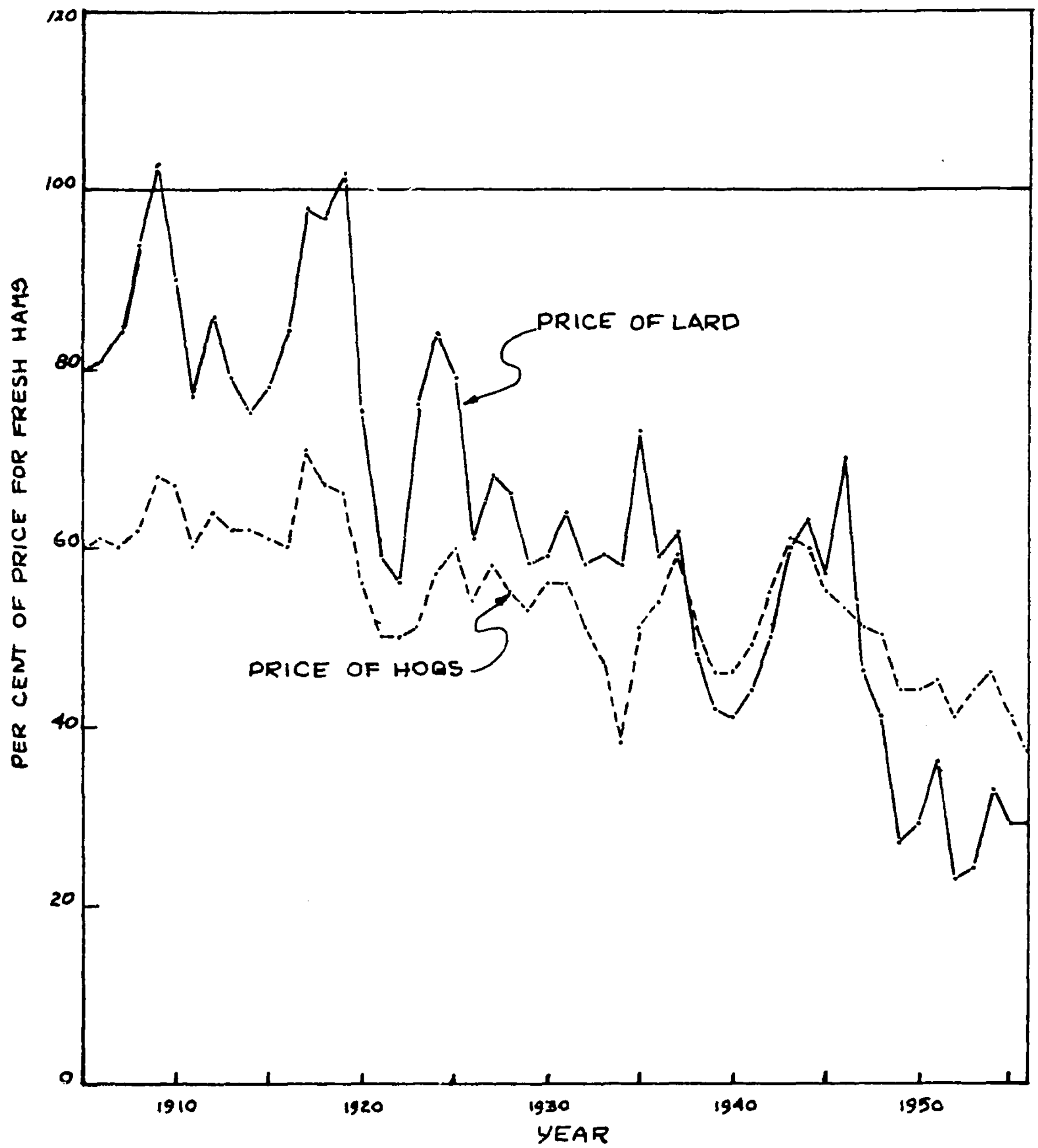

Figure 1. Average annual prices of lard and hogs expressed as a percentage of average annual price of fresh hams 1905 to 1956, Chicago prices (U. S. Agricultural Marketing Service, 1957)

restricted feed intake, the growth rates of fat and muscle are both affected, or only the growth rate of fat is affected is not known. An answer to this question was sought in the present study by comparing full fed and limited fed pigs of the same age.

A genotype-environment interaction exists when the difference between two genotypes is not the same in different environments. Genotype-environment interactions are known to exist in farm animals for wide differences in genotypes and environments such as might exist for British and Indian cattle in temperate and in tropical climates. If genotype-environment interactions are present within a narrower range of genotypes and environments, this could have important consequences in a livestock breeding program. A separate group would need to be bred to fit each set of environmental conditions large enough to justify such effort, if maximum progress is to be made. Furthermore, nutritional and managerial recommendations might not be the same for all genetic groups. An understanding of genotype-environment interactions is of particular importance when choosing an environment for performance testing stations. Several questions present themselves when prospective breeding animals are compared under environmental conditions which have been carefully standardized as much as possible to maximize the accuracy of selection for superior genotypes. Will animals which differ genetically demonstrate the same differences when tested under one environment as if they had been tested under another environment? Is the chosen environment the one which will enable selection for the traits of interest to be most effective? And do environments and genotypes differ enough for interactions between them to be of appreciable importance?

The two main purposes of the present investigation were:

1. To measure how the composition of swine carcasses is affected by certain differences in environment during the finishing period and by differences between two genetic groups of pigs.

2. To evaluate possible genotype-environment interactions for carcass characteristics.

The environmental differences which were compared were:

1. Full feeding versus limited feeding, both when pigs were slaughtered at the same weight and when pigs were slaughtered at the same age.

2. Feeding in concrete dry-lot versus feeding on pasture.

Concurrent with the study outlined above, additional information was also obtained concerning the value of certain indicators of carcass merit. Those of most interest were:

1. Probes taken when the pigs weighed approximately 140 lbs.

2. Probes taken to the false lean compared with probes

taken through the false lean at the site of the shoulder probes.

3. The center of gravity of the carcass.

REVIEW OF LITERATURE

Effect of Growth and Development on Carcass Characteristics

Callow (1935), in a review of the relation of growth to the carcass quality of the pig, stated

> Pigs, like other mammals, have three main phases of growth. During the first phase, the skeleton grows more rapidly than at any later period. During the second phase, muscular growth predominates. This is followed by a phase during which the rate of deposition of fat reaches a maximum, fat is deposited between and in the muscles, and the animal becomes mature and finally overfat.

Callow further reported that when the weight of the growing pig was held constant by a submaintenance diet, bone growth continued, muscle growth continued to a lesser extent than bone, and the fat content of the body progressively diminished.

McMeekan (1940a) presented data from detailed anatomical examination of 13 typical Large White male pigs slaughtered at monthly intervals from birth to seven months of age. The weight of skeleton at 28 weeks of age was 30.5 times that at birth, while muscle weight had increased 81.6 times and fat weight increased 676.7 times during the same period. The rates of growth in grams per week for these three tissues were 131, 381, and 233 from birth to 4 weeks; 279, 1061, and 644 from 8 to 16 weeks; and 213, 1918, and 3028 from 24 to 28 weeks. Well-defined differential growth relationships were observed within any one tissue. For example, the skeletal units of the head and trunk exhibited an anterior-posterior gradient in order of development and the upper units of each limb developed later than the lower units. The muscle and fat surrounding these skeletal units afforded even more marked evidence of similar gradients in these tissues.

McMeekan (1940b and 1940c) studied the effects of marked differences in plane of nutrition on the growth and development of the pig. Two groups of pigs from an inbred line of Large Whites were put on a high plane and on a low plane of nutrition at birth. At the age of 16 weeks six pigs on each plane were slaughtered for detailed anatomical examination. The nutritional differences from birth to 16 weeks were such that the high plane pigs weighed 113 lb. and the low plane pigs weighed 37 lb. at the time they were slaughtered. The weights of the skeleton, muscle, and fat from the high plane pigs were 221, 291 and 1007 per cent of the weights of these tissues from the low plane animals. McMeekan interpreted the observation that the late developing parts of the body were penalized more than the early-developing parts as evidence of "a superiority in the competitive capacity of early-developing units of the body for available nutrition". However, the growth curves for the pigs did not differ as much during the first few weeks as they did during the later part of the 16 week period. This might partially account for the earlier developing parts being affected less by the two levels of nutrition.

At 16 weeks of age approximately half of the remaining pigs on each treatment were switched gradually to the other plane of nutrition. Five pigs on each of the four treatments (high-high, high-low, low-high, low-low) were slaughtered at 200 lbs. The ages at slaughter were 165 days for the high-high group, 211 days for the high-low and low-high groups, and 327 days for the low-low group, which indicates how marked the differences in planes of nutrition were. The percentages of carcass weight which each of the major tissues composed for the high-high, high-low, low-high, and low-low groups respectively were: skeleton 11.0, 11.2, 9.7, and 12.4; muscle 40.3, 44.9, 36.3, and 49.1; and fat 38.3, 33.4, 44.1, and 27.5. Therefore the low-low pigs had the most bone and muscle and the least fat while the low-high animals had the least bone and muscle and the most fat. The high-high and the high-low groups were intermediate with the high-high pigs approaching the composition of the low-high group and the high-low approaching the low-low group.

Pomeroy (1941) observed the tissues were affected in reverse order of their order of development when a sub-maintenance diet was fed to five pigs weighing 330 lbs. initially for 0, 23, 51, 80, and 135 days (slaughter weights were 327, 302, 263, 234, and 188 lbs.). The weight of the bone increased slightly unless the submaintenance diet was prolonged. Generally the earlier developing bones were penalized less than the later developing bones. The tendency for persistent growth in the early stages of submaintenance was much less for muscle than for bone and the final relative losses were much larger. The amount of fat was affected most rapidly and extremely by the submaintenance diet. Also the fat deposits which were affected first were those laid down last.

Loeffel *et al*. (1943) slaughtered five pigs at each of eight different weights from 150 to 400 lbs. The cuts from the right side of each carcass (head, feet, and leaf fat excluded) were separated into fat, lean, bone, and skin. Their results are given in Table 1. Dressing percentage increased from 74 per cent for hogs slaughtered at 150 lbs. to 84 per cent for those slaughtered at 400 lbs.

Table 1. Percentage composition of carcasses of hogs slaughtered at various weights. (Loeffel *et al*., 1943)

	Weight when slaughtered							
Tissue	150	175	200	225	250	300	350	400
Fat	32	37	42	44	45	48	54	55
Lean	52	49	45	43	43	41	35	34
Bone	10	9	9	8	8	7	7	6
Skin	5	4	4	4	4	4	4	4

Comstock and Winters (1944) determined the relative growth rates of certain body measurements for 85 litter mate boar barrow pairs which were measured at intervals of four weeks from 8 weeks of age until they weighed 230 lbs. or were 180 days of age. The pigs were from two breeds, Poland China and Minnesota No. 1, and six inbred lines of the Poland China breed. Their results confirmed the general observation that body form changes as pigs increase in size since most of the relative growth constants were different from one. Also they found breed differences, and in one case line differences, in the relative growth constants which indicated genetic differences in the change in form.

Effect of Level of Feeding on Feed Lot and Carcass Performance

Robison (1932) observed that limiting the feed caused slower gains but saved feed when pigs were fed on pasture.

Ellis and Zeller (1932, 1934) fed three levels of corn and supplement (4, 3, and 2 per cent of body weight) to 17 pigs individually in dry-lot from weights of 65 to 200 lbs. A wheat and supplement ration was fed to 18 pigs under similar conditions. As the feed allowance was reduced, rate of gain was reduced in both groups. Feed requirements were also reduced as the feed intake was lowered, but more for the pigs fed corn than for those fed wheat. Restricting the feed increased the percentage of lean and decreased the percentage of fat in the carcasses. Also the restricted feeding caused a slight decrease in firmness in the corn fed pigs.

Saint-Pierre et al. (1935) studied the relative efficiency of different levels of feeding for fattening pigs in dry-lot. In the first experiment three groups of nine pigs each were fed from 60 to 225 lbs. at three levels of feeding -- all they would clean up when fed twice a day, three-fourths that amount, and one-half that amount. The three groups averaged 1.25, 1.05, and .70 lbs. per day gain and consumed 387, 380, and 411 lbs. of feed per 100 lbs. gain. The dressing percentage was 83.3, 81.4, and 77.6 respectively. In the second experiment the same three levels of feeding were used plus a fourth group which was fed one-half the full feed allowance for 10 weeks and then was full fed to 200 lbs. Ten pigs fed at each level from 65 to 200 lbs. averaged 1.52, 1.00, .60, and .97 lbs. per day gain. The average feed requirements per 100 lbs. of gain were 395, 378, 444, and 422 lbs., respectively, while the dressing percentages were 77.3, 77.2, 77.3, and 76.2 per cent. The carcasses from the pigs fed one-half of the full feed allowance were noticeably softer than those in the other lots. These workers concluded the slight advantage in feed required per 100 lbs. gain for the pigs fed the three-fourths ration would be more than offset by the disadvantages of limited feeding. The disadvantages they listed were slower gains, increased labor cost, additional cost for buildings and equipment when two litters a year are raised, and apparently less desirable carcasses.

McMeekan's (1940b, 1940c, and 1941) detailed studies of the effects of large differences in level of feed intake on carcass composition have already been mentioned. The feed consumed from 16 weeks of age to 200 lbs. body weight in terms of meal equivalent per lb. of gain was 5.8 lbs. for the high-high group, 4.2 lbs. for the high-low group, 5.7 lbs. for the low-high group, and 5.3 lbs. for the low-low group.

Robison (1946), in a study of the influence of the rate of fat deposition on the firmness of fat, compared full feeding and limited feeding (daily intake of 2.75 per cent of body weight) when several levels of fat were included in the ration. The 181 pigs were slaughtered at various weights from 50 to 250 lbs. The limited fed pigs generally made larger gains per unit of feed consumed than did the self-fed pigs. A higher percentage of loin and trimmed ham and a lower percentage of fat cuts were obtained from the carcasses of the limited fed hogs than from those of the full fed hogs of similar weight. Also the full fed hogs had higher dressing percentages and slightly firmer fat than the limited fed hogs. At equal fatness, regardless of weight or length of feeding, little difference was observed in the firmness of fat.

Winters et al. (1949) compared the effects of four planes of nutrition on the economy of gain and carcass quality of 80 pigs. Lot 1 was self-fed from weaning to 215 lbs., Lot 2 was self-fed to 125 lbs. then limited fed, Lot 3 was limited fed to 125 lbs. then self-fed, and Lot 4 was limited fed the entire period. The limited fed pigs received a daily feed allowance of three per cent of their body weight. The respective average daily gains were 1.40, 1.19, 1.11, and .92 lbs. and the feed per 100 lbs. of gain was 383, 381, 391, and 365 lbs. The primal cuts represented 69.5, 70.4, 69.8, and 72.1 per cent of the cold carcass weight, and the fat cuts represented 20.2, 18.4, 18.2, and 16.3 per cent of the cold carcass weight. The meat of Lot 4 was somewhat softer and coarser in texture than that of Lot 1. These workers concluded that the most desirable results may be obtained when animals with an inherent capacity for rapid growth are restricted somewhat in their growth during the finishing stage.

Brugman (1950) reported that pigs which were limited to 70 per cent of a full feed until they reached 150 lbs., then full fed to 220 lbs., produced carcasses with a significantly higher percentage of primal cuts and lower percentage of total lard than pigs which were full fed from weaning to 220 lbs. His data were from 13 limited fed and 12 full fed pigs slaughtered in one year and 23 limited fed and 35 full fed pigs slaughtered the following year. The treatment differences for each year were 3.3 and 2.9 per cent for percentage of primal cuts and 4.5 and 3.9 per cent for percentage total lard.

Gregory and Dickerson (1952) reported that limiting the feed intake from weaning to slaughter to 87 per cent of that under full feeding reduced daily gain by 8 per cent, decreased feed required per unit of gain by 7 per cent, and produced carcasses containing 2 per cent more lean and correspondingly less fat. Also scores for carcass quality were raised by 6 per cent. However no gain in net carcass value was obtained except in the groups which yielded the fattest carcasses because limited feeding lowered the dressing percentage.

Workers at the Tennessee Agricultural Experiment Station (Smith et al., 1950 and Tenn. Agr. Exp. Sta., Annual Report 1951) compared three levels of feeding on pasture for growing and fattening swine from 65 to 215 lbs. The levels of feeding were full feeding, 80 per cent of full feeding, and 60 per cent of full feeding. The average daily gain was 1.68, 1.43, and 1.24 lbs. and the feed required per 100 lbs. of gain was 362, 325, and 293 lbs. respectively. The dressing percentages were 70.5, 69.3, and 68.5 per cent, the depth of backfat was 1.74, 1.57, and 1.48 in., and the percentages of primal cuts (carcass basis) were 65.7, 66.3, and 67.2 per cent. The pigs which were fed at the 60 per cent level produced carcasses that graded only medium hard for firmness and had lean that was described as slightly shady in color. From the standpoint of over-all carcass merit, carcasses produced by feeding 80 per cent of a full feed on pasture were considered most desirable. A total of 226 pigs were included in the averages for rate and economy of gain and 167 carcasses were included in averages for the carcass characteristics.

Whatley et al. (1953) divided 48 pigs at 140 lbs. into two groups. One group was self fed an 88 per cent corn ration while the other was self fed a 65 per cent corn and 20 per cent prairie hay ration. The latter group thus was limited in feed by lowering the energy content of the ration. The average daily gains were 1.68 and 1.45 lbs. and the feed required per 100 lbs. of gain was 357 and 433 lbs., respectively. However, the prairie hay ration was unpalatable and considerable waste was noted around the feeders. The carcass observations for the two levels of feeding included dressing percentage 74.6 and 72.6 per cent; lean cuts (live weight basis) 32.9 and 33.9 per cent; primal cuts (live weight basis) 45.4 and 45.4 per cent; and carcass value per 100 lbs. live weight 22.87 dollars and 22.70 dollars. The authors concluded, ". . . the reduction in dressing percentage of pigs on the restricted energy ration offset the advantage of the leaner carcass; consequently, the carcass value of the live hogs were not improved".

Zobrisky et al. (1954) reported observations on 76 Hampshire hogs which were divided into seven groups and fed different levels from weaning to slaughter weight (215 lbs.). Only grade and quality score data were presented for each group. The number of carcasses in the medium grade increased as the level of feeding was decreased. Also the quality was lowered somewhat in the most restricted groups. The authors felt that full feeding to 160 lbs., then restricting the feed intake to 75 per cent of full feed to 215 lbs., might have some definite advantages over full feeding from weaning to slaughter.

Crampton et al. (1954a) studied how restricting feed intake during the finishing period affected the quality of the bacon carcass. Two groups of 60 purebred Yorkshires were used. One group was fed during the winter and the other during the summer. Half of each group was restricted in feed from 110 to 200 lbs. and the other half was full fed. During the winter the full fed group received 8.3 lbs. feed per day and the restricted group received 6.3 lbs. feed per day. These groups gained 1.72 and 1.27 lbs. per day on 4.8 and 5.0 lbs. of feed per pound of gain. They had 41.0 and 45.2 per cent lean in the rasher and a loin muscle area of 4.8 and 5.2 sq. in. respectively. In the full fed group 58 per cent and in the restricted group 70 per cent of the carcasses were classified Grade A. During the summer the full fed pigs received 7.3 lbs. per day and the restricted pigs received 6.3 lbs. per day (the lower feed consumption of the full fed pigs in the summer than in the winter was not anticipated). These two groups gained 1.74 and 1.50 lbs. per day and each required 4.2 lbs. of feed per pound of gain. The percentage of lean in the rasher was 39.6 and 40.3 per cent, and the loin area was 4.7 and 5.2 sq. in. respectively. In contrast with the winter pigs, 38 per cent of the full fed pigs and 34 per cent of the restricted fed pigs yielded Grade A carcasses. The authors interpreted this to mean that, unless growth rate was restricted to about 1.25 lbs. per day, there is likely to be little practical effect of the restriction of feed intake on carcass grade.

Crampton et al. (1954b) improved the leanness of bacon carcasses by introducing fibrous feeds into the ration during the finishing period (115 to 200 lbs.). Nine different rations were fed to a total of 240 purebred Yorkshires in two seasons. When one-half of a high energy basal ration (wheat or barley) was replaced by either alfalfa or wheat bran, carcass improvement was accompanied by a decrease in rate of gain. However, carcass improvement was also obtained without any change in rate of gain or feed intake when a portion of a barley basal ration was replaced by either wheat bran or wild oats, so that the total ration consisted of one-fourth, by weight, of either of the fibrous feeds. (Carcass improvement was measured by the percentage of Grade A carcasses in each group. The only reason for the carcasses not receiving an A Grade was because they were too fat.) The percentage of lean in the rasher was higher for the pigs fed on the rations composed of one-half fibrous feed than for those whose rations were one-fourth fibrous feed, however.

Lucas and Calder (1955) fed 42 pigs on a high plane of feeding and 42 pigs on a low plane of feeding in the winter and again in the summer. Half the pigs in each group were housed in a good piggery (well insulated with outside runs) and half of them were housed in a poor piggery (uninsulated floor and roof, drafty, no outside runs). Interactions between feeding levels and housing were observed for growth rate and efficiency of gain for the growing period from 45 to 150 lbs. The rate of gain was reduced much more by the low plane of nutrition in the poor piggery, especially in the winter, than it was in the good piggery. The pigs on the low level gained more efficiently than those on the high level when they were housed in a good piggery but gained less efficiently when housed in poor piggery, especially during the winter. The poorly housed pigs on the low plane of feeding were not continued on the experiment after 150 lbs. During the finishing period (100 to 200 lbs.) the pigs on the low plane gained more slowly in both seasons than those on the high plane. Also the gains of the pigs on the low plane were significantly more efficient than those for the well-housed pigs on the high plane, but not significantly more efficient than those of the poorly-housed pigs on the high plane.

The dressing percentage for the well-housed pigs on the high plane was significantly higher than for the poorly-housed pigs on the high plane in both seasons, but only slightly higher in the winter and no higher in the summer than for the pigs on the low plane. The pigs on the low plane had smaller backfat measurements than the pigs on the high plane did. Among the pigs on the high plane, those which were well-housed tended to be fatter than those which were poorly-housed. The pigs on the low plane had larger loin eye areas than those on the high plane. A highly significant feeding level x season interaction was observed for this characteristic because the pigs on the low plane had larger loin eye areas in the winter than in the summer while those on the high plane did not. No difference between levels of feeding was observed for carcass length.

Effect of Feeding Location on Feed Lot and Carcass Performance

Many studies have compared the feed lot performance of pigs fed on pasture with that of pigs fed in the dry-lot. However, carcass data were included in relatively few of these comparisons.

Edwards and Brown (1929) reported the results from comparisons of alfalfa pasture and the dry-lot for growing and fattening spring pigs. Each group was self fed shelled corn, tankage-linseed meal supplement, and a mineral mixture. In addition the dry-lot pigs were fed good quality alfalfa hay. The rate of gain was similar in the two groups. The 45 pigs fed on pasture consumed 12 lbs. more corn and 30 lbs. less supplement per 100 lbs. gain than the 30 pigs fed in a dry-lot. The average cost of 100 lbs. of gain was less for the pigs finished on pasture.

Aubel and Connell (1937) reported that pasture feeding excelled dry-lot feeding by producing faster and more economical gains. In their experiments a total of 30 pigs were self fed corn and tankage on pasture and 30 pigs were self fed corn, tankage, and good quality alfalfa hay under dry-lot conditions. The pasture pigs gained 1.55 lbs. per day on 308 lbs. corn and 16 lbs. tankage per 100 lbs. gain while the dry-lot pigs gained 1.44 lbs. per day on 359 lbs. corn, 33 lbs. tankage and 16 lbs. alfalfa hay.

Carroll and Krider (1950) summarized results from ten experiments in which pasture and dry-lot were compared for feeding pigs from an average of 50 to 205 lbs. The 161 pigs fed on pasture gained 1.44 lbs. per day and required 319 lbs. of grain and 45 lbs. of supplement (including alfalfa hay or meal) to gain 100 lbs., while the 154 pigs fed in dry-lot gained 1.43 lbs. per day and required 314 lbs. of grain and 67 lbs. of supplement to gain 100 lbs. In addition to the lower feed costs because of the saving of supplement, these authors reported that less labor was required for pasture fed pigs and that pigs fed on pasture were usually somewhat more thrifty. Morrison (1956) included data from 40 experiments in a similar summary. The pigs fed on pasture averaged 1.43 lbs. per day gain and required 359 lbs. concentrates per 100 lbs. of gain, and the pigs fed in dry-lot gained 1.40 lbs. per day and required 399 lbs. concentrates per 100 lbs. of gain.

In the Tennessee work already cited (Smith _et al_., 1950, and Tenn. Agr. Exp. Sta. Annual Report, 1951), feed lot and carcass data were obtained on pigs full fed on pasture and pigs full fed in the dry-lot from 65 to 215 lbs. The feed lot data, averaged over four seasons, were presented for 64 hogs which were full fed in dry-lot and 75 hogs which were full fed on various high quality pastures. The gain was 1.57 and 1.68 lbs. per day and the feed required (exclusive of the pasture) for 100 lbs. of gain was 395 and 362 lbs. respectively. Carcass data for 46 hogs full fed in dry-lot and for 54 hogs full fed on pasture revealed little difference between the two groups. The average dressing percentages were 70.7 and 70.5 per cent, and average carcass backfat was 1.68 and 1.74 in. respectively. Both groups averaged 65.7 per cent primal cuts.

Blackmore (1953) compared daily gain and carcass data for one pig from each of 24 litters fed on pasture and another pig from the same 24 litters fed on concrete in small record of performance pens. The pigs fed on pasture gained 1.4 lbs. per day which was significantly slower than the 1.7 lbs. per day gained by their litter mates in concrete pens. The two groups were similar for dressing percentage, percent lean cuts, and percent fat cuts.

Effect of Breed and Type on Feed Lot and Carcass Performance

One scarcely needs to refer to the literature for evidence that breed differences exist. However, a brief review of the events leading to breed and type differences should be pertinent to appreciating the genetic differences between the two groups of pigs used in this study.

The breeds of swine originating in the United States were formed from a very heterogeneous mixture of local groups of pigs in Ohio, Indiana, and the northeastern part of the country. The Polands, Durocs, and Chester Whites emerged as breeds between 1860 and 1880 followed by the Hampshires and Spotted Polands in the early 1900's. The Berkshires trace more directly to importations of pigs from England as early as 1823. As these breeds were being developed, the breeders were interested in a type of hog especially adapted to carrying a maximum load of corn to the packing house. As a result the lard type of pig was produced. Plumb (1920) defined the American, or lard, type of pig as follows:

> The type of swine most valued in the United States possesses great compactness of form, breadth of back, fullness of ham, shortness of limb, and is capable of fattening early and maturing early. It is a type that in its highest-fed and most popular form contains a large amount of fat, especially in leaf lard and external covering.

A distinct type of pig, called the bacon type has also been present in the United States but in smaller numbers. The pigs of this type, mostly Yorkshires and Tamworths, were developed in England specifically to produce high quality bacon carcasses on rations lower in energy than the diet available in the corn belt of the United States.

During the period from 1910 to 1935 much interest in swine type in the American breeds (especially the Polands) was reflected by the research done to compare the small, medium, and big or chuffy, intermediate, and rangy types. Workers at the Iowa Station (Ia. Agr. Exp. Sta. Annual Report, 1921) concluded the "Medium" or "Big" types gained more rapidly, more economically, and yielded a larger proportion of lean meat than the "Small" type did. Carroll et al. (1929), after studying the feed lot performance of 316 Poland China pigs chosen to represent the five types, Very Chuffy, Chuffy, Intermediate, Rangy, and Very Rangy, concluded that the type of swine was not a controlling factor in either their rate or economy of gain. Bull and Longwell (1929), on the basis of the carcasses from the above animals slaughtered at 225 lbs., reported that the Intermediate type yielded the most desirable carcasses because at that weight the carcasses from the Chuffy pigs were too fat and those from the Rangy pigs were too soft and underfinished.

The distinction between the lard type and the bacon type breeds continued during and after the period of interest in the extreme types within some of the American breeds. An increasing awareness of the desirability of developing pigs which would yield a large proportion of high quality lean cuts was felt, however.

Vaughn (1941) stated the term meat-type:

> . . . was first used a few years ago when the price of lard dropped to unusually low levels and packers gave preference to hogs carrying only moderate finish and yielding comparatively more meat and less lard than the well-finished lard-type hog.

He went on to quote instances when the packers paid the most for the fattest hogs at each weight, however. During the last ten years more interest has been shown in developing meat type hogs in all breeds.

Robison (1929) compared the feed lot performance and carcass yields of 30 Yorkshires and 30 Durocs. The Yorkshires gained slightly faster and made more efficient gains than the Durocs. Also, the Yorkshires yielded a higher proportion of lean cuts and belly and lower proportion of fat cuts than the Durocs.

Hankins and Hiner (1937) studied the meat yields of 56 Danish Landrace, 58 Durocs, and 52 Polands. The Durocs yielded significantly less ham than the Landrace and Polands, and the Landrace yielded significantly more loin than the Durocs and Polands. The Durocs yielded the largest percentage of fat cuts followed by the Landrace and the Polands respectively.

Thirty carcasses from each of three breeds, Berkshire, Chester White, and Duroc, were compared by Willman and Krider (1943). The Berkshires had significantly less backfat and had larger loin eye and ham lean areas than the Durocs and Chesters.

Perhaps the best data available to represent the differences found between the present day breeds of hogs are those from the Iowa Swine Testing Station. Munson (1957) found large breed differences in an analysis of the data from the first two seasons of the station's operation (Spring and Fall, 1956). Differences between the ten breed means (Hybrid hogs included as a breed) accounted for from 22.8 to 36.3 per cent of the variation in the traits which were studied -- daily gain, feed requirements, backfat probe, percent lean cuts, and percent defatted ham. The breed means for the first four seasons were reported by Sutherland (1958). Those for daily gain, feed requirements, and backfat probe for the boars and for percent lean cuts for the barrows are given in Table 2. The breeds are ranked in order of the average index for the boars.

Genotype-environment Interactions

The possible existence of interactions between heredity and environment has long been recognized. However, little is known about their importance in farm animals.

Bonnier _et al_. (1948) reported interactions between heredity and environment for growth and milk production of identical twins of the Swedish Red and White breed kept on two planes of nutrition. Osborne (1952) found an interaction between family means and hatching periods for the age at sexual maturity in Brown Leghorns. In South Africa, Joubert (1954) observed four breeds of cattle responded somewhat differently in a comparison of grazing with and without supplementary feeding during the winter months. Working with sheep in Scotland, King and Young (1955) found a genotype-environment interaction in the skeletal growth and wool production of three breeds kept on two levels of nutrition.

Indications of interactions between genotype and environment for feed lot and carcass performance in swine were reported by Lucas and Calder (1956). These workers conducted two experiments to compare the response of lean-type and fatter-type pigs to varying levels of feeding from

Table 2. Breed means for first three seasons at Iowa Swine Testing Station (Sutherland, 1958)

Breed	N	Daily gain	Feed require-ments	Probe	N	Percent lean cuts
Yorkshire	60	1.85	283	1.20	24	49.9
Landrace	70	1.94	291	1.21	28	50.0
Hampshire	131	1.93	295	1.29	48	50.8
Spotted Poland	45	1.92	293	1.32	15	50.0
Berkshire	32	1.74	299	1.24	13	49.9
Poland	111	1.82	299	1.28	43	50.8
Duroc	157	1.93	293	1.40	66	48.6
Tamworth	21	1.86	313	1.53	9	46.9
Chester	45	1.77	309	1.59	19	46.7

weaning to bacon weight. In the first experiment the lean-type pigs were from a Swedish Landrace x Large White cross and the fatter type were from a Wessex Saddleback x Large White cross. Three levels of feeding were used with one male and one female from each of three litters from each cross on each level. The levels were a high energy ration from 35 to 200 lbs. (VH-VH), a high energy ration from 35 to 100 lbs. with progressive restriction from 100 to 200 lbs. (VH-R), and a low energy ration from 35 to 200 lbs. (VL-VL). The second experiment was carried out in the same manner as the first with two exceptions -- an Essex

Saddleback cross rather than a Wessex Saddleback cross was used and the VL-VL plane of feeding was changed to a L-L plane.

The breed x plane of feeding interaction was significant at the one per cent level for the depth of fat over the eye muscle in the first experiment. Breed x plane of feeding interactions significant at the five per cent level were found for rate of gain, efficiency of gain, carcass length, thickness of streak, percentage fore, and percentage ham in the second experiment. (The interaction for percentage middle approached significance at the 10 per cent level also.) The breed and feeding level group means for each trait which showed a breed x plane of feeding interaction in either experiment are given in Table 3 to illustrate the exact nature of the differences which gave rise to the interactions.

Although both experiments gave some evidence of possible interactions in the response of two types of pigs to different planes of feeding they were not in agreement as to which traits showed such interactions. Possibly this was because the Essex and Landrace crosses differed more than the Wessex and Landrace crosses. Another possibility is that at least some of these interactions were the result of an approximately one in twenty chance in sampling.

Kristjansson (1957) observed that genotype-environment interactions may exist in Canadian Yorkshire swine. Four sires were represented by four litters each in his study. One male and one female from each litter were self-fed in a

Table 3. Treatment-breed group means for traits showing a breed x plane of feeding interaction (Lucas and Calder, 1956)

Trait	Breed cross	Plane of feeding: VH-VH, Experiment 1	VH-VH, Experiment 2	VH-R, Experiment 1	VH-R, Experiment 2	VL-VL, L-L, Experiment 1	VL-VL, L-L, Experiment 2
Gain (lb. per week)	Landrace	(9.4)[a]	9.8	(8.6)	9.0	(5.4)	6.4
	Wessex or Essex	(9.6)	9.4	(8.7)	8.3	(5.5)	6.6
TDN (lb.) per lb. gain	Landrace	--	2.30	--	2.33	--	2.62
	Wessex or Essex	--	2.42	--	2.46	--	2.52
Length (cm.)	Landrace	(81.5)	80.1	(82.6)	79.2	(82.2)	77.3
	Wessex or Essex	(81.2)	78.0	(82.4)	77.0	(81.6)	78.0
Thickness of streak (cm.)	Landrace	(3.2)	3.3	(3.1)	3.7	(3.1)	3.3
	Wessex or Essex	(3.3)	3.8	(3.1)	3.6	(3.4)	3.2
Percentage fore	Landrace	--	26.1	--	28.4	--	27.4
	Wessex or Essex	--	27.7	--	27.7	--	28.8
Percentage middle	Landrace	--	(47.3)	--	(44.1)	--	(43.3)
	Wessex or Essex	--	(47.1)	--	(46.5)	--	(45.3)

[a]Group means in parentheses did not show a significant breed x plane of feeding interaction.

Table 3 (continued)

Trait	Breed cross	Plane of feeding					
		VH-VH		VH-R		VL-VL, L-L	
		Experiment 1	Experiment 2	Experiment 1	Experiment 2	Experiment 1	Experiment 2
Percentage ham	Landrace	--	26.6	--	27.5	--	29.3
	Wessex or Essex	--	25.2	--	25.8	--	25.9
Fat over the eye muscle (cm.)	Landrace	2.4	(2.5)	1.7	(2.4)	1.3	(2.3)
	Wessex or Essex	2.0	(3.1)	2.0	(2.8)	1.2	(2.3)

piggery and another male and female from each litter were self-fed the same feeds on pasture. The sire x treatment interaction reached significance at the 10 per cent level for rate of gain from 56 to 140 days of age. The pigs fed in the piggery gained significantly faster (.11 lb. per day) than did those on pasture. The sire x treatment interaction fell just short of significance at the 10 per cent level for the Advanced Registry score. For carcass length the sire x treatment interaction was very small, although the sire differences were significant. The pigs raised on pasture were 0.5 in. shorter than the pigs raised in the piggery and this was highly significant statistically. The sire x treatment interaction was significant at the five per cent level for the loin area. A marked difference in the rank of the sire means on the two treatments was observed for this trait as for Advanced Registry score. The average backfat thickness showed differences between sires that were significant at the five per cent level, and the sire x treatment interaction was significant at the 10 per cent level. No mention was made of how much the sires differed, although their progeny means averaged over both treatments differed significantly for carcass length and average carcass backfat.

Two other suggestions of genotype-environment interactions in swine, although rather tenuous, might also be cited. Lindgren et al. (1932) observed that the percentage of leaf and fat back was reduced more by limited feeding in

Chunky type than in Big type Chester Whites. A marked difference in the rank of seven breeding groups for feed efficiency under two levels of feeding was noted in the data of Whatley et al. (1953).

Indicators of Carcass Merit

Indicators of carcass merit used on live hogs

Willman and Krider (1943) obtained a correlation of .42 between visual appraisal for fatness and the thickness of backfat on 214 head of Berkshires, Durocs, Chesters, and their crosses. (A correlation of .47 was also observed between live weight and thickness of backfat in these data.) A score for firmness determined by handling the hogs before slaughter was not correlated with backfat thickness.

Bratzler and Margerum (1953) studied the correlations between three experienced judges' estimates of body length, backfat thickness, and yield of preferred cuts (bellies, closely trimmed hams, loins, Boston butts, and picnics expressed as a percentage of the chilled carcass weight) and the carcass measurements for these traits. The correlations between each judge's estimates and the carcass measurements for 265 hogs in the 201-220 lb. range were as follows: carcass length, .39, .42, and .29; backfat thickness, .42, .42, and .50; and yield of preferred cuts, .08, .22, and .13.

Holland (1957) found a total correlation of .58 between condition score and percent fat cuts on 102 barrows of seven breeds. The correlation was .22 when calculated on an intra-breed basis.

Hetzer et al. (1950) examined the relationship between eight body measurements (shoulder height, shoulder width, middle width, width of hams, chest depth, middle depth, chest circumference, and length from ear to tail) and the percentage of primal cuts. Correlations were calculated separately for the 71 barrows and the 70 gilts, all crossbreds, which were used. An average of four readings was used for each measurement except chest circumference for which two readings were averaged. The largest simple correlations for the barrows and gilts respectively were .41 and .50 for shoulder height, -.40 and -.47 for middle width, and .43 and .49 for middle depth. When all eight measurements were combined in a multiple regression equation, they accounted for about 46 per cent of the variation in the yield of the five primal cuts from both barrows and gilts.

Holland (1957) measured the length of the body and the circumference at the flank, middle, chest, and jowl. The total and the intra-breed correlations for the respective measurements and percent fat cuts were -.33 and .06, .37 and .20, .69 and .43, .54 and .32 and -.16 and -.15.

Hazel and Kline (1952) described a "probing" method of measuring backfat thickness on live hogs. Three of the probing sites were about 1-1/2 in. off the midline of the body and immediately behind the shoulder, at the middle of the back, and at the middle of the loin. The fourth site studied was at the middle of the loin over the exact midline of the body. The pigs were restrained, a small incision was made in the skin, and a narrow metal ruler with a blunt end was pressed through the fat to the firm tissue underneath. After the pressure on the ruler was relaxed an instant the reading was marked at skin level, the ruler withdrawn, and the measurement recorded. The average of the four backfat measurements taken on live hogs was correlated -.50 with percent primal cuts, -.44 with loin lean area, -.54 with ham lean area, and .81 with average carcass backfat. The probe measurements were somewhat more highly correlated with the two lean area measurements and the percentage of primal cuts than were the carcass backfat measurements.

Hazel and Kline (1953) further studied probing live hogs to measure fatness and leanness by comparing the accuracy of probes at eight sites. Correlations of percent lean cuts with the probe measurements were as follows: behind the shoulder -.69; middle of back -.55; middle of loin -.70; middle of loin over the lumbar vertebrae -.48; top of ham -.65; tailhead -.57; side of shoulder -.47; and side of ham -.29. The correlation between the average of four backfat measurements on the carcass and percent lean cuts was -.75.

Douce (1954) took probe measurements 1, 2, 3, and 4 in. off the midline of the body just behind the shoulder and at the middle of the loin. The correlations between the probe measurement at each location and percent lean cuts ranged from -.72 to -.79. The average of the loin and shoulder probes taken 2 in. from the midline of the back was practically as highly correlated with percent lean cuts as was the multiple correlation of the eight separate probes (-.86 and -.87).

The probe technique for estimating fatness and leanness of live hogs has since been examined by a number of workers. Zobrisky et al. (1954) found somewhat lower correlations between probe measurements and carcass traits. The correlations between percent lean cuts (live weight basis) and various probe measurements were: shoulder probe -.21, hip probe -.43, probe at the top of the ham -.35, and the average of the three -.36. Hetzer et al. (1956) reported intra-line and sex correlations of percent primal cuts and percent fat cuts with probe measurements as follows: behind the shoulder, -.20 and .36; middle of back, -.34 and .41; middle of loin, -.12 and .50; and the average of three probes, -.24 and .54. These correlations, also lower than those previously reported, were based on data from 140 boars, barrows, and gilts.

DePape and Whatley (1956) observed an intra-breed and sex correlation of -.57 between percent lean cuts and the average of backfat probes taken on both sides of the midline behind the shoulder, at the middle of the back, and at the middle of the loin. Pearson et al. (1956c) reported the live probe was correlated -.67 with percent lean cuts and .67 with fat trim. A correlation of -.57 between the weight of lean cuts and the average of three probe measurements was found by Lasley et al. (1956). Holland (1957), with some of the same pigs Lasley et al. (1956) used, reported a total correlation between the average of three probes and percent lean cuts of -.78, while the intra-breed correlation for the same two traits was -.64. The total and intra-breed correlations for the average probe and percent fat cuts were .87 and .80 respectively.

Holland (1957) also took probe measurements of the depth of fat and of the depth of lean over the shaft of the ilium and over the scapula on both sides of 105 pigs of seven breeds. The total correlations of ilium fat and ilium lean depth with percent lean cuts were -.68 and .26 and with percent fat cuts were .64 and -.23. The total correlations of scapula fat and scapula lean depth with percent lean cuts were -.49 and -.10 and with percent fat cuts were .54 and .03. The intra-breed correlations were generally lower.

Several workers have measured the relationship between probe measurements taken at various times before slaughter weight is reached and carcass characteristics. Douce (1954) took probe measurements at average weights of 135 to 170 lbs.

as well as at 215 lbs. when the pigs were slaughtered. The correlations of these probes (adjusted for differences in the weights of the pigs when they were taken) and percent lean cuts were -.65, -.77, and -.86. Hetzer et al. (1956) probed pigs at weights of 150, 175, 200, and 225 lbs. The intra-sex and line correlations between the average of three probe measurements taken at each weight and the percent primal cuts when slaughtered at 225 lbs. were -.24, -.24, -.22, and -.28 at the respective weights. The average probe measurements were correlated .42, .47, .48, and .54 with percent fat cuts and .38, .53, .55, and .72 with carcass backfat. DePape and Whatley (1956) took three probe measurements on 73 pigs at 56, 84, 112, and 140 days of age. The average weights at these ages were 39, 74, 128, and 185 lbs. The intra-sex and breed correlations between the average probe measurements at each weight and carcass backfat when slaughtered at 210 lbs. were .01, .11, .30, and .51.

Robison et al. (1957) found a multiple correlation of .70 between weight, backfat probe at the shoulder and loin, and six body measurements all taken at 154 days of age and percent lean cuts on hogs slaughtered at 210 lbs. The combination of two measurements which gave the highest multiple correlation with percent lean cuts was 154 da. weight and the shoulder probe.

Saffle et al. (1958) studied the relationship between blood and urinary creatinine, live probe, and leanness in market hogs. The correlations for these three measures of leanness with percent lean cuts (carcass basis) were .33, .65, and -.88. The multiple correlation of the urinary creatinine coefficient and live probe with percent lean cuts was .89.

Carcass characteristics used as indicators of carcass merit

Hankins and Ellis (1934) reported a correlation of .84 between the average of five carcass backfat measurements and the percentage of fat (determined by ether extract) in the edible portion of the carcass. Also they reported a high association ($r = .93$) between the percentage of fat in the trimmed right ham and the percentage of fat in the edible portion of the carcass. Their data were from a very heterogeneous group of 60 hogs which ranged from 93 to 250 lbs. in final weights.

Warner et al. (1934) found that the yield of fat cuts (belly, leaf fat, backfat and fat trimmings as a percentage of chilled carcass weight) was a good indicator of the fat content of the edible portion of the carcass. They obtained a correlation of .91 between these two variables on 75 pigs which ranged from 99 to 342 lbs. in final live weight.

McMeekan (1941), using 20 carcasses which varied considerably in composition, but were from pigs slaughtered at 200 lbs., studied the relationship between certain carcass measurements and the weight of muscle, fat, and bone in the carcasses. The highest association observed between carcass measurements and the amount of muscle in the carcass was for twice the width plus the depth of the loin eye muscle ($r = .93$). This was followed by a correlation of .84 between the loin eye area (width x depth) and the weight of the muscle in the carcass. The average of five measurements of the depth of backfat was correlated .96 with the amount of fat in the carcass. The best indicator of the amount of bone in the carcass was the weight of the cannon bones ($r = .90$).

Jordan et al. (1956) studied the relationships between percent lean cuts, average backfat thickness, and the percentage of fat determined by chemical analysis of a sample of meat of the entire right half of 198 carcasses. They found percent lean cuts was correlated -.96, -.83, -.91, and -.92 with the percentage of fat in the carcass in their four experiments while average backfat thickness was correlated .93, .73, .84, and .74 with the percentage of fat in the carcass.

Brown et al. (1951) determined the specific gravity of 66 carcasses and found that the percentage of lean cuts was more highly correlated with specific gravity (.84) than with backfat thickness (-.72). Similarly, the percentage of fat cuts was more highly correlated with specific gravity (-.78) than with backfat thickness (.69). The chemical composition of one side of 32 of the carcasses was determined, and the fat or lean content was as highly correlated with specific gravity as with percent fat cuts or percent lean cuts. Whiteman and Whatley (1953) also found a higher correlation for specific gravity than for backfat thickness in relation to several measures of carcass leanness. They further reported that the specific gravity of the untrimmed ham was correlated .94 with the specific gravity of the side from which it was taken. Correlations of .93, .91, and .87 between the specific gravity of the left ham, loin, and shoulder and that for the entire carcass were reported by Pearson et al. (1956a). They obtained correlations of .72, .69, and -.49 between percent lean cuts and specific gravity of the carcass, specific gravity of the left ham, and carcass backfat (average of four measurements) respectively. Their data were from 103 pigs which weighed from 170 to 234 lbs. at slaughter. Price et al. (1957) found the specific gravity of the untrimmed ham was correlated .86 with the specific gravity of the carcass in the 36 carcasses in their study. They further observed that specific gravity was more closely associated with chemical composition and loin lean area than were live probe or backfat thickness, although the later measurements were more closely associated with carcass cut-out values.

Aunan and Winters (1952), using a coring device, found the percentage of lean in a sample taken between the fifth and sixth ribs in the belly region of swine carcasses was correlated .79 with the percentage of separable lean in one-half of the carcass and .67 with percent lean cuts. The correlations were lower between the lean content of samples from four other locations and the amount of lean in the carcass and between the fat content of the samples and the amount of fat in the carcass.

Tracings of the cut surface of the Longissimus dorsi or loin eye muscle at the tenth or last rib are routinely taken in carcass studies. A reasonably large loin eye area is considered desirable in itself in addition to its value as an indicator of the amount of muscling in the carcass. Correlations between the area of the loin eye muscle and percent lean cuts which have been reported by various workers are as follows: .51 Brown et al. (1951), .46 (barrows) and .68 (barrows and gilts), Whiteman and Whatley (1953); .57, Zobrisky et al. (1954); .66 (both at tenth and last rib), Kline and Hazel (1955); .52 (tenth rib) and .53 (last rib), Pearson et al. (1956b); .69 (with weight of lean cuts), Lasley et al. (1956); and .57 and .42 (total and intra-breed, tenth rib) and .58 and .43 (total and intra-breed, last rib), Holland (1957). Aunan and Winters (1949) found a partial correlation (carcass weight held constant) of .58 between the area of the loin lean and the percentage of separable lean in the carcass.

Pearson et al. (1956b) studied the fat-lean ratio in tracings of the rough loin at the last rib. A correlation of approximately -.60 was obtained between the ratio and percent lean cuts, percent primal cuts, and specific gravity. However, they doubted that calculating the ratio was worth the extra effort because the area of the lean at the tenth rib or last rib was only slightly less reliable than the ratio of fat to lean for estimating cut-out values.

Tracings of the cut surface of the ham have been studied by numerous workers, too. Aunan and Winters (1949) reported that the ham lean area was correlated .35 with the percentage of separable lean in the carcass. This correlation could have been lowered somewhat because the 30 hogs in their study ranged from 182 to 251 lbs. in final weight.

Whiteman and Whatley (1953) reported that the area of lean in the butt of the ham was correlated .71 with percent lean cuts in a group of barrows and gilts and .60 with percent lean cuts in a group of barrows. They further concluded that the area of lean in the ham gave little information about the carcass if the specific gravity, average backfat thickness or loin lean area were known.

Zobrisky _et al_. (1954) observed a correlation of .46 between ham lean area and the total weight of the lean cuts and lean trim expressed as a percentage of shrunk live weight.

Fredeen _et al_. (1955a) evaluated specific gravity of the ham and certain planimeter areas of tracings of the butt end and the center cut of the ham in terms of their utility for predicting the proportions of fat, lean, and bone in the ham. Of all the variables studied the percent area of lean in the ham surface of the butt end had the closest relationship (r = .80) with the percent lean in the ham. Fredeen et al. (1955b) further reported a correlation of .79 between loin lean area and percent lean in the ham. However, they concluded that percent area of lean in the face of the ham was a somewhat more reliable measure of carcass lean than loin lean area because it was more closely associated with each of the three backfat measurements studied.

McMeekan (1941) investigated the possibility of using the composition of a sample joint as an indicator of the composition of the carcass. The weight of bone, muscle, and fat in the hind leg were correlated .90, .97, and .88 with the weight of bone, muscle, and fat in the carcass respectively. Similar values were found for the loin. Whiteman and Whatley (1953) observed that percent ham was correlated .89 with percent lean cuts. However, Zobrisky et al. (1954) found the weight of the ham was correlated .73 with the total weight of the lean cuts in their data. Lasley et al. (1956) reported that the weight of the trimmed ham was correlated .88 with the total weight of the lean cuts. The defatted ham as an indicator of carcass value was studied by Smith et al. (1957). They found a correlation of .89 between percent defatted ham and percent lean cuts when calculated within entries, breeds, and seasons for 300 barrows from the Iowa Swine Testing Station.

In Norway, Skjervold and Indrebø (1958) developed a method of determining the center of gravity of swine carcasses to aid in the evaluation of bacon type by supplementing the subjective scores for the proportions of fore and hind quarters. The method which they used on 100 chilled carcasses from pigs slaughtered at about 90 kg. involved two scales with one end of a bridge placed on each. A caliper was fastened exactly over the center of gravity of the bridge. Then each side of the split carcass was moved in a longitudinal direction on the bridge until both scales registered exactly the same weight. Then the caliper was used to mark the center of gravity. The center of gravity index was defined as the ratio of the length of the carcass to the horizontal distance from the anterior edge of the pelvic bone to the center of gravity. Each half of the carcass was cut into five parts, and the correlations between the center of gravity index and the weight of the different cuts was calculated. These correlations are presented in Table 4. Skjervold and Indrebø concluded that the center of gravity gave a relatively good measure of the proportional weight of hams, shoulders, and head.

For a more complete review of the literature on pig carcass evaluation, especially of the European literature on the subject, the reader is referred to Harrington (1958).

Table 4. Correlations, total and partial (slaughter weight constant), between the center of gravity index and the weight of different cuts. (Skjervold and Indrebø, 1958)

Cut	Correlations Total	Partial
Hindquarter	0.21[a]	0.38[b]
Head	-0.20[a]	-0.31[b]
Shoulder	-0.22	-0.27[b]
Flank and streak	-0.03	-0.02
Back and collar	-0.11	-0.16
Thickness of backfat	-0.01	0.01

[a]Significant at the five per cent level.

[b]Significant at the one per cent level.

EXPERIMENTAL PROCEDURE

Plan of the Experiment

A total of 96 barrows representing 32 litter mate groups of three pigs each were used in this experiment. These barrows were farrowed in the spring of 1957 in the Iowa Experimental Station herds. Two lines of breeding which had proved in earlier work to differ considerably in fatness were each represented by 16 litter mate groups. Within each breeding group eight litters were chosen at random to be fed on concrete and the other eight were to be fed on pasture. Each pig in a litter mate group was randomly assigned to one of three treatments, and then placed on the experiment when he reached a weight of 130 lbs. Pigs on treatment I were full fed until they reached a minimum weight of 200 lbs. Pigs on treatment II were limited to 85 per cent of a full feed allowance until they reached a minimum weight of 200 lbs. The pigs on treatment III were full fed and were slaughtered at the same time as their treatment II litter mates. Thus pigs on treatments I and II were slaughtered at the same weight after having received different levels of feeding, and the pigs on treatments II and III were slaughtered at the same age after having received different levels of feeding.

Experimental Animals

The plan of the experiment required two groups of pigs known to differ considerably with respect to carcass meatiness. For the leaner group of pigs purebred Yorkshires produced in the swine breeding herd at Napier were available. Too few purebred Durocs were available so a group of crossbred pigs sired by Duroc boars and out of Poland-Landrace crossbred dams was used. They were farrowed in the swine breeding herd at Ankeny.

Litters were chosen with as narrow a range in farrowing date and average weight as possible so that the pigs would begin the experiment more nearly at the same time. When more than three barrows were available in a litter the three most similar in weight were used. In a few cases two groups of three barrows were used from the same litter. They were treated as separate litters in the analysis. Therefore the litter differences also include some additional differences which resulted from selecting pigs more alike than randomly chosen litter mates. This should increase the precision with which the three treatment effects and the treatment x genetic group, treatment x feeding location, and treatment x genetic group x feeding location interactions were estimated at the expense of the precision had for comparing the two breeding groups, the two feeding locations, and the interaction of these two factors.

Both groups of pigs were self-fed a growing ration on pasture after they were weaned. The crossbred barrows to be used on the experiment were selected on May 28 and moved to Napier where they were self-fed on pasture until they reached the desired weight to go on test. The pigs were weighed at weekly intervals and placed with the group to which they had previously been assigned when they attained a weight of at least 130 lbs. The average initial weight for each group is given in Table 5. The average weight at the beginning of the experiment was 140.1 $\pm$ 7.1 lbs. The group means ranged from 136.4 lbs. for the treatment III Yorkshires on concrete to 143.8 lbs. for both the treatment I Crossbreds and Yorkshires on pasture. Table 5 also lists the average initial age of each group of pigs. The Yorkshires averaged one week older than the Crossbred when they reached 140 lbs. in weight. Therefore the Crossbreds had gained faster during the pre-experimental period. The Crossbred pigs were farrowed earlier than the Yorkshires and thus went on experiment earlier. The first of the Crossbred pigs were started on experiment June 14 and the last ones went on experiment July 8. The starting date for the Yorkshires ranged from July 9 to September 9. Some seasonal effects thus may be confounded with the differences between the genetic groups in addition to possible differences due to other pretest environmental conditions not being the same for the two groups.

Table 5. Group means for weight, age, and probe of the pigs at the beginning of the experiment

Treatment		Crossbreds			Yorkshires	
	Pasture	Concrete	Av.	Pasture	Concrete	Av.
			Initial weight (lbs.)			
I $\bar{X}$	143.8	136.5	140.2	143.8	140.8	142.3
II $\bar{X}$	142.6	136.9	139.8	138.0	141.1	139.6
III $\bar{X}$	142.0	137.4	139.7	142.5	136.4	139.4
Av.	142.8	136.9	139.9	141.4	139.4	140.4
			Initial age (da.)			
I $\bar{X}$	116.2	113.5	114.8	123.5	120.9	122.2
II $\bar{X}$	118.0	116.5	117.2	121.6	126.9	124.2
III $\bar{X}$	118.4	114.4	116.4	126.6	120.7	123.6
Av.	117.5	114.8	116.2	123.9	122.8	123.4
			Initial probe (in.) (Av. of six)			
I $\bar{X}$	1.10	1.08	1.09	.93	.97	.95
II $\bar{X}$	1.09	1.08	1.08	.87	.86	.86
III $\bar{X}$	1.05	1.04	1.04	1.00	.93	.96
Av.	1.08	1.07	1.07	.93	.92	.93

Backfat probe measurements were taken on the pigs when they were placed on experiment. The probe measurements were taken approximately 1 to 1-1/2 in. off of the midline on both sides of each animal just behind the shoulders, at the middle of the back, and at the middle of the loin in the manner described by Hazel and Kline (1952). The average initial backfat probes are given in Table 5. In every treatment-location group the Yorkshires had from .05 to .22 in. less backfat than the Crossbreds with an average difference of .14 in. between the two genetic groups. The Yorkshires on treatment II, however, had .09 and .10 in. less backfat than those on treatments I and III respectively.

Feeding Procedure

The barrows fed during the finishing period on concrete were grouped in pens of four from the same genetic group in the record of performance pens at the Napier farm. Full fed pigs were penned together, two sets of treatment I and III litter mates per pen, and the limited fed pigs were penned together. The pigs fed on pasture were fed in two acre lots of alfalfa pasture with a shelter provided. Four pasture lots were used, one each for the full fed Crossbreds, the limited fed Crossbreds, the full fed Yorkshires, and the limited fed Yorkshires.

The present study does not constitute a good comparison of the cost of feeding on pasture versus feeding on concrete because the same ration was fed to the pigs on pasture and on concrete. Many studies have shown that a major advantage of feeding on pasture is a saving of expensive protein supplement rather than any saving of carbohydrate feeds. However, for the purposes of this study, it was considered preferable to feed the same ration to all groups. The ration which was used is given in Table 6.

Table 6. Ration

Ingredient	Pounds per ton
Ground yellow corn	1491
Meat and bone scraps (50 per cent protein)	50
Soybean oil meal (45 per cent protein)	225
Condensed fish solubles (30 per cent protein)	40
Dried whey	50
Dehydrated alfalfa meal (17 per cent protein)	50
Cane molasses	50
Calcium carbonate (38 per cent Ca)	9
Dicalcium phosphate (26 per cent Ca and 18 per cent P)	18
Iodized salt	10
Trace mineral premix (swine)	4
Vitamin-antibiotic-arsenical premix	10

An attempt was made to limit the feed consumption of pigs on treatment II to 85 per cent of that for the full fed pigs of the same genetic group at the same feeding location. The full fed pigs were fed in self-feeders and a record was kept of the amount of feed put in each feeder. Feed was weighed back weekly to determine the average daily consumption per pig of each group the previous week. The limited fed pigs were then hand fed twice a day 85 per cent of the amount consumed by the corresponding group of full fed pigs.

The average daily feed consumption for the pigs in each group is given in Table 7a. Difficulty in limiting the feed

Table 7a. Feed consumption per day (lbs.)

	Crossbreds			Yorkshires		
Treatment	Pasture	Concrete	Av.	Pasture	Concrete	Av.
I and III	6.84	7.19	7.02	5.55	5.51	5.53
II	5.51	5.23	5.37	4.71	4.63	4.67
II as a percentage of I and III	80.6	72.7	76.5	84.9	84.0	84.4

of the Crossbreds the desired amount was encountered. This was partly because of the variability in the initial feed consumption between the pens which were full fed on concrete. The fact that the limited fed Crossbreds on concrete were limited nearly twice as much as the limited fed Yorkshires will need to be kept in mind in the comparison made between these groups. Also the full fed Crossbreds on concrete ate an average of .35 lbs. more feed per day than the full fed Crossbreds on pasture. Possibly this was the result of the pigs fed on pasture satisfying part of their appetite with pasture, but the feed consumption did not differ appreciably between feeding locations for the full fed Yorkshires. The full fed Yorkshires consumed only slightly more feed per day than did the limited fed Crossbreds.

The pigs were removed individually from the experiment at the time designated by their particular treatment on the basis of weights taken at weekly intervals after they began approaching the desired weight.

Due to poor health, two of the Yorkshires on concrete were removed from the experiment during the course of the study. One was on treatment II and one was on treatment III. They were from different litters. Their weight gain to the time they were taken off test (although it was low) was included in computing the feed requirements. The treatment III litter mate to the treatment II barrow which did not finish the experiment was removed from the experiment when he weighed 229 lbs.

Final probe measurements were taken on all the animals as they were removed from the experiment. These were taken on both sides of the midline at the same three locations used for the initial probes. However, two readings were taken at the shoulder probe. The first was a measure of the depth to the false lean and the second was a measure of the depth to the muscle below the false lean after the false lean had been penetrated by the probe. Also all the pigs on treatment III were probed in the same manner as soon as they reached 200 lbs. if they were not yet to be removed from the experiment. During the earlier part of the experiment one man who was experienced in probing did the probing and trained a second man who did the probing during the latter part of the study.

After the pigs were taken off the experiment, they were held approximately 24 hours without feed but with access to water before they were brought into the Meats Laboratory to be slaughtered. Immediately before the pigs were slaughtered, shrunk live weight was taken to the nearest pound.

Carcass Measurements

The pigs were slaughtered packer style except the leaf fat and kidneys were loosened and left in the carcasses. The hams were not faced. The unsplit carcasses were then chilled in a cooler at approximately 34° F.

The center of gravity determinations were made after the carcasses had chilled 24-30 hours. To determine the center of gravity of the longitudinal plane of the carcasses two Toledo 75 pound platform scales were used. Metal covers were made which fit over the platform of each scales.
A short angle iron was fastened to each cover at right angles

to the dial of the scales and across the center of the platform. The angle irons were fastened with the angle-edge up. A section of aluminum warehouse roller track was then placed with each end resting on one of the angle irons which served as fulcrums for the "bridge" between the two scales. (The warehouse roller track was a ladder-like structure about 8 ft. long and 1 ft. wide with rollers instead of rungs approximately 8 in. apart.) The track was slightly notched at each end at the points which rested on the fulcrum when the scales registered exactly the same weight. Therefore it could be placed in the same position each time it was used. The point exactly half way between the notches in the ends was also marked.

After removing the leaf fat and kidneys each chilled, unsplit carcass was laid on the roller track with the left side down. The carcass was then rolled back and forth until exactly the same weight registered on both scales. Since the carcasses were all chilled hanging from a gambrel placed under the tendons in the hind legs, the position of the legs was fairly uniform. An effort was made to keep the legs in the same position that they had maintained while the carcass was hanging.

When both scales registered the same weight an indelible marking pencil and a combination square were used to draw lines across the back and belly of the left side of the carcass immediately above the line marked on the center of the roller track. These lines marked the center of gravity until its length was measured the following day. Each carcass was then returned to the cooler with its leaf fat and kidneys attached by skewers. The center of gravity determinations could be made in two or three minutes per carcass after the equipment was in place.

The carcasses were usually split in the cooler immediately after the center of gravity determinations had been made. The following day, or approximately 48 hours after slaughter, carcass length, the distance from the first rib to the center of gravity, and carcass backfat were measured. These measurements were taken on the left side of the carcass while it was hanging on the rail. First a string was tied around the side at the exact level of the lines marking the center of gravity. Carcass length was then measured with a steel tape as the distance, to the nearest tenth of an inch, from the anterior edge of the first rib to the anterior edge of the aitch bone. While the steel tape was in position for the carcass length measurement, the distance between the anterior edge of the first rib and the point at which the string around the side crossed the tape was recorded to the nearest tenth of an inch. The fraction of carcass length in front of the point marking the center of gravity of the longitudinal plane of the carcass was then used as the center of gravity measurement. Carcass backfat was measured to the nearest tenth of an inch at the first and last thoracic vertebrae and the last lumbar vertebra. The thickness of the skin was not included in these measurements.

The weight of each side including the leaf fat and kidney was recorded to the nearest tenth of a pound. The weights of the two sides of a carcass were then added together to determine chilled carcass weight.

Both sides of each carcass were cut into wholesale cuts following the procedure outlined by Cole (1951). Each side was separated into three parts, the front, the middle, and the rear, and their weights recorded before the feet were removed or any trimming was done. Weights were recorded for skinned ham, closely trimmed loin, Boston butt, picnic, and belly. The bellies were cut to a fairly standard length to facilitate curing. The clear plate, the fat back, and the fat trim from the jowl, picnic, belly, and skinned ham were combined and weighed as fat trim. The weight of the leaf fat was determined after the kidney had been removed. The lean trim from the jowl, shoulder, and belly was combined and weighed as lean trim. The weight of the defatted ham was determined after all the skin and fat had been removed from the exterior of the ham musculature. All weights were recorded to the nearest tenth of a pound, and the sum of the weights of the respective cuts from both sides was used in the calculations. The same person cut practically all the carcasses into front, middle and rear portions, separated the loins from the bellies, and cut the loins at the tenth rib for the loin tracings. The other cutting and trimming operations were performed by a crew of two to four people who largely did the same operations throughout the experiment.

Tracings were made of the entire cut surface of the untrimmed loin at the tenth rib and of the face of the unskinned ham. Measurements made of the loin tracing consisted of planimeter readings of the area of the Longissimus dorsi or loin eye muscle and of the area of fat which was above that muscle. The latter was defined as the area of the fat dorsal to a line drawn through the longest axis of the Longissimus dorsi and medial to a line drawn perpendicular to the first line and tangent to the outer, or lateral, edge of the area of lean. Before the areas of fat were measured, the right and left tracings were compared for each carcass and adjustments were made in the tracings from carcasses which were not split down the center of the backbone. A fat-lean ratio similar to that described by Pearson et al. (1956b) was calculated. The area of the Multifidus dorsi was not included in the area of lean in the present study, however, because in many cases the edges of this muscle were poorly defined, and in a few instances, it was mutilated due to improper splitting of the carcasses. On the ham tracings a planimeter reading of the total area of lean and intermuscular fat was taken first. Next the areas of intermuscular or seam fat deposits were measured. These areas of fat were added together to determine the area of intermuscular fat in the tracing. The lean area of the ham tracing was determined by subtracting the total area of intermuscular fat from the first reading. The size of the fat deposit was used as the sole criterion for deciding whether it was intermuscular or intramuscular. Therefore some of the coarser marbling may have been included in the area of intermuscular fat.

The dressing percentage was calculated by expressing chilled carcass weight as a percentage of shrunk live weight. Percent front, percent middle, and percent rear were determined by expressing the weight of each part as a percentage of the combined weight of the three parts. Percent lean cuts was determined by expressing the sum of the weights of skinned ham, loin, Boston butt, and picnic as a percentage of chilled carcass weight. Percent defatted ham was calculated by expressing the combined weight of the two defatted hams as a percentage of chilled carcass weight. Percent fat cuts was computed by expressing the total weight of the fat trim and leaf fat as a percentage of chilled carcass weight.

The carcass index which was used is 1.04 skinned ham + loin + .64 belly + .75 Boston butt + .55 picnic expressed as a percentage of chilled carcass weight. This index was calculated from the Chicago carlot fresh pork prices quoted in the <u>National Provisioner</u> for cuts of the approximate weights of those in the present study. The prices used were taken at two week intervals for the period of July 1, 1955 to July 1, 1957. The prices were weighted according to the total number of hogs slaughtered in Chicago the previous week and averaged. The average price for each cut was then expressed as a percentage of the average price for loins to give the relative economic values of each cut in the index.

Method of Analysis

The genetic groups, feeding locations, and treatments were regarded as fixed effects in the analyses. Two missing values were estimated for all traits. More exact tests of significance than those provided by use of the missing estimates were not calculated because only one-eighth of the data were missing from two of the twelve genetic group-treatment-feeding location combinations. Also some lack of homogeneity of variance, which will be discussed later, made exact tests of significance impossible for some of the traits anyway.

The genetic group x feeding location, genetic group x treatment, and genetic group x treatment x feeding location interactions were used as measures of the importance of genotype-environment interactions. The error terms used to test the interactions contain what treatment x litter interaction is present in the data which also is an interaction between genotypes and environment. However, the magnitude of an interaction involving genetic groups would be expected

Table 7b. Expected composition of the mean squares

Source of variation	d.f.	Expectation
Genetic groups (G)	1	$E^2 + 8\ {}^2L/(GF) + 48k_G{}^2$
Feeding locations (F)	1	$E^2 + 8\ {}^2L/(GF) + 48k_F{}^2$
GF	1	$E^2 + 8\ {}^2L/(GF) + 24k_{GF}{}^2$
Error a (Litters/(GF))	28	$E^2 + 8\ {}^2L/(GF)$
Treatments	2	$E^2 + 32k_T{}^2$
TG	2	$E^2 + 16k_{TG}{}^2$
TF	2	$E^2 + 16k_{TF}{}^2$
TGF	2	$E^2 + 8k_{TGF}{}^2$
Error b (TL/(GF))	56	E^2

to be enough larger than a litter x treatment interaction to permit testing for the presence of a genotype-environment interaction in this manner.

The expected composition of the mean squares for the analysis of variance is listed in Table 7b. The pen effects were ignored in the analyses and are thus confounded with treatment effects for some of the treatment comparisons.

RESULTS

Treatment, Feeding Location, and Genetic Group Effects

Pre-slaughter data

The means and standard deviations for weight and age when taken off the experiment and the means for the number of days on the experiment are given in Table 8. The variation in final weight was much larger among the pigs on treatment III than among those on treatments I and II, but this resulted from the plan of the experiment rather than from a biological difference between the treatments. The pigs on treatments I and II were removed from the experiment at as near the same weight as possible while the pigs on treatment III were removed from the experiment at the same time as their litter mates on treatment II, regardless of their own weight. Therefore, as a result of an imperfect correlation between litter mates for rate of gain, the final weights of the pigs on treatment III ranged from 185 to 258 lbs. while those on treatments I and II ranged from 197 to 217 lbs.

The average final weights for the four groups on treatment III also varied considerably. These four groups would be expected to have the same final weights if the growth rate of the limited fed pigs was the same percentage of the growth rate of the full fed pigs in all four groups, if the pigs on treatments II and III in each group had the same average initial ages and weights, and if the initial weights of the pigs on treatment II were the same for all four groups. An examination of the data in Table 8, the growth curves given in Figure 2, and the means for daily gain listed in Table 9 reveals several exceptions to these three conditions.

Among the Crossbreds, the rate of gain of the limited fed pigs was 82 and 74 per cent of the rate of gain for the full fed pigs on pasture and on concrete. Among the Yorkshires, the rate of gain of the limited fed pigs was 90 and 86 per cent of that for the pigs full fed on pasture and on concrete. The differences in the amount the feed was restricted in the various groups on treatment II were sufficient to explain most of the observed differences in the amount their growth rate was reduced. (The feed intake was restricted to 81 and 73 per cent of a full feed for the Crossbreds fed on pasture and on concrete and to 85 and 84 per cent of a full feed for the Yorkshires fed on pasture and on concrete.)

If the growth rates had been reduced the same percentage for the two groups of Crossbreds on treatment II as for the two groups of Yorkshires on treatment II (an average of 12 per cent), their average ages when taken off experiment would have been 163 and 157 days for those on pasture and those on concrete. If the two groups of treatment III Crossbreds had been removed from the experiment at these average ages and if they had gained at the same rate as was observed for each

Table 8. Group means and standard deviations for weight and age when taken off experiment and group means for the number of days on experiment

Treatment		Crossbreds Pasture	Crossbreds Concrete	Crossbreds Av.	Yorkshires Pasture	Yorkshires Concrete	Yorkshires Av.
		Weight off experiment (lbs.)					
I	$\bar{X}$	207.4	207.0	207.2	206.8	208.0	207.4
	s	4.7	3.6		5.3	5.1	
II	$\bar{X}$	207.1	203.0	205.0	205.6	206.7	206.2
	s	5.7	3.6		3.7	6.0	
III	$\bar{X}$	219.6	232.0	225.8	214.4	219.1	216.8
	s	15.2	19.2		23.2	10.8	
Av.		211.4	214.0	212.7	208.9	211.3	210.1
		Age off experiment (da.)					
I	$\bar{X}$	156.2	151.6	153.9	167.5	162.6	165.0
	s	11.2	11.9		16.4	5.7	
II	$\bar{X}$	166.5	166.4	166.4	172.8	173.4	173.1
	s	13.4	16.5		20.1	15.4	
III	$\bar{X}$	166.5	166.4	166.4	172.8	171.4	172.1
	s	13.4	16.5		20.1	10.6	
Av.		163.1	161.5	162.3	171.0	169.1	170.1
		Days on experiment					
I	$\bar{X}$	39.2	38.1	38.7	44.0	41.8	42.9
II	$\bar{X}$	48.5	49.9	49.2	51.1	46.7	48.9
III	$\bar{X}$	48.1	52.0	50.0	46.1	54.7	50.4
Av.		45.3	46.7	46.0	47.1	47.7	47.4

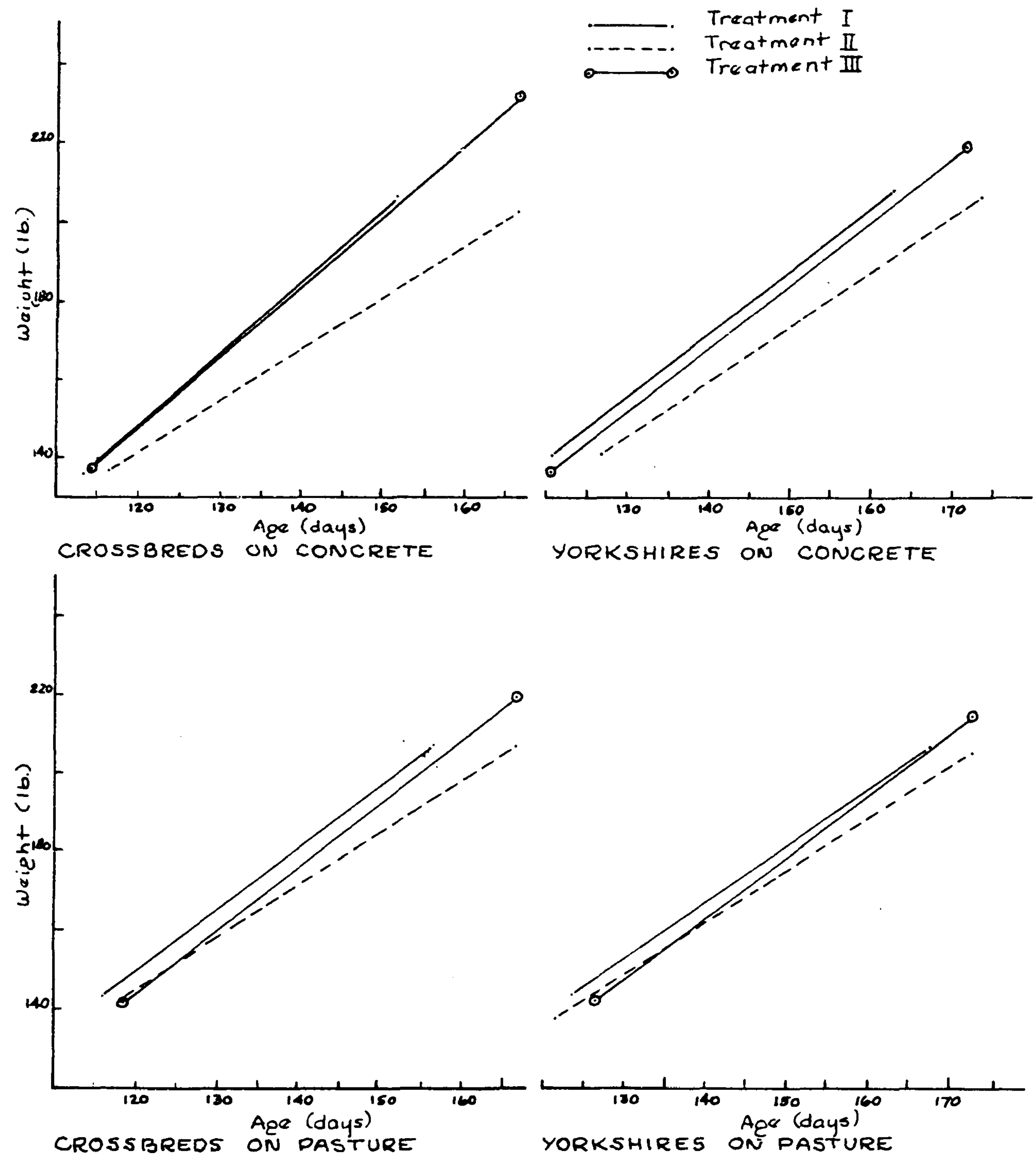

Figure 2. Initial and final weights and ages

Table 9. Group means for daily gain, feed requirements, final probe, and live shrink

Treatment	Crossbreds Pasture	Crossbreds Concrete	Crossbreds Av.	Yorkshires Pasture	Yorkshires Concrete	Yorkshires Av.
			Av. daily gain (lbs.)			
I $\bar{X}$	1.62	1.88	1.75	1.54	1.64	1.59
II $\bar{X}$	1.33	1.38	1.36	1.40	1.42	1.41
III $\bar{X}$	1.61	1.83	1.72	1.58	1.65	1.62
Av.	1.52	1.70	1.61	1.51	1.57	1.54
			Feed requirements per 100 lbs. gain			
I and III	426	396	411	371	344	358
II	414	395	404	356	342	349
Av.	420	396	408	364	343	354
			Final probe, av. of six (in.)			
I $\bar{X}$	1.75	1.83	1.79	1.31	1.31	1.31
II $\bar{X}$	1.56	1.46	1.51	1.24	1.26	1.25
III $\bar{X}$	1.72	1.73	1.72	1.50	1.41	1.46
Av.	1.68	1.67	1.68	1.35	1.33	1.34
			Live shrink (lbs.)			
I $\bar{X}$	11.8	13.1	12.4	9.9	10.4	10.2
II $\bar{X}$	12.0	7.2	9.6	4.0	5.6	4.8
III $\bar{X}$	14.0	13.2	13.6	9.1	8.4	8.8
Av.	12.6	11.2	11.9	7.7	8.1	7.9

group, their average final weights would have been 216 and 211 lbs. for those fed on pasture and on concrete instead of the 220 and 233 lbs. which were observed. Also some of the difference in final weight between the two groups of Yorkshires on treatment III can be explained on the basis of differences in initial age and weight between the two groups on treatment II and their corresponding groups on treatment III (see Figure 2). The above considerations indicate the observed differences in average final weight among the four groups on treatment III were not likely the result of different responses to treatment III by the pigs in the four genetic group-feeding location combinations.

Daily gain. The means for daily gain for each group are given in Table 9, and the analysis of variance for daily gain is in Table 10.

The effect of treatments was highly significant with the pigs on treatment II gaining 0.29 lbs. per day less than those on treatments I and III. The Crossbreds gained slightly faster than the Yorkshires even though on treatment II they were limited more than the Yorkshires. Also the pigs on concrete gained an average of .12 lbs. per day faster than those on pasture. Neither the effect of genetic group or feeding location approached statistical significance, however.

Feed requirements. No tests of significance were made of the differences in feed requirements between the groups, but the means given in Table 9 indicate the Yorkshires

Table 10. Analyses of variance for pre-slaughter characteristics

		Daily gain		Final probe		Live shrink	
Source	d.f.	M.S.	F	M.S.	F	M.S.	F
G	1	.1600	1.12	2.6467	57.41[b]	388.0	20.75[b]
F	1	.2688	1.89	.0043	.09	6.0	0.32
GF	1	.1291	.91	.0011	.02	19.0	1.02
L/(GF)	28	.1422		.0461		18.7	
T	2	.9433	23.52[b]	.3982	15.08[b]	171.0	20.60[b]
TG	2	.0710	1.77	.1270	4.81[a]	17.5	2.11
TF	2	.0638	1.59	.0171	.65	13.0	1.57
TGF	2	.0042	.10	.0328	1.24	32.0	3.86[a]
LT/(GF)	54	.0401		.0264		8.3	

[a]Significant at the five per cent level.

[b]Significant at the one per cent level.

required considerably less feed per pound of gain during the experimental period than did the Crossbreds. The differences in feed requirements per 100 lbs. gain between the two genetic groups were 55 lbs. for full fed pigs and 58 lbs. for the limited fed pigs on pasture and 52 lbs. for full fed pigs and 53 lbs. for the limited fed pigs on concrete. These differences indicate that for feed requirements the difference between the two genetic groups was similar with the different combinations of levels and locations of feeding.

Restricting the feed saved feed on pasture but saved practically no feed on concrete. When fed on pasture, the limited fed pigs required an average of 14 lbs. less feed per

100 lbs. of gain than the full fed pigs required. When fed on concrete, the limited fed pigs required an average of about 2 lbs. less feed per 100 lbs. of gain than the full fed pigs required.

The pigs finished on pasture required more feed to reach market weight than did the pigs finished in concrete dry-lot. The amount of additional feed required depended on the level of feeding. The full fed pigs required 28 lbs. more feed to produce 100 lbs. of gain when fed on pasture than when fed on concrete. The limited fed pigs, on the other hand, required 16 lbs. more feed to produce 100 lbs. of gain when fed on pasture than when fed on concrete.

Final probe measurements. The means for the average probe measurements taken when the barrows completed the experiment are listed in Table 9. These averages were determined from six of the final probes on each animal. The shoulder probes measuring the depth of fat to the false lean were not included in these averages. The probe measurements were not adjusted for differences among the pigs in final weight. The analysis of variance for the average probe measurements is given in Table 10.

The differences in the average probes for the three treatments were highly significant. This was mainly because the probe measurements for the pigs on treatment II averaged 0.17 in. less than those for the pigs on treatment I and 0.21 in. less than those for the pigs on treatment III. However, the treatment x genetic group interaction was significant at the 5 per cent level because the difference between treatments I and II was larger for the Crossbreds (0.28 in.) than for the Yorkshires (0.06 in.).

The Crossbreds had considerably more backfat as measured by the probes than did the Yorkshires, although the indication of the presence of a treatment x genetic group interaction suggests that the amount by which the Crossbreds exceeded the Yorkshires depended on which treatment was used. The Crossbreds had 0.48, 0.26, and 0.26 in. larger probe measurements than the Yorkshires on treatments I, II, and III respectively. The pigs fed on pasture and on concrete did not differ in any consistent manner for the probe measurements.

Live shrink. The differences in the group means were not the same for shrunk live weight as for weight off experiment. This indicated that the groups differed in the weight which the animals lost while being held off feed 24 hours and transported to the Meats Laboratory. The average live shrink for each group is listed in Table 9, and the analysis of variance for live shrink is included in Table 10.

The effects of the treatments were highly significant because on the average the limited fed groups shrank less than the full fed groups. However, the limited fed Crossbreds on pasture shrank the same amount as the full fed Crossbreds on pasture. The limited fed pigs in the other three genetic group - feeding location combinations shrank an average of 5.0 lbs. less than the full fed pigs in those groups. This treatment x genetic group x feeding location interaction was significant at the 5 per cent level. The Crossbreds shrank an average of 4.0 lbs. or 51 per cent more than the Yorkshires -- a difference which was statistically highly significant. (As previously mentioned, however, the genetic group difference was not the same for all treatment-feeding location combinations.) With the exception of the limited fed Crossbreds, there was little evidence that pigs finished on pasture shrank more or less than pigs finished on concrete.

Carcass data

The actual weight of a particular cut, rather than the percentage it constituted of the carcass weight or live weight, was studied for many of the carcass comparisons. This was necessary in order to compare the muscle development of the pigs of the same age which had been fed at different levels during the finishing period.

The group means and standard deviations for chilled carcass weight are listed in Table 11. The lack of homogeneity of variance in chilled carcass weight among the three treatments is obvious when the standard deviations are compared. Although the statistical significance of this lack of homogeneity of variance disappears as the carcass is divided into smaller parts, the underlying cause of the lack of

Table 11. Group means and standard deviations for cold carcass weight and group means for dressing percentage

Treatment		Crossbreds			Yorkshires		
		Pasture	Concrete	Av.	Pasture	Concrete	Av.
				Cold carcass weight (lbs.)			
I	$\bar{X}$	148.4	146.7	147.6	148.2	149.2	148.7
	s	3.4	3.8		4.9	4.7	
II	$\bar{X}$	147.2	146.4	146.0	147.7	148.1	147.9
	s	5.0	5.0		3.3	2.8	
III	$\bar{X}$	156.9	168.2	162.6	155.5	158.9	157.2
	s	11.3	13.5		21.4	9.0	
Av.		150.8	153.8	152.3	150.5	152.1	151.3
				Dressing percentage			
I	$\bar{X}$	76.1	75.7	75.9	75.2	75.5	75.4
II	$\bar{X}$	75.4	74.8	75.1	73.3	73.4	73.4
III	$\bar{X}$	76.3	77.0	76.6	75.7	75.4	75.6
Av.		75.9	75.8	75.9	74.7	74.8	74.8

homogeneity remains unchanged. That is, the pigs from treatments I and II were slaughtered at as near the same weight as possible and those from treatment III were slaughtered at the same time as their treatment II litter mates regardless of weight. To the extent that the variance in treatment III is larger than the variances for treatments I and II, the significance of the difference between treatments I and II will be underestimated and the significance of the difference between treatments II and III will be overestimated.[1] Histograms of the chilled carcass weights for each group are presented in Figure 3 to aid in interpreting the data which are affected by differences in carcass size.

Dressing percentage. Table 11 lists the mean dressing percentage for each group, and Table 12 contains the analysis of variance for dressing percentage. The limited fed pigs dressed 1.4 percentage points lower than their full fed litter mates slaughtered at the same weight and 1.8 percentage points lower than their full fed litter mates slaughtered at the same age. These differences were highly significant. The difference between treatments I and II was larger for the Yorkshires than for the Crossbreds, although the treatment x genetic group interaction failed to approach significance. The difference in the average dressing percentage for the Crossbreds, 75.9 per cent, and for the Yorkshires, 74.8 per cent, was highly significant. Feeding location apparently had little effect on dressing percentage.

Carcass proportions. A general picture of the effects of the variables under study on general carcass conformation

[1]Adjusting the data to a standard weight would vitiate the treatment II-III comparison. A transformation to reduce the heterogeneity of variance for each weight hardly seems worth the effort because the group with the largest variance in chilled carcass weight has weights both above and below the range of weights for treatments I and II.

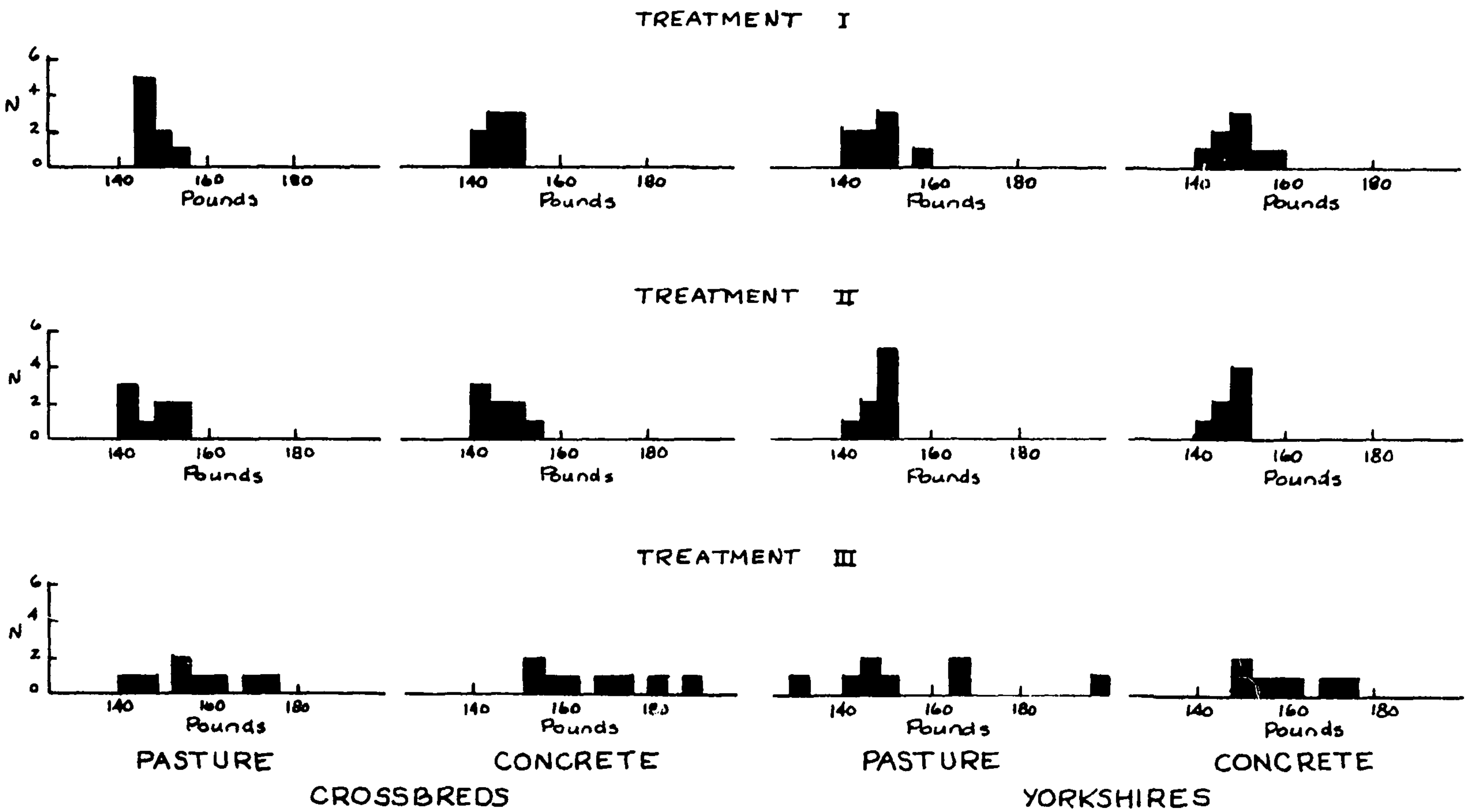

Figure 3. Distribution of chilled carcass weight within each experimental group

Table 12. Analysis of variance for dressing percentage

Source	d.f.	M.S.	F
G	1	24.10	9.49[b]
F	1	.08	.03
GF	1	.86	.34
L/(GF)	28	2.54	
T	2	26.39	15.34[b]
TG	2	2.16	1.26
TF	2	.24	.14
TGF	2	2.53	1.47
TL/(GF)	54	1.72	

[b]Significant at the one per cent level.

can be obtained by examining the distribution of weight into the front, middle, and rear parts of the carcass. (These three parts certainly are not independent -- an increase in the percentage one part comprises of the total weight of the three must be accompanied by a decrease in one or both of the other parts. Cutting errors that make one part too large automatically make the adjoining part too small.) The average percentage each part comprised of the total weight of the three is given in Table 13 for each of the treatment-genetic group-feeding location groups. Table 14 gives the analysis of variance for the percentage each part was of the total.

The largest differences in carcass proportions were those between the two genetic groups. The Crossbreds had 2.5 per cent more of their carcass weight in the middle portion of

Table 13. Group means for carcass proportions

Treatment	Crossbreds Pasture	Crossbreds Concrete	Crossbreds Av.	Yorkshires Pasture	Yorkshires Concrete	Yorkshires Av.
			Percent front			
I $\bar{X}$	27.6	27.5	27.6	28.6	28.6	28.6
II $\bar{X}$	27.8	27.4	27.6	29.5	29.3	29.4
III $\bar{X}$	27.1	27.5	27.3	29.3	28.9	29.1
Av.	27.5	27.5	27.5	29.1	28.9	29.0
			Percent middle			
I $\bar{X}$	48.1	48.4	48.2	46.0	46.0	46.0
II $\bar{X}$	47.5	47.3	47.4	44.6	44.9	44.8
III $\bar{X}$	48.6	48.4	48.5	45.8	45.8	45.8
Av.	48.1	48.0	48.0	45.5	45.6	45.5
			Percent rear			
I $\bar{X}$	24.3	24.1	24.2	25.4	25.4	25.4
II $\bar{X}$	24.7	25.2	25.0	25.9	25.9	25.9
III $\bar{X}$	24.2	24.0	24.1	25.0	25.3	25.2
Av.	24.4	24.4	24.4	25.4	25.5	25.5

the carcass and, consequently, 1.5 per cent less in the front and 1.1 per cent less in the rear portions than the Yorkshires had. These differences in carcass proportions were significant well beyond the one per cent level. The slightly larger difference in percent front than in percent rear is rather surprising because the rear contains a higher

Table 14. Analyses of variance for carcass proportions

		Percent front		Percent middle		Percent rear	
Source	d.f.	M.S.	F	M.S.	F	M.S.	F
G	1	56.12	39.80[b]	153.26	77.80[b]	25.01	26.33[b]
F	1	.31	.24	.05	.03	.07	.07
GF	1	.24	.17	.13	.07	.02	.02
L/(GF)	28	1.41		1.97		.95	
T	2	1.60	1.67	11.60	8.35[b]	5.28	9.78[b]
TG	2	1.24	1.29	.54	.39	.18	.33
TF	2	.18	.19	.12	.09	.06	.11
TGF	2	.58	.60	.28	.20	.75	1.39
LT/(GF)	54	.96		1.39		.54	

[b]Significant at the one per cent level.

proportion of lean than the front does.

The average effects of the treatments did not approach significance for percent front, but were significant beyond the one per cent level for percent middle and percent rear, largely because treatment II differed from treatments I and III. Limiting the feed decreased the percent middle and increased the percent rear by about one per cent. A slight genetic group difference was observed in the response to the two feeding levels as the percent front was increased more and the percent rear was increased slightly less by limited feeding among the Yorkshires than among the Crossbreds. However, this interaction easily could have been due to sampling variation. Whether the pigs were finished on pasture or on concrete apparently had no effect on carcass proportions.

Composition of the front, middle, and rear of the carcass. The influences of the various combinations of feeding levels, genetic groups, and feeding locations on the weight of the three main parts of the carcass, the wholesale cuts from each part, and the remainder of each part after the cuts had been removed were studied. The remainder of each part was studied for clarity in understanding how the various components of the carcass were affected by the treatments, although this yields little additional information beyond that obtained from considering the weights of the cuts from each part and the total weight of the part. Each cut was studied separately to see if all muscle or lean cuts responded in a like manner to the variables under study.

Composition of the front portion of the carcass. Table 15 gives the group means and standard deviations for the weight of the front and the group means for the weights of the Boston butt, picnic, and remainder of the front. The analyses of variance for these weights are in Table 16. The remainder of the front includes the clear plate, jowl, neck-bones, front feet, and trimmings from the Boston butt and the picnic. The results in Table 15 are represented graphically in Figure 4.

The average effects of the treatments were highly significant for the weight of the front portion of the carcass and

Table 15. Composition of the front portion of the carcass

Treatment		Crossbreds Pasture	Crossbreds Concrete	Crossbreds Av.	Yorkshires Pasture	Yorkshires Concrete	Yorkshires Av.
		Weight of front (lbs.)					
I	$\bar{X}$	39.4	38.9	39.1	41.2	41.6	41.4
	s	1.8	2.8		1.1	1.8	
II	$\bar{X}$	39.4	38.7	39.1	42.4	42.3	42.3
	s	1.6	1.6		1.3	1.9	
III	$\bar{X}$	40.9	44.5	42.7	44.2	44.7	44.4
	s	2.8	3.1		5.4	2.7	
Av.		39.9	40.7	40.3	42.6	42.8	42.7
		Boston butt (lbs.)					
I	$\bar{X}$	8.2	7.6	7.9	8.8	8.3	8.6
II	$\bar{X}$	8.2	7.8	8.0	9.0	9.0	9.0
III	$\bar{X}$	8.6	8.9	8.8	8.9	9.4	9.2
Av.		8.3	8.1	8.2	8.9	8.9	8.9
		Picnic (lbs.)					
I	$\bar{X}$	12.7	12.5	12.6	13.9	14.0	13.9
II	$\bar{X}$	13.0	13.1	13.0	14.0	14.3	14.1
III	$\bar{X}$	13.8	14.5	14.1	14.2	14.8	14.5
Av.		13.1	13.3	13.2	14.0	14.3	14.2
		Remainder (lbs.)					
I	$\bar{X}$	18.5	18.9	18.7	18.5	19.3	18.9
II	$\bar{X}$	18.3	17.8	18.0	19.5	19.0	19.2
III	$\bar{X}$	18.5	21.1	19.8	21.1	20.5	20.8
Av.		18.4	19.3	18.9	19.7	19.6	19.6

Table 16. Analyses of variance for the front of the carcass and its components

Source	d.f.	Front M.S.	Front F	Boston butt M.S.	Boston butt F	Picnic M.S.	Picnic F	Remainder M.S.	Remainder F
G	1	144.55	20.42[b]	11.830	23.61[b]	22.620	15.73[b]	14.65	3.88
F	1	7.15	1.01	.250	.50	2.100	1.46	2.98	.79
GF	1	1.65	.23	.440	.88	.190	.13	5.65	1.49
L/(GF)	28	7.08		.501		1.438		3.78	
T	2	101.62	15.95[b]	4.815	8.48[b]	9.775	10.45[b]	25.02	12.90[b]
TG	2	5.64	.89	.780	1.37	1.890	2.02	2.34	1.21
TF	2	13.84	2.14	1.795	3.16	1.375	1.47	3.62	1.87
TGF	2	9.86	1.55	.070	.12	.015	.02	8.36	4.31[a]
TL/(GF)	54	6.37		.568		.935		1.94	

[a]Significant at the five per cent level.

[b]Significant at the one per cent level.

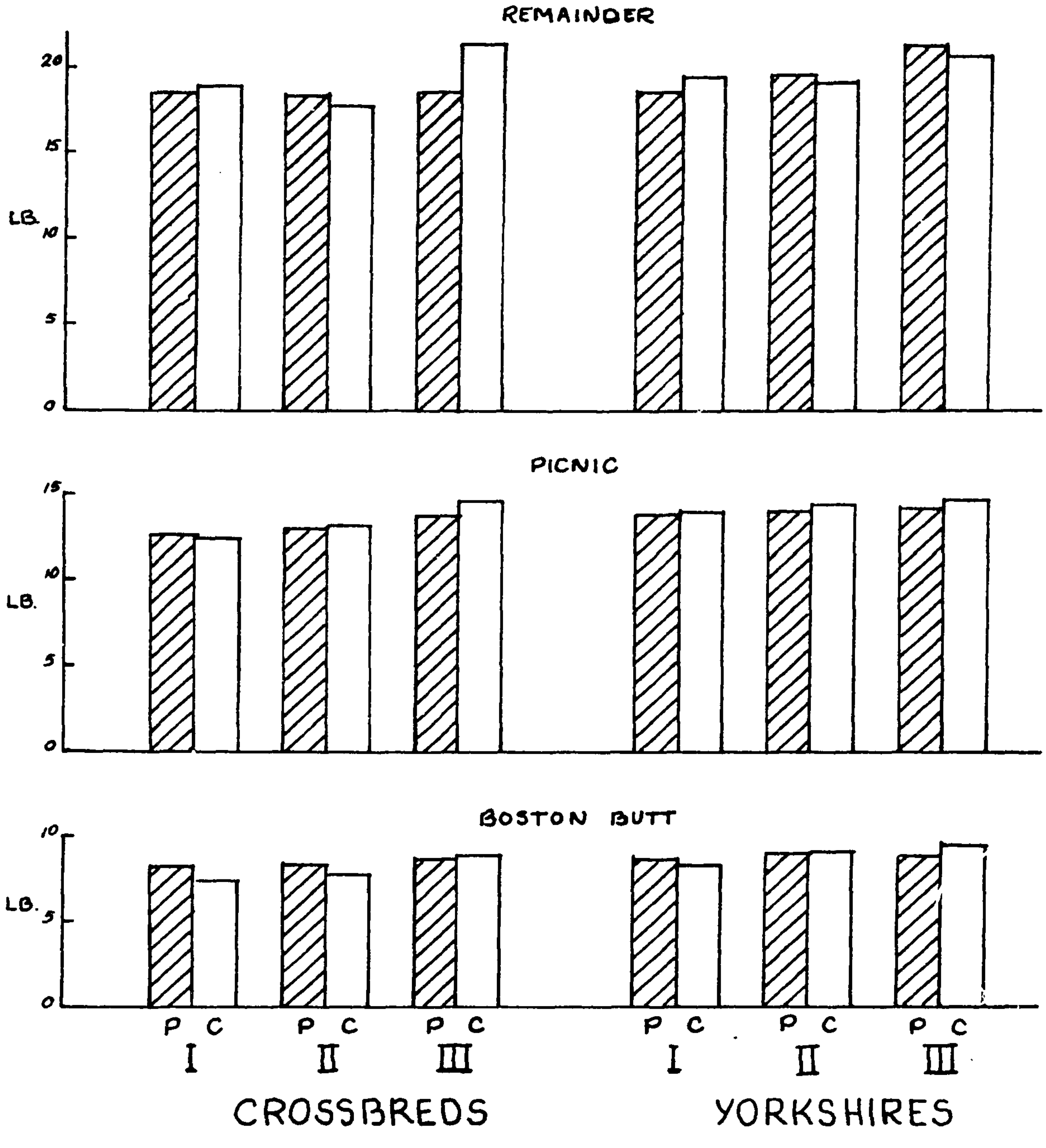

Figure 4. Composition of the front portion of the carcass

each of its three parts. The average weights of the front were 40.3, 40.7, and 43.6 lbs. for treatments I, II, and III respectively. These totals were composed of 8.2, 8.5, and 9.0 lbs. of Boston butt; 13.2, 13.6, and 14.3 lbs. of picnic; leaving 18.8, 18.6, and 20.3 lbs. in the remainder of the front. However, the treatment x genetic group x feeding location interaction for the remainder of the front was significant at the 5 per cent level. The Crossbreds fed on pasture showed the smallest treatment differences, and those fed on concrete showed the largest treatment differences for remainder of front among the four genetic group-feeding location combinations. Also, the treatment x feeding location interaction just failed to be significant at the 5 per cent level for Boston butt. The treatment differences for Boston but were larger for pigs fed on concrete than for pigs fed on pasture.

The Yorkshires had 2.4 lbs. more front than the Crossbreds did which was the result of having 0.7 lbs. more Boston butt, 0.9 lbs. more picnic, and 0.8 lbs. more in the remainder of the front. Each of these differences was highly significant statistically except the difference in the weight of the remainder of the front which fell short of significance at the 5 per cent level. Also, as stated previously, there was some evidence that the genetic group differences for the remainder of the front were not the same for all combinations of treatments and locations.

With the exception of the possible interactions involving locations, the two feeding locations did not differ measurably in their effect on the weight of the front of the carcass or its three components.

Composition of the middle portion of the carcass. The group means and standard deviations for the weight of the middle are listed in Table 17 along with the group means for the weights of the loin, belly, and remainder of the middle. The analyses of variance for these traits are given in Table 18. The remainder of the middle is comprised largely of fat. It includes the fat back, the lean and fat trim from the belly, and the spareribs. The composition of the middle of the carcass is represented graphically in Figure 5.

Treatment effects were responsible for a highly significant portion of the variation in the weight of the middle and each of its three parts. The limited fed pigs averaged 1.8 lbs. or 3 per cent less for total middle weight than did their litter mates that were slaughtered at the same weight. The limited fed pigs had an average of 5 per cent more loin, slightly less belly, and 10 per cent less in the remainder of the middle than the pigs on treatment I had. The weight of middle for the pigs on treatment III averaged 7.3 lbs. or 11 per cent heavier than those on treatment II. This was the result of the pigs on treatment III yielding 4 per cent heavier loins (actually 8 per cent heavier for the Crossbreds and no heavier for the Yorkshires), 10 per cent heavier

Table 17. Composition of the middle portion of the carcass

Treatment		Crossbreds			Yorkshires		
		Pasture	Concrete	Av.	Pasture	Concrete	Av.
				Weight of middle (lbs.)			
I	$\bar{X}$	68.7	68.5	68.6	66.3	67.0	66.6
	s	2.8	2.9		3.2	3.0	
II	$\bar{X}$	67.3	66.8	67.0	64.3	64.8	64.5
	s	2.7	3.0		2.0	2.6	
III	$\bar{X}$	73.6	78.5	76.1	69.4	70.8	70.1
	s	6.6	7.6		10.5	4.5	
Av.		69.9	71.3	70.6	66.7	67.5	67.1
				Loin (lbs.)			
I	$\bar{X}$	20.6	20.2	20.4	22.7	22.0	22.3
II	$\bar{X}$	21.6	21.6	21.6	23.0	23.4	23.2
III	$\bar{X}$	22.7	24.0	23.4	22.6	23.8	23.2
Av.		21.6	22.0	21.8	22.8	23.1	22.9
				Belly (lbs.)			
I	$\bar{X}$	17.7	17.2	17.4	16.1	16.9	16.5
II	$\bar{X}$	17.0	17.2	17.1	15.7	16.4	16.0
III	$\bar{X}$	18.8	19.1	19.0	17.3	17.9	17.6
Av.		17.8	17.8	17.8	16.4	17.0	16.7
				Remainder (lbs.)			
I	$\bar{X}$	30.4	31.1	30.8	27.6	28.1	27.9
II	$\bar{X}$	28.7	27.9	28.3	25.5	25.0	25.3
III	$\bar{X}$	32.1	35.4	33.7	29.5	29.1	29.3
Av.		30.4	31.5	30.9	27.5	27.4	27.5

Table 18. Analyses of variance for the middle of the carcass and its components

		Middle		Loin		Belly		Remainder	
Source	d.f.	M.S.	F	M.S.	F	M.S.	F	M.S.	F
G	1	279.48	10.54[b]	29.04	6.68[a]	29.04	16.69[b]	279.14	19.01[b]
F	1	34.08	1.29	2.10	.48	3.15	1.81	6.88	.47
GF	1	.89	.03	.03	.01	3.60	2.07	7.09	.48
L/(GF)	28	26.51		4.35		1.74		14.68	
T	2	457.22	18.85[b]	29.74	14.03[b]	26.98	15.78[b]	171.73	18.63[b]
TG	2	38.56	1.59	10.60	5.00[a]	.16	.09	6.72	.73
TF	2	23.92	.99	5.98	2.82	.34	.20	7.76	.84
TGF	2	14.27	.59	.30	.14	.52	.30	11.04	1.20
TL/(GF)	54	24.25		2.12		1.71		9.22	

[a]Significant at the five per cent level.

[b]Significant at the one per cent level.

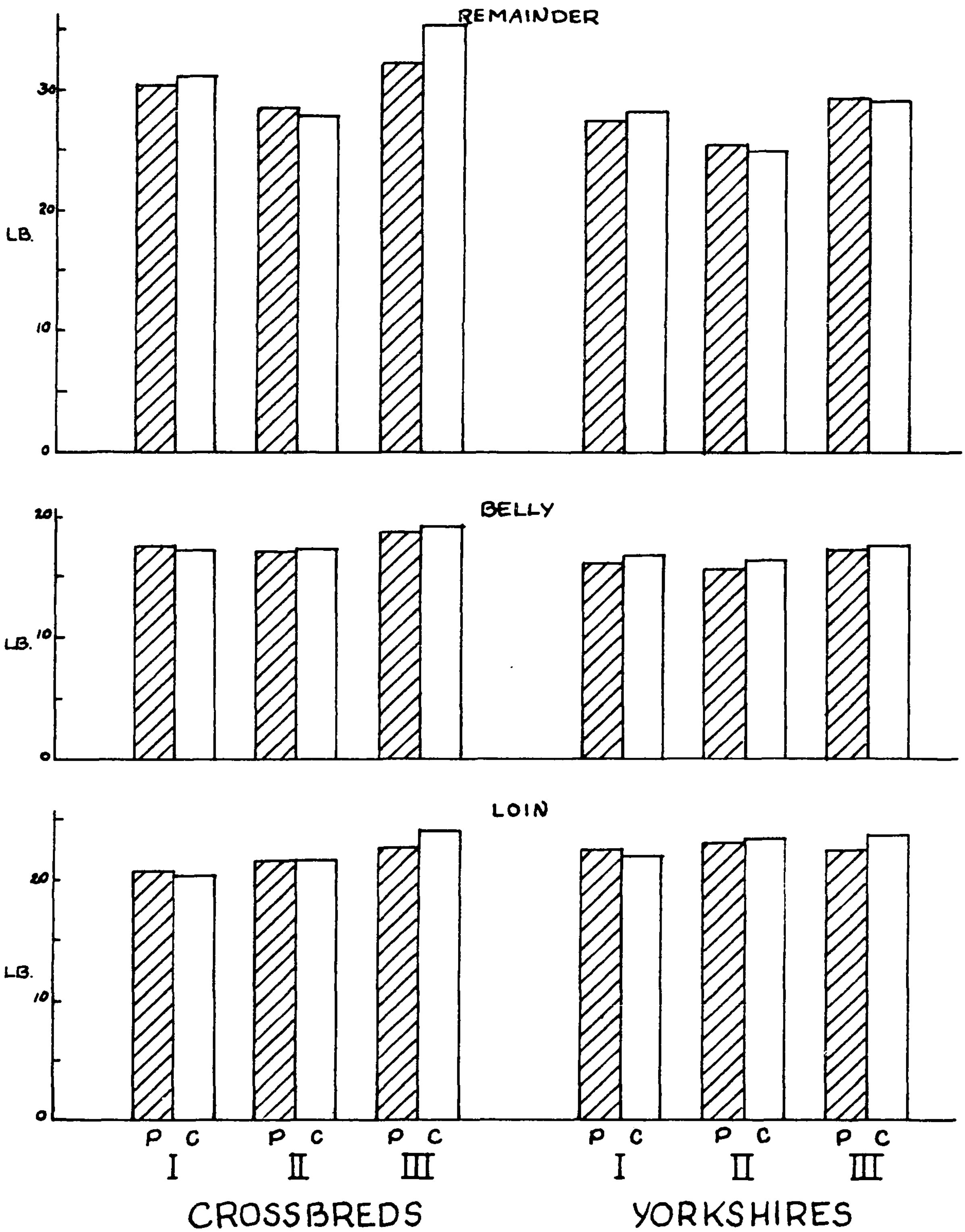

Figure 5. Composition of the middle portion of the carcass

bellies, and 18 per cent more in the remainder of the middle than the pigs on treatment II did. The treatment x genetic group interaction was significant at almost the 1 per cent level for loin weight. This was largely because the limited fed Yorkshires had loins as heavy as those of the full fed litter mates of the same age while the limited fed Crossbreds had loins that were 1.8 lbs. lighter than those of their full fed litter mates of the same age.

Differences between the two genetic groups were highly significant for total middle weight, weight of belly, and weight of the remainder of the middle. Those for loin weight were only significant at the 5 per cent level. The Yorkshires had 3.5 lbs. less middle and at the same time had more loin, especially on treatments I and II, than the Crossbreds had. The Crossbreds consequently had heavier bellies, and more in the remainder of the middle than the Yorkshires did. Little positive evidence was found that feeding locations had an influence upon the composition of the middle portion of the carcass.

Composition of the rear portion of the carcass. The data for the weights of the rear of the carcass and its parts are summarized in Tables 19 and 20. The remainder of the rear after the skinned ham has been removed includes the hind feet, some of the sacral vetebrae, and the fat and skin removed from the ham. The skinned ham was further divided into the weight of the defatted ham and a remainder which

Table 19. Composition of the rear portion of the carcass

Treatment		Crossbreds Pasture	Crossbreds Concrete	Crossbreds Av.	Yorkshires Pasture	Yorkshires Concrete	Yorkshires Av.
		Weight of rear (lbs.)					
I	$\bar{X}$	34.7	34.2	34.4	36.5	37.0	36.8
	s	1.5	1.5		1.3	1.4	
II	$\bar{X}$	35.1	35.5	35.3	37.4	37.3	37.3
	s	1.4	1.8		1.9	1.7	
III	$\bar{X}$	36.6	38.9	37.7	37.7	39.0	38.4
	s	2.5	3.4		4.5	2.5	
Av.		35.4	36.2	35.8	37.2	37.8	37.5
		Skinned ham (lbs.)					
I	$\bar{X}$	25.7	25.3	25.5	28.7	28.8	28.8
II	$\bar{X}$	26.5	27.0	26.7	29.6	29.6	29.6
III	$\bar{X}$	26.9	28.9	27.9	29.2	30.6	29.9
Av.		26.4	27.0	26.7	29.2	29.7	29.4
		Remainder (lbs.)					
I	$\bar{X}$	9.0	8.9	9.0	7.8	8.2	8.0
II	$\bar{X}$	7.7	8.6	8.2	7.7	7.7	7.7
III	$\bar{X}$	9.6	10.0	9.8	8.6	8.5	8.5
Av.		8.8	9.2	9.0	8.0	8.2	8.1

Table 20. Analyses of variance for the rear of the carcass and its components

		Rear		Skinned ham		Remainder	
Source	d.f.	M.S.	F	M.S.	F	M.S.	F
G	1	68.52	12.08[b]	176.59	41.75[b]	25.110	23.16[b]
F	1	11.28	1.99	8.17	1.93	.250	.23
GF	1	.12	.02	.16	.04	.000	.00
L/(GF)	28	5.67		4.23		1.084	
T	2	52.66	10.21[b]	25.80	7.46[b]	9.055	16.96[b]
TG	2	5.88	1.14	3.38	.98	.410	.77
TF	2	8.30	1.61	7.48	2.16	.040	.07
TGF	2	1.98	.58	.73	.21	.370	.69
TL/(GF)	54	5.16		3.46		.534	

[b]Significant at the one per cent level.

represented the fat and skin removed from the skinned ham when it was defatted. The group means for these two weights are given in Table 21 and the analyses of variance are in Table 22. The composition of the rear of the carcass is represented graphically in Figure 5.

The main effects of treatments and genetic groups were highly significant for total weight of the rear and the weight of each part of the rear, while the main effect for feeding locations did not approach significance for any of the weights.

The rear portion of the carcass was 0.7 lbs. heavier for the pigs on treatment II than for those on treatment I and was 1.7 lbs. heavier for the pigs on treatment III than for those on treatment II. The difference in the means for

Table 21. Group means for the components of the skinned ham

Treatment	Crossbreds			Yorkshires		
	Pasture	Concrete	Av.	Pasture	Concrete	Av.
			Defatted ham (lbs.)			
I $\bar{X}$	22.1	21.2	21.6	25.2	25.4	25.3
II $\bar{X}$	22.7	23.2	22.9	26.4	26.5	26.4
III $\bar{X}$	23.0	24.2	23.6	25.4	26.9	26.2
Av.	22.6	22.8	22.7	25.6	26.2	26.0
			Remainder (lbs.)			
I $\bar{X}$	3.58	4.12	3.85	3.50	3.44	3.47
II $\bar{X}$	3.84	3.79	3.82	3.28	3.14	3.21
III $\bar{X}$	3.90	4.64	4.27	3.76	3.63	3.70
Av.	3.77	4.18	3.98	3.51	3.40	3.46

Table 22. Analyses of variance for the components of the skinned ham

Source	d.f.	Defatted ham		Remainder of skinned ham	
		M.S.	F	M.S.	F
G	1	247.69	69.85[b]	6.000	9.74[b]
F	1	4.09	1.15	.700	1.14
GF	1	.59	.17	1.400	2.27
L/(GF)	28	3.55		.616	
T	2	19.06	6.78[b]	1.800	7.14[b]
TG	2	2.69	.96	.085	.34
TF	2	6.16	2.19	.300	1.19
TGF	2	1.43	.51	.380	1.51
TL/(GF)	54	2.81		.252	

[b] Significant at the one per cent level.

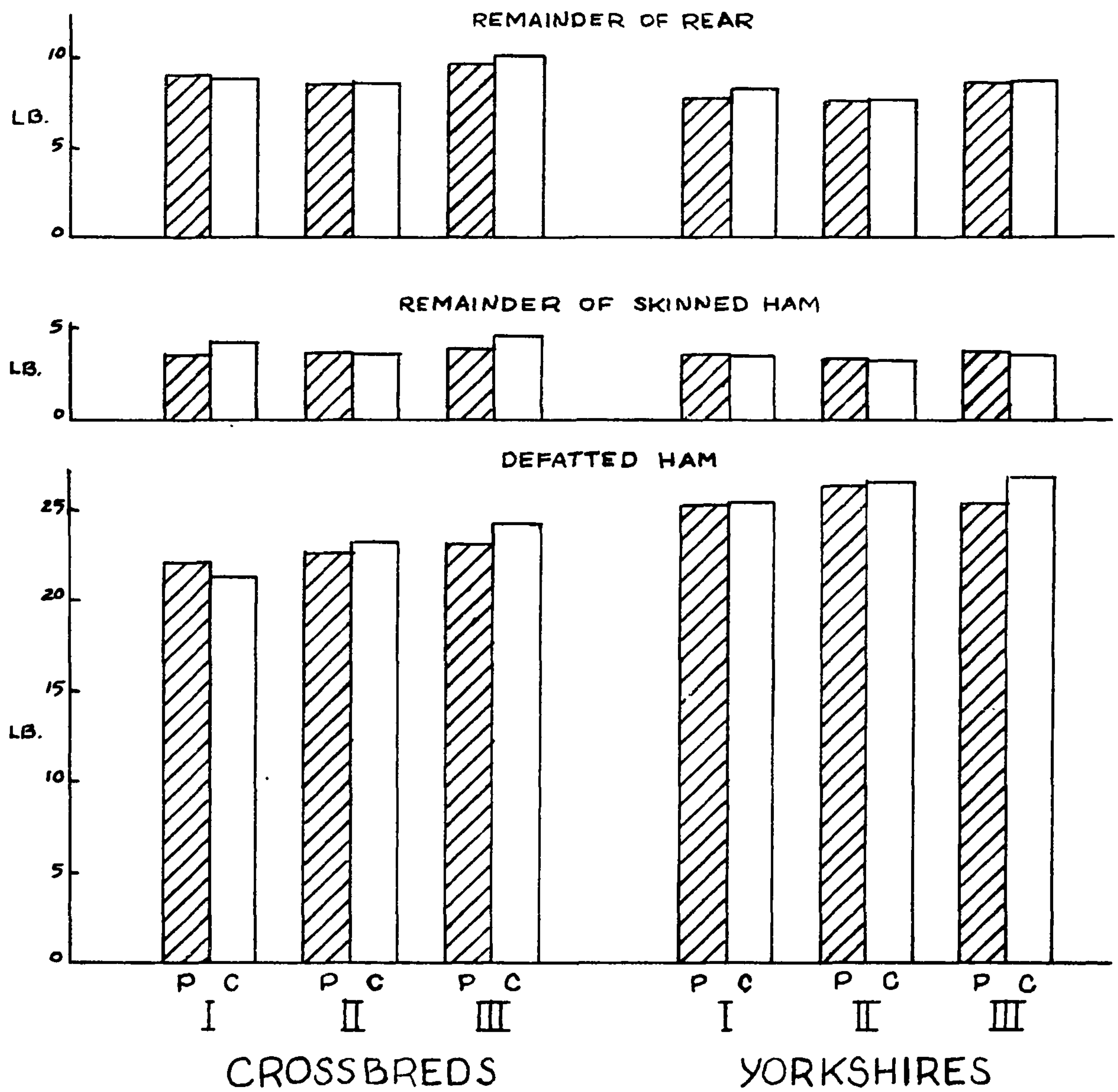

Figure 6. Composition of the rear portion of the carcass

treatments I and II was the consequence of the limited fed pigs having 1.1 lbs. heavier skinned hams and slightly less in the remainder of the rear than did their full fed litter mates which were slaughtered at the same weight. The limited fed pigs further had 1.2 lbs. heavier defatted hams and slightly less fat trim from the skinned ham than did the pigs on treatment I.

The pigs on treatments II and III differed in the weight of the rear of the carcass, partially at least because the pigs on treatment III were heavier at slaughter than those on treatment II were. However, the pigs on treatment III had 2.5 per cent (0.7 lbs.) heavier skinned hams and 12.6 per cent (1.0 lbs.) more in the remainder of the rear than the limited fed pigs did. Also the skinned hams from the pigs on treatment III had more fat on them than did those from the limited fed pigs. Thus the defatted hams from the pigs on treatment III were only 0.2 lbs. heavier than those from the pigs on treatment II. The treatment x feeding location interactions for skinned ham and defatted ham approached significance at the 10 per cent level because the average treatment differences were larger for pigs finished on concrete than for those finished on pasture.

The rear portions of the carcass from the Yorkshires were 1.7 lbs. heavier than those from the Crossbreds. The Yorkshires had 2.7 lbs. more skinned ham and 1.0 lbs. less in the remainder of the rear than the Crossbreds did. When the skinned hams were defatted, the Yorkshires had 3.2 lbs. more defatted ham and 0.5 lbs. less fat trim from the skinned hams than did the Crossbreds.

Carcass composition with respect to lean and fat. The influences of the variables on the development of lean and fat tissue were studied by using the total weight of the lean cuts and the weight of the lean trim as indicators of lean tissue development and the weight of the fat trim and the weight of the leaf fat as indicators of fat tissue development. Table 23 includes the group means for total lean cuts, lean trim, fat trim, and leaf fat. The analyses of variance for these weights are presented in Table 24. The group means for lean cuts and fat trim are represented graphically in Figure 7.

The over-all treatment means for total lean cuts were 69.9, 72.6, and 75.5 lbs. for treatments I, II, and III respectively. The average differences due to treatments were highly significant. However, a significant treatment x genetic group interaction was observed as a result of the treatment differences being smaller for the Yorkshires than for the Crossbreds, especially for comparisons of treatment III with treatments I and II. Also a significant treatment x feeding location interaction resulted because the average treatment differences were smaller for the pigs that were finished on pasture than for those that were finished on concrete. Yet the pigs on treatment I yielded the lightest

Table 23. Group means for total lean cuts, lean trim, fat trim, and leaf fat

Treatment	Crossbreds Pasture	Crossbreds Concrete	Crossbreds Av.	Yorkshires Pasture	Yorkshires Concrete	Yorkshires Av.
			Total lean cuts (lbs.)			
I $\bar{X}$	67.1	65.5	66.3	74.0	73.1	73.5
II $\bar{X}$	69.2	69.4	69.3	75.6	76.3	76.0
III $\bar{X}$	72.0	76.3	74.2	74.9	78.6	76.8
Av.	69.4	70.4	69.9	74.8	76.0	75.4
			Lean trim (lbs.)			
I $\bar{X}$	6.59	6.01	6.30	6.69	6.21	6.45
II $\bar{X}$	6.54	6.12	6.33	7.64	7.10	7.37
III $\bar{X}$	6.09	6.58	6.34	6.85	6.66	6.76
Av.	6.41	6.24	6.32	7.06	6.66	6.86
			Fat trim (lbs.)			
I $\bar{X}$	40.0	42.1	41.1	35.8	37.3	36.5
II $\bar{X}$	37.9	36.4	37.2	32.8	32.3	32.5
III $\bar{X}$	41.7	48.1	44.9	39.4	38.7	39.0
Av.	39.9	42.2	41.0	36.0	36.1	36.0
			Leaf fat (lbs.)			
I $\bar{X}$	4.98	4.06	4.52	3.39	3.15	3.27
II $\bar{X}$	4.68	4.60	4.64	3.10	3.06	3.08
III $\bar{X}$	5.35	5.44	5.40	3.59	3.70	3.64
Av.	5.00	4.70	4.85	3.36	3.30	3.33

Table 24. Analyses of variance for weights of lean and fat

Source	d.f.	Total lean cuts M.S.	Total lean cuts F	Lean trim M.S.	Lean trim F	Fat trim M.S.	Fat trim F	Leaf fat M.S.	Leaf fat F
G	1	722.71	32.11[b]	6.820	4.83[a]	588.06	17.80[b]	53.550	62.70[b]
F	1	27.74	1.23	1.980	1.40	40.04	1.21	.560	.66
GF	1	.27	.01	.360	.25	26.25	.79	.520	.61
L/(GF)	28	22.51		1.412		33.03		.854	
T	2	247.28	15.46[b]	2.025	2.50	388.06	22.76[b]	4.400	6.68[b]
TG	2	50.64	3.17[a]	1.830	2.26	5.44	.32	.455	.69
TF	2	58.17	3.64[a]	.945	1.17	26.88	1.58	1.105	1.68
TGF	2	.65	.41	.420	.52	41.13	2.41	.220	.33
TL/(GF)	54	15.99		.809		17.05		.659	

[a]Significant at the five per cent level.

[b]Significant at the one per cent level.

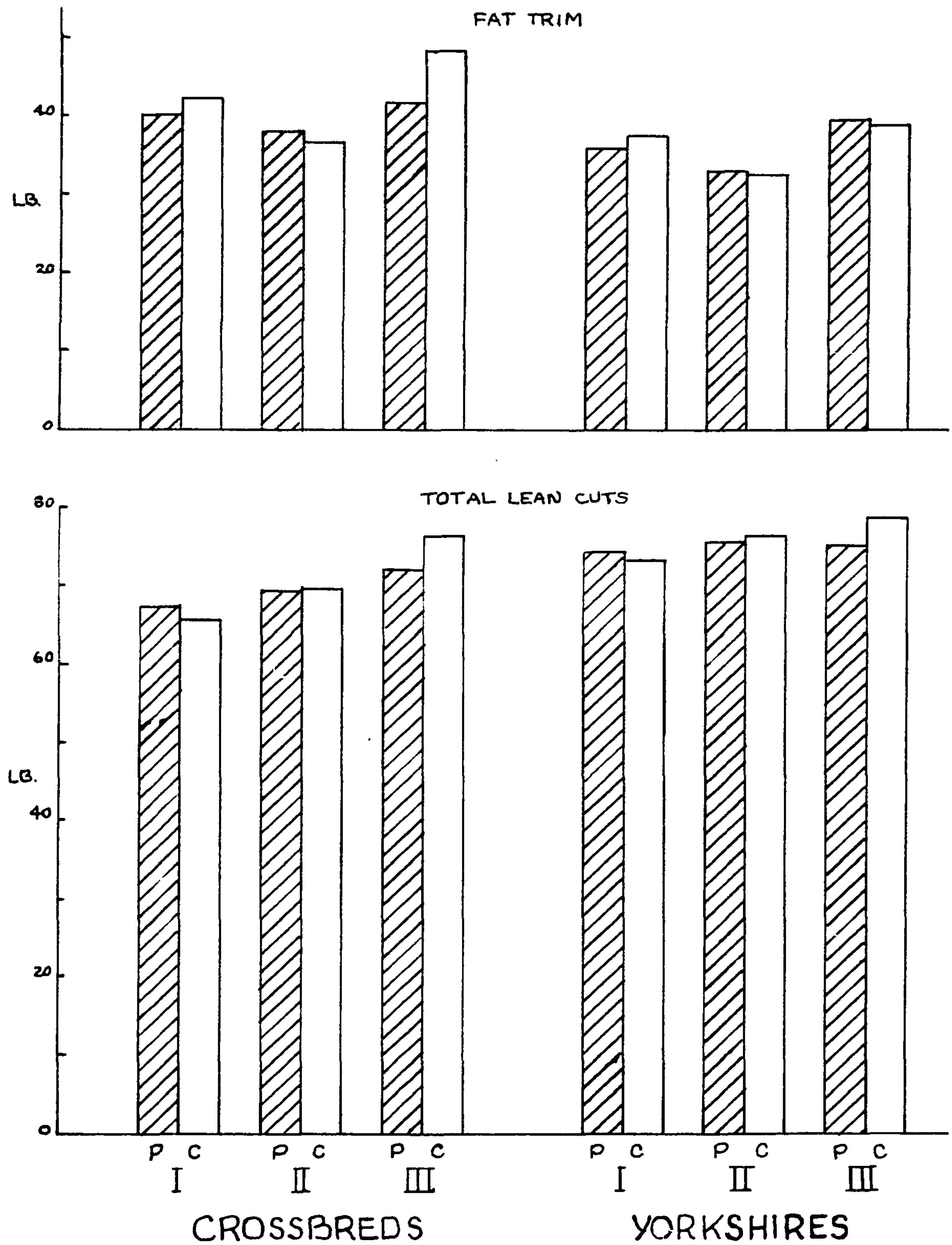

Figure 7. Total lean cuts and fat trim

lean cuts for all four combinations of genetic groups and locations, and the pigs on treatment III yielded the heaviest lean cuts for all combinations except the Yorkshires on pasture.

The Yorkshires produced more pounds of lean cuts than the Crossbreds did for each treatment-feeding location combination. However, the difference between the two genetic groups was larger for treatments I and II than for treatment III. The average difference of 5.5 lbs. more lean cuts for the Yorkshires than for the Crossbreds was highly significant.

For lean trim the average treatment effects reached significance at the 10 per cent level and the treatment x genetic group interaction approached significance at the 10 per cent level. These observations were the result of the Yorkshires on treatment II averaging 0.9 lbs. and 0.6 lbs. more lean trim than those on treatments I and III respectively, while the treatment means did not differ appreciably for the Crossbreds.

The Yorkshires produced 0.5 lbs. more lean trim than the Crossbreds, a difference that was significant at the 5 per cent level. (The differences between the genetic groups were 0.2, 1.0, and 0.4 lbs. for the three treatments.) The pigs finished on pasture produced an average of 0.3 lbs. more lean trim than those finished on concrete, but this difference did not approach significance.

The weight of the fat trim represents a fairly large portion of the weight of the chilled carcass and is composed almost entirely of fat. The average effects of the treatments on the weight of the fat trim were highly significant. The limited fed pigs had 4.0 lbs. less fat than did their full fed litter mates that were slaughtered at the same weight and 7.1 lbs. less fat than their full fed litter mates slaughtered at the same age.

The average genetic group difference of 5.0 lbs. more fat trim for the Crossbreds than for the Yorkshires was highly significant. The treatment x genetic group x feeding location interaction was significant at the 10 per cent level. This was because the treatment differences (especially the difference between treatments II and III) were smaller for the Crossbreds finished on pasture and larger for the Crossbreds finished on concrete than the corresponding treatment differences for the Yorkshires. The average difference of 1.2 lbs. less fat for the pigs finished on pasture than for those finished on concrete did not approach significance.

The treatment effects were highly significant for leaf fat chiefly because the treatment III pigs had more leaf fat than those on either treatment I or II. The Crossbreds had an average of 1.5 lbs. more leaf fat than the Yorkshires had which was also highly significant. There was very little indication that location had any influence on the weight of the leaf fat.

Percent lean cuts and percent defatted ham. Group means for percent lean cuts and percent defatted ham are listed in Table 25 and the analyses of variance for these traits are given in Table 26.

The treatment effects for percent lean cuts were highly significant because the limited fed pigs had 49.3 per cent lean cuts while the full fed pigs on treatments I and III had 47.2 and 47.3 per cent lean cuts. The difference of 4.0 percentage points between the two genetic groups in percent lean cuts was highly significant also and was twice as large as the difference between the limited fed and full fed groups. Differences in location of feeding during the finishing period were not an important cause of variations in percent lean cuts.

For percent defatted ham the mean squares for treatments and genetic groups were both significant well beyond the one per cent level. The pigs on treatment II had an average percent defatted ham 0.9 and 1.1 percentage points higher than did the pigs on treatments I and III. Furthermore, the percent defatted ham for the Yorkshires was 2.2 percentage points higher than that for the Crossbreds. The interactions and the main effect of locations did not approach significance.

Other carcass characteristics. Carcass measurements. Table 27 lists the group means for carcass backfat, carcass length, and the center of gravity. The analyses of variance for carcass backfat and carcass length are included in

Table 25. Group means for percent lean cuts and percent defatted ham

Treatment	Crossbreds Pasture	Crossbreds Concrete	Crossbreds Av.	Yorkshires Pasture	Yorkshires Concrete	Yorkshires Av.
			Percent lean cuts			
I $\bar{X}$	45.2	44.7	45.0	50.0	49.0	49.5
II $\bar{X}$	47.0	47.4	47.2	51.2	51.5	51.4
III $\bar{X}$	46.0	45.3	45.6	48.4	49.5	49.0
Av.	46.1	45.8	45.9	49.9	50.0	49.9
			Percent defatted ham			
I $\bar{X}$	14.9	14.4	14.7	17.0	17.0	17.0
II $\bar{X}$	15.4	15.8	15.6	17.8	17.9	17.9
III $\bar{X}$	14.7	14.4	14.6	16.4	16.9	16.7
Av.	15.0	14.9	15.0	17.1	17.3	17.2

Table 26. Analyses of variance for percent lean cuts and percent defatted ham

Source	d.f.	Percent lean cuts M.S.	Percent lean cuts F	Percent defatted ham M.S.	Percent defatted ham F
G	1	374.46	52.23[b]	116.160	67.22[b]
F	1	.24	.03	.010	.01
GF	1	.81	.11	.350	.20
L/(GF)	28	7.17		1.728	
T	2	42.27	15.26[b]	10.180	14.02[b]
TG	2	3.20	1.16	.110	.15
TF	2	2.56	.92	.270	.37
TGF	2	3.04	1.10	1.035	1.43
LT/(GF)	54	2.77		.726	

[b]Significant at the one per cent level.

Table 27. Group means for center of gravity, carcass backfat, and carcass length

Treatment	Crossbreds Pasture	Crossbreds Concrete	Crossbreds Av.	Yorkshires Pasture	Yorkshires Concrete	Yorkshires Av.
			Center of gravity			
I $\bar{X}$	48.0	47.3	47.6	48.4	47.9	48.2
II $\bar{X}$	48.0	48.6	48.3	48.3	47.9	48.1
III $\bar{X}$	48.7	48.3	48.5	47.6	47.8	47.7
Av.	48.2	48.1	48.2	48.1	47.9	48.0
			Carcass backfat, av. of three (in.)			
I $\bar{X}$	1.65	1.70	1.68	1.37	1.36	1.36
II $\bar{X}$	1.51	1.51	1.51	1.36	1.29	1.32
III $\bar{X}$	1.55	1.77	1.66	1.51	1.47	1.49
Av.	1.57	1.66	1.62	1.41	1.37	1.39
			Carcass length (in.)			
I $\bar{X}$	29.7	29.6	29.6	30.9	30.7	30.8
II $\bar{X}$	30.2	30.2	30.2	30.8	31.1	30.9
III $\bar{X}$	30.4	31.0	30.6	30.6	30.9	30.8
Av.	30.1	30.2	30.1	30.8	30.9	30.8

Table 28. Analyses of variance for carcass backfat and carcass length

Source	d.f.	Carcass backfat M.S.	Carcass backfat F	Carcass length M.S.	Carcass length F
G	1	1.1441	21.27[b]	11.140	9.16[b]
F	1	.0182	.34	.470	.39
GF	1	.0875	1.63	.010	.01
L/(GF)	28	.0538		1.216	
T	2	.2050	8.40[b]	2.045	5.48[b]
TG	2	.0473	1.94	2.270	6.09[b]
TF	2	.0295	1.21	.565	1.51
TGF	2	.0227	.93	.210	.56
LT/(GF)	54	.0244		.373	

[b]Significant at the one per cent level.

Table 28. Because of the apparent lack of any consistent differences in the center of gravity means an analysis of variance was not calculated for this measurement.

The average effects of the treatments were highly significant for carcass backfat chiefly because the limited fed pigs had 0.10 in. less backfat than those on treatment I and 0.16 in. less backfat than those on treatment III. The genetic group difference of 0.23 in. more backfat for the Crossbreds than for the Yorkshires was highly significant. The treatment x genetic group interaction was noticeable because the difference between treatments I and II was larger for the Crossbreds than for the Yorkshires (as was observed for the probe measurements), although the interaction did not reach significance at the 10 per cent level. The data offered very little indication that the depth of carcass backfat on pigs finished on pasture differed from that of pigs finished on concrete.

For carcass length both the average effects of treatments and the treatment x genetic group interaction were highly significant. The limited fed pigs had longer carcasses than their full fed litter mates slaughtered at the same weight by 0.5 in. for the Crossbreds and 0.1 in. for the Yorkshires. The limited fed Crossbreds had 0.4 in. shorter carcasses than their full fed litter mates of the same age, but the limited fed Yorkshires had 0.1 in. longer carcasses than their full fed litter mates of the same age. Thus the treatment differences were much larger for the Crossbreds than for the Yorkshires and even opposite in direction for the comparison of treatments II and III. The Yorkshires had an average of 0.7 in. longer carcasses than the Crossbreds, but the differences between the genetic groups were 1.2, 0.7, and 0.2 in. for treatments I, II, and III respectively. Feeding locations were a relatively unimportant source of variation in carcass length.

Tracing measurements. The loin and ham tracing data are presented in Tables 29 and 30. A measure of the accuracy of the tracing measurements was obtained by correlating a measurement taken on the tracing from the right side of the

Table 29. Group means for loin and ham tracing measurements

Treatment	Crossbreds			Yorkshires		
	Pasture	Concrete	Av.	Pasture	Concrete	Av.
			Loin eye area, 10th rib (sq. in.)			
I $\bar{X}$	3.12	3.02	3.07	3.16	3.28	3.22
II $\bar{X}$	3.11	3.25	3.18	3.37	3.57	3.47
III $\bar{X}$	3.25	3.30	3.28	3.37	3.54	3.46
Av.	3.16	3.19	3.18	3.28	3.46	3.38
			Loin fat/lean ratio			
I $\bar{X}$	2.32	2.39	2.36	1.80	1.82	1.81
II $\bar{X}$	2.14	1.92	2.03	1.59	1.42	1.50
III $\bar{X}$	2.36	2.43	2.40	1.83	1.73	1.78
Av.	2.27	2.25	2.26	1.74	1.66	1.70
			Ham lean area (sq. in.)			
I $\bar{X}$	14.71	13.23	13.97	16.78	16.38	16.58
II $\bar{X}$	14.84	15.05	14.94	17.03	17.19	17.11
III $\bar{X}$	14.79	15.09	14.94	16.48	17.40	16.94
Av.	14.78	14.46	14.62	16.76	16.99	16.88
			Area of intermuscular fat in ham tracing (sq. in)			
I $\bar{X}$	1.53	1.32	1.42	1.29	1.00	1.14
II $\bar{X}$	1.50	1.40	1.45	1.07	.93	1.00
III $\bar{X}$	1.59	1.79	1.69	1.32	1.00	1.16
Av.	1.54	1.50	1.52	1.23	.98	1.10

Table 30. Analyses of variance for loin and ham tracing measurements

Source	d.f.	Loin eye area		Loin fat/lean ratio		Ham lean area		Ham intermuscular fat area	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F
G	1	.966	4.19	7.387	42.31[b]	120.02	45.12[b]	416.67	38.05[b]
F	1	.206	.90	.058	.33	.12	.05	46.48	4.24[a]
GF	1	.096	.42	.012	.07	1.54	.58	25.21	2.30
L/(GF)	28	.230		.175		2.66		10.95	
T	2	.429	3.69[a]	1.092	12.23[b]	5.09	3.07	37.66	4.75[a]
TG	2	.050	.43	.012	.14	.87	.53	11.44	1.44
TF	2	.052	.45	.115	1.29	5.15	3.11	9.38	1.18
TGF	2	.012	.10	.020	.22	.82	.50	11.28	1.42
TL/(GF)	54	.116		.089		1.65		7.93	

[a]Significant at the five per cent level.

[b]Significant at the one per cent level.

carcass with the same measurement taken on the tracing from the left side of the carcass. These correlations are listed in Table 31.

The average effects of the treatments were significant at the 5 per cent level for loin eye area, largely because

Table 31. Repeatability between right and left side for tracing measurements

Measurement	Crossbreds	Yorkshires	Total
N	48	46	94
Loin eye area	.82	.88	.85
Ham lean area including intermuscular fat	.83	.71	.84
Intermuscular fat in the ham lean area	.36	.67	.60

the area of the loin eye muscle was smaller for the treatment I barrows than for the barrows on the other two treatments. The area of the loin eye was an average of 0.20 sq. in. larger for the Yorkshires than for the Crossbreds. This main effect for genetic groups barely missed being significant at the 5 per cent level. Apparently the feeding locations had very little influence on the area of the loin eye muscle.

For the loin fat/lean ratio the main effects of treatments were highly significant because the ratio was 0.32 lower for the limited fed pigs than it was for either full fed group. The Crossbreds had a 0.56 higher fat/lean ratio than the Yorkshires -- a highly significant difference. The average fat/lean ratio was similar for both feeding locations, and none of the interactions even closely approached significance.

The most important source of variation in the area of lean in the face of the ham appeared to be the genetic groups. The Yorkshires were 2.26 sq. in. larger than the Crossbreds for this measurement which was a highly significant difference. The average effects of the treatments were just short of significance at the 5 per cent level. The variation due to treatments was mostly the result of the smaller areas of lean in the hams from the pigs on treatment I than in those from pigs on treatments II and III. The treatment x location interaction was almost significant at the 5 per cent level. The treatment I pigs finished on concrete had smaller and the treatment II and III pigs finished on concrete had larger areas of lean in the face of the ham than the corresponding groups finished on pasture. Also the area of lean was somewhat smaller for the pigs on treatment III than for those on treatment II when they were finished on pasture and slightly larger when they were finished on concrete. With the exception of the possible treatment x feeding location interaction, locations appeared to have little influence on variations in the area of lean in the ham tracings.

Variation was fairly large within each group for the area of intermuscular fat in the ham tracing. The average treatment differences were significant at the 5 per cent level. Most of the variation due to treatments was the result of the barrows on treatment III having a larger area of intermuscular fat in the ham tracings than those on treatments I or II. Also, Yorkshires on treatment II had slightly less intermuscular fat than those from treatment I, but this was not true for the Crossbreds. The main effect for genetic groups was highly significant as the Crossbreds had an average of 0.42 sq. in. more intermuscular fat in the ham tracings than the Yorkshires had. The average difference of 0.14 sq. in. more intermuscular fat for the pigs finished on pasture than for those finished on concrete was significant at the 5 per cent level. (However, the treatment III Crossbreds finished on pasture had 0.20 sq. in. less intermuscular fat than those finished on concrete.)

Confidence intervals. Some of the more important differences between treatments I and II and treatments II and III are given in Table 32 with the approximately 95 per cent confidence intervals for these differences. Separate differences between the treatments were calculated for each genetic group and/or feeding location in cases in which interactions were significant at the 10 per cent level or higher. The fact that two of the observations for each trait were missing was not taken into account when the confidence intervals were

Table 32. Some of the more important differences between treatments I and II and treatments II and III and the approximately 95 per cent confidence intervals for these differences

Trait		II-I	C.I.	III-II	C.I.
Dressing percentage		-1.4	±0.7	1.8	±0.8
Boston butt	P	0.1	±0.5	0.2	±0.5
	C	0.5	±0.5	0.8	±0.5
Picnic		0.3	±0.5	0.7	±0.5
Loin	C	1.2	±1.0	1.8	±1.0
	Y	0.9	±1.0	0.0	±1.0
Belly		-0.4	±0.7	1.7	±0.8
Skinned ham		1.0	±0.9	0.7	±0.8
Lean cuts	C	3.0	±2.8	4.8	±2.8
	Y	2.4	±2.8	0.8	±2.8
	P	1.8	±2.8	1.0	±2.8
	C	3.6	±2.8	4.6	±2.8
Fat trim	CC	-5.7	±4.2	11.7	±5.0
	CP	-2.1	±4.2	3.7	±5.0
	YC	-5.0	±4.2	6.4	±5.0
	YP	-3.0	±4.2	6.6	±5.0
Percent lean cuts		2.1	±1.0	-2.0	±0.8
Carcass backfat		-0.10	±0.08	0.16	±0.09
Carcass length	C	0.53	±0.43	0.49	±0.43
	Y	0.14	±0.43	-0.17	±0.52
Loin eye area		0.18	±0.17	0.05	±0.17

calculated. This would make the figures given slightly smaller than they should be. Also, for traits in which the variance was larger for treatment III than for treatments I and II the confidence intervals as given would be larger for the comparison between treatments I and II and slightly smaller for the comparison between treatments II and III than they should be.

Indicators of Carcass Merit

The correlation between the average of the six probe measurements taken when each pig was placed on experiment and the average of six probe measurements taken when it reached 200 lbs. was calculated. The latter averages included the shoulder probes which were taken through the false lean, the back probes, and the loin probes. The initial probe measurements were not available on one full fed Yorkshire, and three of the pigs on treatment III were not included in the correlations because they were removed from the experiment before they reached 200 lbs. The correlations were calculated separately for the limited fed and the full fed pigs because the levels of feeding influenced the depth of backfat after the initial probes were taken. Also the correlations were calculated separately for each genetic group. The feeding locations were ignored in the calculations of the correlations. A total correlation and an intra-genetic group-feeding location correlation were also computed. These correlations are given in Table 33.

For the following correlations involving the probe measurements, center of gravity, and other carcass characteristics, the two genetic groups were again analyzed separately because they differed quite markedly in their carcass and backfat characteristics. Also it was felt that perhaps the relationships might not be the same among traits in a lean, meaty breed as among traits in a fatter group.

Table 33. Correlations between backfat probes at 140 lbs. and at 200 lbs.

	Crossbreds		Yorkshires			Intra-
	FF	LF	FF	LF	Total	group
d.f.	30	14	27	13	90	87
r	.66[b]	.42	.50[b]	.75[b]	.68[b]	.56[b]

[b]Significant at the one per cent level.

The pigs on treatment III ranged from 185 to 258 lbs. in weight when they were taken off experiment, and consequently their chilled carcass weights ranged from 128 to 198 lbs. The probe measurements and many of the carcass measurements such as backfat, respective areas of the tracings, carcass length, and weights of the cuts vary with the size of the carcass. Therefore, only the data from the 13 pigs on treatment III which were removed from the experiment within the weight range of the pigs on treatments I and III were used in the subsequent correlation calculations. They were grouped with the pigs on treatment I in the analysis. Correlations for each feeding level-genetic group combination were calculated separately to see if any trends were indicated, although the numbers in the groups were not large enough to establish differences between them.

The correlations of the initial probe measurements, final probe measurements, and average carcass backfat with percent lean cuts and percent fat cuts are given in Table 34. The probes taken at various sites are designated in Table 34 by the following symbols: behind the shoulder, S; middle of the back, B; middle of the loin, L; behind the shoulder to the false lean, S I; and behind the shoulder through the false lean, S II.

The correlations between the center of gravity and various carcass traits are given in Table 35. Table 36 contains a number of the more important correlations between various carcass characteristics. The carcass index was considered the best single estimate of carcass merit. However, because the carcass index was so highly correlated with percent lean cuts and because in the literature percent lean cuts is often used as the most important single measure of carcass merit, more correlations were calculated between the various

Table 34. Correlations between probe and carcass backfat measurements and carcass composition

Back fat measurement	Crossbreds FF	Crossbreds LF	Yorkshires FF	Yorkshires LF	Total	Intra-group
d.f.	20	14	22	13	75	73
			Percent lean cuts			
Probe at 140 lbs.						
S	-.67[b]	-.30	-.53[b]	-.57[a]	-.49[b]	-.45[b]
B	-.55[b]	-.48	-.33	-.56[a]	-.68[b]	-.46[b]
L	-.68[b]	-.52[a]	-.38	-.56[a]	-.77[b]	-.54[b]
Av.	-.69[b]	-.49	-.48[a]	-.72[b]	-.74[b]	-.57[b]
Probe at 200 lbs.						
S I	-.52[a]	-.56[a]	.17	-.07	-.60[b]	-.33[b]
S II	-.67[b]	-.71[b]	-.28	-.63[a]	-.75[b]	-.59[b]
B	-.71[b]	-.76[b]	-.25	-.76[b]	-.82[b]	-.65[b]
L	-.69[b]	-.81[b]	-.43[a]	-.48	-.83[b]	-.59[b]
Av. six	-.80[b]	-.83[b]	-.40[a]	-.70[b]	-.86[b]	-.70[b]
Carcass backfat Av. three	-.74[b]	-.65[b]	-.25	-.67[b]	-.76[b]	-.62[b]
			Percent fat cuts			
Probe at 140 lbs. Av. six	.74[b]	.34	.72[b]	.71[b]	.76[b]	.62[b]
Probe at 200 lbs.						
S I	.47[a]	.47	-.22	.63[a]	.55[b]	.29[a]
S II	.66[b]	.66[b]	.13	.55[a]	.71[b]	.53[b]
Av. six	.84[b]	.74[b]	.36	.71[b]	.84[b]	.70[b]
Carcass backfat Av. three	.76[b]	.70[b]	.41[a]	.79[b]	.80[b]	.70[b]
			Carcass backfat (Av. three)			
Probe at 200 lbs. Av. six	.73[b]	.61[a]	.46[a]	.85[b]	.80[b]	.70[b]

[a]Significant at the five per cent level.

[b]Significant at the one per cent level.

Table 35. Correlations of center of gravity with selected carcass characteristics

Trait	Crossbreds FF	Crossbreds LF	Yorkshires FF	Yorkshires LF	Total	Intra-group
d.f.	20	14	22	13	75	73
Carcass index	.58[b]	.51[a]	.03	.38	.35[b]	.44[b]
Percent lean cuts	.44[a]	.52[a]	.06	.40	.28[a]	.37[b]
Percent fat cuts	-.64[b]	-.48	-.12	-.29	-.36[b]	-.44[b]
Rear/front ratio	.82[b]	.66[b]	.42[a]	.66[b]	.70[b]	.70[b]
Percent front	-.70[b]	-.16	-.21	-.09	-.35[b]	-.47[b]
Percent middle	.30	-.52[a]	-.06	-.40	-.44[b]	-.01
Percent rear	.64[b]	.71[b]	.34	.70[b]	.49[b]	.57[b]
Percent defatted ham	.59[b]	.74[b]	.19	.63[a]	.37[b]	.53[b]

[a]Significant at the five per cent level.

[b]Significant at the one per cent level.

Table 36. Correlations among carcass characteristics

	Crossbreds FF	Crossbreds LF	Yorkshires FF	Yorkshires LF	Total	Intra-group
d.f.	20	14	22	13	75	73
Carcass index						
Percent lean cuts	.96[b]	.98[b]	.98[b]	.98[b]	.98[b]	.97[b]
Loin eye area	.83[b]	.46	.63[b]	.36	.61[b]	.61[b]
Carcass length	.02	.15	-.25	.02	.34[b]	-.04
Percent lean cuts						
Loin eye area	.79[b]	.56[a]	.57[b]	.28	.58[b]	.58[b]
Loin fat area	-.60[b]	-.77[b]	-.24	-.64[b]	-.79[b]	-.54[b]
Loin fat/lean ratio	-.89[b]	-.77[b]	-.71[b]	-.74[b]	-.88[b]	-.79[b]
Ham lean area	.61[b]	.78[b]	.64[b]	.35	.77[b]	.61[b]
Percent defatted ham	.93[b]	.89[b]	.81[b]	.88[b]	.95[b]	.88[b]
Percent skinned ham	.91[b]	.89[b]	.75[b]	.82[b]	.94[b]	.85[b]
Skinned ham (lbs.)	.89[b]	.76[b]	.41[a]	.62[a]	.85[b]	.69[b]
Carcass length	.08	.16	-.13	.12	.41[b]	.04
Percent fat cuts	-.94[b]	-.95[b]	-.77[b]	-.84[b]	-.94[b]	-.91[b]
Loin eye area						
Ham lean area	.61[b]	.63[b]	.42[a]	.49	.56[b]	.53[b]
Carcass length	-.01	-.18	-.56[b]	-.47	-.12	-.32[b]
Percent fat cuts						
Loin fat/lean ratio	.87[b]	.77[b]	.72[b]	.89[b]	.90[b]	.81[b]

[a]Significant at the five per cent level.

[b]Significant at the one per cent level.

indicators of carcass merit and percent lean cuts than between the indicators and carcass index.

DISCUSSION

Treatment, Location, and Genetic Group Effects

The main effects of the treatments, locations, and genetic groups and the interactions among these factors will be discussed first for the pre-slaughter characteristics and then for the carcass characteristics. The main effects will be discussed first in each case, although these are of secondary importance for the traits for which interactions were observed.

Pre-slaughter data

Full feeding versus limited feeding. The lower feed intake resulted in a reduced rate of gain as would be expected. The amount of reduction in rate of gain depended on the amount the feed intake was restricted and on the effect of limiting the feed on the feed requirements. Some variation occurred in the amount the four limited fed groups were limited. Also, as will be discussed later, limiting the feed lowered feed requirements for pigs fed on pasture, but it did not for pigs fed on concrete. As a result of these two factors, the rate of gain for the limited fed Crossbreds was reduced 18 per cent when they were fed on pasture and 27 per cent when they were fed on concrete, and the rate of gain for the Yorkshires was reduced 9 per cent when they were fed on pasture and 13 per cent when they were fed on concrete. The limited fed pigs had smaller probe measurements than the full fed pigs. Also, the limited fed pigs shrank less than the full fed pigs, except for the Crossbreds fed on pasture, which will be discussed later.

Pasture versus concrete dry-lot. The pigs finished on pasture gained an average of .12 lbs. less per day than those finished on concrete, but this difference was not statistically significant. The difference in rate of gain is slightly smaller than it should be because the limited fed Crossbreds were limited more on concrete than on pasture. The lower rate of gain for pigs fed on pasture is in agreement with the findings of Blackmore (1953) and Kristjansson (1957), but not in agreement with most of the recent reports in the literature. Perhaps the effect of confining the pigs on concrete versus not confining them on pasture is involved. In the studies by Blackmore and Kristjansson, as in the present study, the pigs fed on concrete were confined considerably more than those fed on pasture were.

Contrary to the results reported by Smith et al. (1950), Morrison (1956), and others, the pigs fed on pasture required more feed per 100 lbs. of gain than those fed on concrete (the difference was 28 lbs. when the pigs were full fed and 17 lbs. when they were limited fed). Two factors probably contributed to this observation. The pigs fed on pasture were fed a complete mixed ration and could not replace part of the protein portion of their diet with forage without also lowering their intake of carbohydrates. Then, because the pigs on pasture were not confined nearly as much as the pigs on concrete, they probably got more exercise and consequently had higher maintenance requirements than those fed on concrete. When Hutchinson et al. (1957) fed a complete ration to pigs on pasture and on concrete, they observed the feed requirements were about the same for the two groups in one experiment and were lower for the pigs fed on pasture in another experiment. In their study the pigs fed on concrete were not confined as much as those in the present study were.

Yorkshires versus Crossbreds. A marked difference was observed in the appetites of the two genetic groups. The full fed Yorkshires consumed 1.5 lbs. (21 per cent) less feed per day than the full fed Crossbreds did. The Crossbreds gained only slightly faster than the Yorkshires and had more backfat as measured by the probe. These differences were similar to the differences between Yorkshires and Durocs observed at the Iowa Swine Testing Station (Sutherland, 1958) for daily gain and probe measurements. The average probe measurements for the Crossbreds were 0.14 in. larger than those for the Yorkshires both when the initial and when the final probes were taken. The feed requirements were much lower (54 lbs. per 100 lbs. gain) for the Yorkshires than for the Crossbreds. As would be expected from their lower feed intake, the

Yorkshires shrank less (4 lbs.) than the Crossbreds. The difference in live shrink between the genetic groups was much larger when they were limited fed on pasture than for the other combinations of levels and locations of feeding. This will be discussed with the other genotype-environment interactions.

Genotype-environment interactions. The probe measurements were not reduced as much by limited feeding in the Yorkshires as in the Crossbreds among animals slaughtered at the same weight. This interaction was significant at the 5 per cent level. A similar, but non-significant, interaction was noted for carcass backfat. As the Crossbreds were limited somewhat more severely than the Yorkshires, their probe measurements would be expected to be affected more on that account. However, the other carcass measures of fat did not indicate that the deposition of fat had been restricted more in the Crossbreds than in the Yorkshires by limited feeding. The length of the carcass increased more in the limited fed Crossbreds than in the limited fed Yorkshires in comparison to their full fed litter mates slaughtered at the same weight. If the weight of the backfat remained unchanged, the increase in depth would have to be less on the limited fed Crossbreds because they increased more in length. But the differences were not large enough to make this argument very important.

The limited fed Yorkshires slightly outgained the limited fed Crossbreds while the reverse was true when they were full fed. This interaction did not approach significance and was no doubt inflated by the differences in the amounts the feed was restricted for the two genetic groups. Lucas and Calder (1956) observed a possible interaction between breeds and feeding levels, but they were considering larger differences in level of feeding than the current one. Kristjansson (1957) found some indication of an interaction between genotypes and feeding location (pasture versus piggery) for growth rate. In the present study the difference in rate of gain between pigs fed on pasture and on concrete was larger for the Crossbreds than for the Yorkshires. This interaction was far from significant, but would have been larger if the treatment II Crossbreds fed on concrete had not been limited to 73 per cent of a full feed while those fed on pasture were limited to 81 per cent of a full feed. The treatments used by Lucas and Calder and by Kristjansson were employed from weaning to slaughter rather than from 140 lbs. to slaughter.

Each group of limited fed pigs shrank an average of 47 per cent or 5.0 lbs. less than their respective full fed litter mates, except the Crossbreds fed on pasture. This resulted in a significant treatment x genetic group x feeding location interaction. One would expect the limited fed pigs to shrink less because they had less feed in their digestive tracts at the time the final weights were taken. The limited fed pigs on pasture, however, could have eaten forage to compensate for the difference in fill which would result from a lower intake of concentrates. The lower feed requirements for the limited fed pigs on pasture than for the full fed pigs on pasture indicated that they were perhaps eating more forage, but this observation was similar for both genetic groups. Apparently before the limited fed Crossbreds on pasture were weighed, they had taken on a fill equal to that of the full fed pigs and larger than that of the limited fed Yorkshires fed on pasture. The pigs of both genetic groups were weighed at approximately the same time of day each week. However, the Crossbreds on pasture came off the experiment between July 29 and August 19, and the Yorkshires on pasture came off the experiment between August 19 and October 7. Perhaps the Crossbreds had grazed more before they were weighed than the Yorkshires had. Thus the evidence indicates the size of the difference in live shrink between Crossbreds and Yorkshires depended on what feeding level and feeding location were used, but other factors may have been involved too.

Interactions between feeding levels and feeding locations. The limited fed pigs had lower feed requirements than the full fed pigs when they were fed on pasture but the two feeding levels had similar feed requirements when fed on concrete. Results from various studies of the effect of restricting the feed intake on feed requirements have not been in agreement. Robison (1932) and Smith et al. (1950) reported more efficient gains when pigs were limited fed on pasture. Others (Ellis and Zeller, 1932 and 1934; McMeekan, 1941; Robison, 1946; Gregory and Dickerson, 1952) have also found lower feed requirements with restricted feeding while some (Saint-Pierre et al., 1935; and Winters et al., 1949) have reported lower feed requirements for one level of restriction and higher feed requirements when another level of restriction was employed. Crampton et al. (1954a) did not observe any difference in feed requirements between full feeding and limited feeding. Lucas and Calder (1955) found that limited feeding lowered the feed requirements when the pigs were well housed but increased them when they were poorly housed, especially in the winter. Many other conflicting reports concerning the effects of limited feeding on feed requirements have been reviewed by Lucas and Calder (1956). The observation in the present study that limiting the feed saved feed on pasture but did not on concrete can be interpreted as an indication that the limited fed pigs on pasture satisfied more of their feed requirements by eating pasture than did the pigs fed on pasture that had all the concentrates they wanted to eat. The limited fed pigs on concrete, on the other hand, could not compensate in any way for their reduced feed intake.

Carcass observations

Full fed and limited fed pigs slaughtered at the same weights. The limited fed pigs had significantly lower dressing percentages than the full fed pigs (74.2 per cent compared to 75.6 per cent). Other workers have also reported a reduction in dressing percentage as a result of limited feeding (Whatley et al., 1953; Tenn. Agr. Exp. Sta. Annual Report, 1951; Winters et al., 1949; Saint-Pierre et al., 1935; and to a lesser extent, Lucas and Calder, 1955 and 1956).

The change in carcass proportions was largely due to the limited fed pigs having less backfat and belly fat. Therefore, they had a smaller percentage of their carcass weight in the middle portion of the carcass and a larger proportion in the front and rear portions of the carcass than the full fed pigs had.

The limited fed pigs had approximately 4 per cent heavier lean cuts and 10 per cent less fat trim than the full fed pigs. More lean and less fat has long been a recognized result of limited feeding (Ellis and Zeller, 1932). The increase of 2 percentage points in percent lean cuts as a result of limiting the feed to approximately 85 per cent of a full feed is in substantial agreement with other reports of the effects of limited feeding on carcass composition. The area of the loin eye muscle and lean in the face of the ham also reflected the increase in leanness of the limited fed pigs. Although the fat trim was reduced 10 per cent by limited feeding, the weight of the belly was reduced only 2 per cent and the weight of the leaf fat reduced less than 2 per cent.

Restriction of feed intake at more severe levels has been reported to result in softer carcasses. Very little variation in the carcasses in the present study was observed when they were examined subjectively for hardness after they had chilled.

The carcasses from the limited fed pigs were longer than those from the full fed pigs of the same weight (but younger) in both genetic groups, but the difference was larger for the Crossbreds than for the Yorkshires. This interaction will be discussed later.

Because the dressing percentage is lowered and the percent lean cuts is increased by limited feeding, it is of considerable practical importance to know whether the net carcass value of the live hog is raised or lowered by limited feeding. The carcass value of the full fed and the limited fed pigs slaughtered at the same weight was computed using the average 1956 prices (U. S. Agricultural Marketing Service, 1957) for each cut and for lard. Using the price for processed lard results in a slight bias in favor of the full fed hogs, but prices were not available to estimate the value of the unrendered fat. The yield of lard from the fat trim was figured at 80 per cent and from the leaf fat was figured at 93 per cent. The remainder of the chilled carcass weight not included in the weights of the lean cuts, belly, lean trim, fat trim, and leaf fat (12.2 lbs. for each group) was ignored as was the offal when the net carcass value was figured. The value of the full fed pigs was 16.25 dollars per 100 lbs. and that of the limited fed pigs was 16.68 dollars per 100 lbs. of their final feed lot weights. When figured on the basis of their shrunk live weights, the value per 100 lbs. was 17.19 dollars and 17.28 dollars for the full fed and the limited fed pigs, respectively. Therefore, when pigs were limited to 85 per cent of a full feed during the finishing period, their value per pound live weight was increased because the increase in the weights of the more valuable cuts was sufficient to offset the decrease in dressing percentage resulting from limited feeding. In the study conducted by Whatley _et al_. (1953) the carcass value per 100 lbs. live weight was 22.87 dollars for full fed hogs and 22.70 dollars for the hogs fed the lower energy diet from 140 lbs. to slaughter. However, the difference between full fed and limited fed hogs in carcass value on the live weight basis is dependent on the price differential between the lean cuts and fat cuts.

Although the present data indicate limiting the feed will result in market hogs of slightly higher value, this small difference in value could not be transmitted to producers with any degree of consistency in our present system of marketing live hogs. If producers sold hogs on the basis of grade and yield, the slight reduction in backfat and slight increase in length would help the grade while the yield would be reduced.

Limited fed and full fed pigs slaughtered at the same age. The difference in dressing percentage was larger between the two levels among animals of the same age than among animals of the same weight due to the additional difference in fatness. The differences in carcass proportions were similar to those observed between the two levels of feeding when the animals were slaughtered at the same weight.

When full fed pigs were slaughtered at the same age as limited fed pigs they not only yielded carcasses that were 13 lbs. or 8.8 per cent heavier with 7.8 lbs. or 20.2 per cent more fat trim and leaf fat, but their carcasses also had 2.8 lbs. or 3.9 per cent more lean cuts than those from the limited fed pigs. Thus evidence was given that the weight of the lean cuts in the limited fed pigs would have been somewhat heavier if the pigs had been full fed rather than limited fed to the age at which they were slaughtered. (The treatment III Yorkshires had no more loin and only 0.8 lbs. more lean cuts than the treatment II Yorkshires while the treatment III Crossbreds had 1.8 lbs. more loin and 4.8 lbs. more lean cuts than the treatment II Crossbreds.) However, the weights and measurements which most nearly measured the amount of lean exclusively showed slight if any advantages for treatment III over treatment II. The defatted ham was only 0.2 lbs. or 1 per cent heavier and the area of the loin eye muscle was only .05 sq. in. or 2 per cent larger in the carcasses from treatment III than in those from treatment II. The area of lean in the face of the ham and the weight of the lean trim were actually slightly less for the full fed pigs slaughtered at the same age as the limited fed pigs. The area of intermuscular fat in the face of the ham was 0.2 sq. in. or 16 per cent larger in the pigs from treatment III than in those from treatment II. Therefore, the slight increase in the absolute weight of the lean cuts observed for treatment III over treatment II may well have been the result of more fat in the lean cuts. This conclusion is supported by the results of Loeffel _et al_. (1943), Callow (1948), and others that have shown that fattening increases the percentage of chemical fat in the muscular tissues as well as in the fatty tissues.

Pigs fed on pasture and pigs fed on concrete. The carcasses from pigs finished on concrete were very similar to those from pigs finished on pasture, with the exception of the possible interactions involving feeding locations which will be discussed later. The area of intermuscular fat in the lean in the face of the ham was significantly larger (.14 sq. in.) for the pigs fed on pasture than for those fed on concrete. No explanation for this difference is apparent. Kristjansson (1957) reported that pigs fed from weaning to slaughter on pasture were significantly shorter (0.5 in.) than those fed in a piggery. The pigs fed on pasture in the present study were very slightly shorter (.14 in.) than those fed on concrete. Blackmore (1953) and workers at the Tennessee station (Tenn. Agr. Exp. Sta. Annual Report, 1951) also found very little difference in the carcasses from pigs fed on pasture and those fed on concrete.

<u>Yorkshires versus Crossbreds</u>. The Yorkshires differed considerably from the Crossbreds for all carcass characteristics, as they were expected to. Although the full fed Yorkshires consumed about the same amount of feed per day as the limited fed Crossbreds did, they were leaner. For most measures of leanness the Yorkshires differed from the Crossbreds in the same direction and roughly twice as much as the limited fed pigs differed from their full fed litter mates of the same weight. However, the difference in dressing percentage was slightly larger between treatments I and II than between the Yorkshires and the Crossbreds. Winters <u>et al</u>. (1949) and Whatley <u>et al</u>. (1953) also noted that breeding groups which differ in leanness often do not have as large a difference in dressing percentage as accompanies a corresponding difference in leanness due to differences in level of feeding.

The carcass value on the live weight basis was calculated for the Yorkshires and the Crossbreds in the same manner as was done for the full fed and limited fed pigs. The value of the Yorkshires was 16.82 dollars per 100 lbs. and that of the Crossbreds was 16.15 dollars per 100 lbs. of their final feed lot weights. When figured on the basis of their shrunk live weights the value per 100 lbs. was 17.48 dollars and 17.10 dollars for the Yorkshires and the Crossbreds, respectively.

<u>Genotype-environment interactions</u>. Carcass length was the only trait studied which showed a highly significant

treatment x genetic group interaction. The Crossbreds on treatment II were significantly longer (0.5 in.) than those on treatment I and significantly shorter (0.5 in.) than those on treatment III, whereas the three treatments caused no significant differences in the carcass length of the Yorkshires. These results indicate that at the ages in this study the Yorkshires were not continuing skeletal growth in the region measured by carcass length as much as the Crossbreds were and that the increase with age in the Crossbreds was larger when the pigs were full fed than when they were limited fed. Thus, the Crossbreds, which were earlier maturing than the Yorkshires from the standpoint of fat deposition, appeared to be later maturing with respect to skeletal growth as measured by carcass length. That the carcass length would be affected at all by the mild differences in level of feeding imposed after the animals reached 140 lbs. is a little surprising in view of the results found by McMeekan (1940c) and Pomeroy (1941). But these workers were using Large White (Yorkshire) pigs in their studies. McMeekan (1940a) observed that the skeleton in the loin region is the latest developing part of the skeletal tissue. Hammond and Murray (1937) and Comstock and Winters (1944) reported breed differences in the relative growth rates of various carcass and body measurements.

The genetic group x treatment interaction was significant for the weight of the loin and total lean cuts. The differences between the treatments were larger for the Crossbreds, especially the differences between treatments II and III, than for the Yorkshires, as was observed for carcass length. Probably the interaction for loin weight (which approached significance at the one per cent level) is partially a reflection of the differences in carcass length. A similar interaction was also observed among the genetic group-treatment means for loin eye area, although those means were not estimated with enough precision to merit any confidence in the reality of the interaction. The interaction for loin weight is a contributing factor to the interaction for the weight of the lean cuts. These interactions are presented graphically in Figure 8 along with the means for chilled carcass weight and percent lean cuts. Analyses of variance were performed on the data from treatments I and II only for carcass length, weight of the loin, and weight of the lean cuts. When this was done the treatment x genetic group interaction was nearly significant at the 10 per cent level for carcass length, but was far from significant for the other two variables as would be expected from the diagrams in Figure 8.

The difference between treatments II and III in chilled carcass weight was larger for the Crossbreds (16.6 lbs.) than for the Yorkshires (9.3 lbs.) which certainly contributed to the observed interactions in loin weight and weight of lean cuts (and carcass length to some extent). The treatment x genetic group interaction was far from significant when an analysis of variance was done for chilled carcass weight.

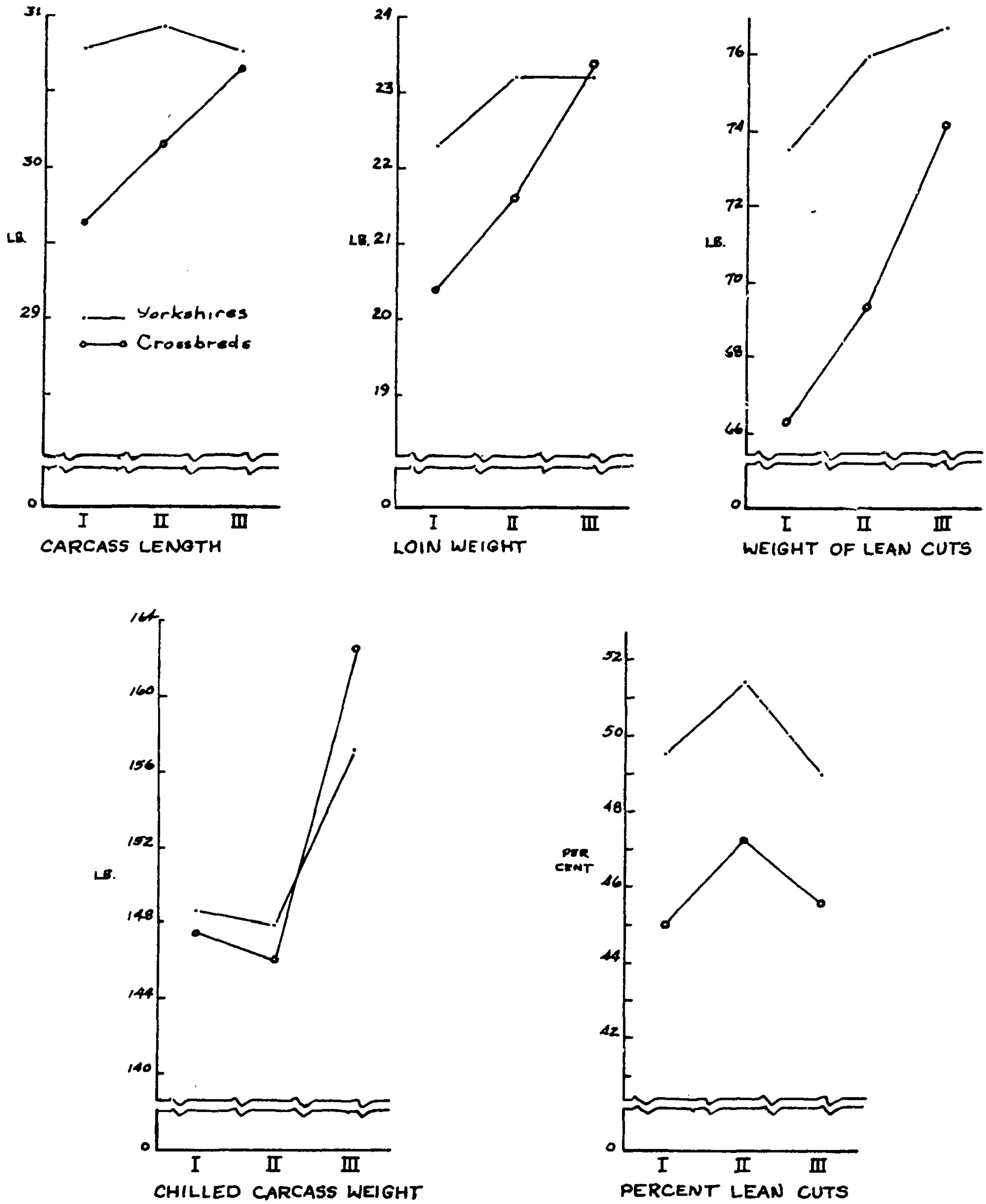

Figure 8. Treatment x genetic group interactions

But, since an increase in the size of the carcass does not represent a proportional increase in the size of each of its parts, significant interactions could arise in the weights of some of the later developing parts as a result of an interaction in carcass weight that did not reach statistical significance. These differences in carcass weight are not completely sufficient to explain the discrepance between the difference between treatments II and III in the weight of the lean cuts of 4.8 lbs. for the Crossbreds and 0.8 lbs. for the Yorkshires. However, when the weight of the lean cuts was expressed as a percentage of chilled carcass weight the interaction was much smaller and did not approach statistical significance.

The three-factor interaction for the remainder of the front portion of the carcass was significant and the one for the weight of the fat trim approached significance. These two characteristics are related because the weight of the clear plate and other fat trim from the remainder of the front is included in the total fat trim. A major factor in these interactions was the large difference between treatments II and III for the Crossbreds finished on concrete. This was largely a result of the treatment III Crossbreds finished on concrete having heavier carcasses than did any of the other groups.

In view of the differences in chilled carcass weight for treatment III, which were largely the result of differences in the amount the groups on treatment II were limited, the actual evidence for any genotype-environment interaction in the carcass characteristics (other than perhaps carcass length) is not very strong.

Interactions between feeding levels and feeding locations. The treatment III pigs fed on concrete had heavier Boston butts and total lean cuts than those fed on pasture while the difference between the feeding locations was smaller or opposite in sign on treatments I and II. (Another way to describe these treatment x feeding location interactions is that the treatment differences were larger among the pigs fed on concrete than among those fed on pasture.) The interaction was significant for lean cuts and almost significant for Boston butt. The group means for loin weight showed a similar interaction which approached significance. Among the pigs on treatment III, Yorkshires finished on concrete had slightly heavier chilled carcass weights (3.4 lbs.) than the Yorkshires finished on pasture which probably helped the 11 lb. advantage in weight of the Crossbreds on concrete over the Crossbreds on pasture increase the size of the interactions just mentioned. This argument would not wholly account for the interaction because the treatment III Yorkshires on concrete had 3.7 lbs. more lean cuts than those on pasture. Also the difference between treatment I and II was twice as large among pigs finished on concrete as among those finished on pasture. However, the treatment x feeding level interaction was very small for percent lean cuts, and the observed interactions in the weights of Boston butt, loin, and total lean cuts probably were not the result of real differences in the effects of feeding locations because surely pigs full fed on concrete do not have lighter lean cuts when slaughtered at 200 lbs. and heavier lean cuts when slaughtered at 220 lbs. than pigs full fed on pasture to the same weights.

Indicators of Carcass Merit

Probes at 140 lbs.

The pigs with thicker backfat at 140 lbs. were inclined to have a smaller proportion of lean cuts (r = .57) and a larger proportion of fat cuts (r = .62) in their carcass when slaughtered at approximately 210 lbs. The correlation between initial probe and percent lean cuts is slightly less than the correlation of -.65 between probe at 135 lbs. and percent lean cuts at 215 lbs. found by Douce (1954). However, he did not compute the correlations on an intra-breed basis and he adjusted the probes in his data for differences in weight (the ranges in weight were 96 to 160 lbs. and 208 to 232 lbs.) which was not done in the present study (the ranges in weight were 130 to 160 lbs. and 196 to 219 lbs.). Hetzer et al. (1956) found lower correlations between probes at 150 and 175 lbs. and percent lean cuts (-.24 for both weights) and percent fat cuts (.42 and .47) when the hogs were slaughtered at 225 lbs. than those in the present study. (In their data carcass backfat was correlated -.29 and .54 with percent lean cuts and percent fat cuts.)

The results indicate that the average probe at the lighter weight is not as accurate for predicting carcass merit at a later time as are probe measurements taken nearer to slaughter (which thus more nearly measure the trait being predicted). However, these probes are more closely related to carcass fatness than the relationships reported between scores for fatness at the time of slaughter and carcass fatness (Willman and Krider, 1943; Bratzler and Margerum, 1953; and Holland, 1957) and between percent primal cuts or percent lean cuts and individual body measurements (Hetzer et al., 1950, and Holland, 1957). Thus probing at 140 lbs. may be useful when culling cannot be postponed past that weight. The correlation between average probe at 140 lbs. and average probe at 200 lbs. was no larger than that between average probe at 140 lbs. and percent lean cuts.

Probes at slaughter weight

Considerable difficulty was encountered in probing the Yorkshires to the false lean. The false lean was difficult to identify, and in several cases the septum between the two layers of backfat was mistaken for the false lean. This partly accounts for the discrepance between the correlations at the first shoulder probe and the other locations with percent lean cuts and percent fat cuts for the Yorkshires. Even in the Crossbreds, where the false lean was usually readily identified by probing, the association of the first shoulder probe with the percent lean cuts and percent fat cuts was lower than the association between the second shoulder probe and these traits.

Hazel and Kline (1952) reported the probe behind the shoulder was the most accurate single indicator of the percentage of primal cuts. In their later report (Hazel and Kline, 1953) the probes taken behind the shoulder and at the middle of the loin were more closely associated with percent lean cuts and percent fat cuts than the probes at other sites studied. Douce (1954) found little difference in the shoulder and loin probes. However, other workers (Zobrisky et al., 1954 and Holland, 1957) reported the probe behind the shoulder had the lowest relationship with carcass leanness and fatness for the sites they studied. Holland (1957) suggested that failure to probe either to or through the false lean consistently caused the lower association in his data. The present results indicate that consistently probing through the false lean is more accurate for predicting leanness or fatness of the animal from the depth of fat at the shoulder.

The conlusions of Hazel and Kline (1953) that probe measurements at some sites reflect fatness and leanness as accurately as backfat measurements on the carcasses is substantiated in the present study. Both probes and carcass backfat were less closely associated with percent lean cuts and percent fat cuts in the full fed Yorkshires than in the other three groups. However, the full fed Yorkshires were more uniform for the above traits than the other groups were.

Center of gravity

Two principal price differentials exist among the cuts of pork carcasses. The most important is the difference between the primal cuts and the fat cuts. The second is a posterior-anterior gradient in the price of the primal cuts with the ham and loin being the most valuable cuts of the carcass followed by the Boston butt, belly, and picnic. The price differential between the front and rear of the carcass is increased because the principal fat deposits are on the shoulder and middle of the carcass.

The center of gravity was fairly closely associated with the ratio of the rear to the front of the carcass ($r = .70$). The center of gravity was more highly correlated with the percentage of the carcass in the rear of the carcass and with percent defatted ham in the present study (.57 and .53) than with the weight of the hindquarters (.38) in the study reported by Skjervold and Indrebø (1958). Also the center of gravity was more highly correlated with the percentage of the carcass in the front portion of the carcass (-.47) in the present study than with the weight of the shoulder (-.27) in their study. However, the carcasses were cut differently in the two studies, and the head was left on the carcass when the center of gravity was determined by Skjervold and Indrebø. Dawson *et al*. (1955), working with cattle, found a correlation of .66 between the percentage of live weight carried by the hind legs and the percentage of the empty body weight (slaughter weight minus the contents of the digestive tract) contained in the hindquarters.

The information provided by the center of gravity did not prove to be very valuable in indicating carcass index, however. The intra-group correlation between the center of gravity and carcass index was .44, while carcass backfat was correlated -.61 with carcass index. The intra-group multiple correlation of center of gravity and carcass backfat with carcass index was .66 which indicates that the center of gravity did not supply much additional information about the value of the carcass over that supplied by carcass backfat alone. The average probe was correlated -.67 with the carcass index. The reason for the limited value of knowledge concerning the proportion of the carcass in the front or rear is because 94 per cent of the variation in carcass index could be accounted for by the variation in percent lean cuts.[1]

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[1]Percent lean cuts probably does not account for quite 94 per cent of the variation in carcass value because the value of the fat was ignored (*i.e.*, evaluated as zero) in the carcass index.

Another limitation to the value of the information supplied by the center of gravity measurement is that in many instances the actual weights of the cuts can be obtained with as little additional effect as would be required to determine the center of gravity because the carcasses will be cut anyway.

The center of gravity was more closely associated with carcass index and percent lean cuts in the Crossbreds than in the Yorkshires. Perhaps this was partially because the variation in these traits was somewhat less for the full fed Yorkshires than for the other three groups. Also, the data for each genetic group were divided into several groups on the basis of carcass length and the relationship between center of gravity and percent lean cuts plotted for each group. On the basis of the small numbers involved, the correlation between center of gravity and leanness appeared larger in the Crossbred pigs which were 29.0 to 29.9 in. in carcass length (the shortest group) than in any of the other groups.

Other indicators of carcass merit

The correlation of .88 between percent defatted ham and percent lean cuts is in good agreement with the .89 reported by Smith et al. (1957). However, the percent skinned ham is almost as highly associated with percent lean cuts and is an easier measurement to obtain. Also the defatted ham is slightly less desirable for curing and cooking purposes than a ham with a thin covering of fat over the musculature. The correlation of .85 between percent skinned ham and percent lean cuts is in close agreement with the correlation of .88 reported by Lasley et al. (1956) between the weight of the ham and the weight of the lean cuts. However, it is larger than the correlation of .73 between these two variables reported by Zobrisky et al. (1954).

The loin fat/lean ratio was appreciably more highly correlated with percent lean cuts than was loin eye area alone (-.79 and .58). Pearson et al. (1956b) observed a correlation of -.60 for the loin fat/lean ratio with percent lean cuts which was not considered enough higher than the correlation of .53 for the area of the loin eye muscle with percent lean cuts to be worth the additional measurements and computations in most cases. In their study a tracing from only one side of the carcass was used, whereas in the present study tracings from both sides of the carcass were averaged. In addition, the two tracings from a carcass were compared, and the outline of the fat on each tracing was adjusted for cutting errors in splitting the carcass. These two factors probably account for the higher correlations and the larger advantage of the ratio over the lean area alone as a predictor of lean cuts and fat cuts found in the present study compared to the results of Pearson et al.

SUMMARY

The purpose of this study was to observe the effects of two levels of feeding on the carcass composition of pigs that were slaughtered at the same weight and pigs that were slaughtered at the same age after they had been fed on pasture and on concrete during the finishing period. Two genetic groups which differed considerably with respect to leanness were used to see if they responded in the same way or differently under these comparisons.

A total of 48 purebred Yorkshires and 48 Duroc x Landrace x Poland Crossbreds were used with each genetic group represented by 16 litter mate groups of three barrows each. Half the groups were finished on pasture and half were finished on concrete. One pig of each litter was full fed to 200 lbs., one was limited fed (85 per cent of a full feed) to 200 lbs., and the third was full fed and slaughtered at the same time (i.e., same age) as its limited fed litter mate.

When full fed and limited fed pigs were slaughtered at the same weight the former were, of course, younger and fatter. The limited fed pigs had a significantly lower dressing percentage (74.2 and 75.6 per cent) and a significantly higher percent lean cuts (49.3 and 47.2 per cent) than the full fed pigs. The value of the market hogs on a live weight basis was slightly increased by limited feeding because the

increase in the weights of the more valuable cuts was sufficient to offset the decrease in dressing percentage.

When limited fed pigs and full fed pigs were slaughtered at the same age, the weight of the lean cuts was 4 per cent heavier (7 per cent for the Crossbreds and 1 per cent for the Yorkshires) for the full fed pigs. The difference between the two levels of feeding was smaller for those measures which more nearly reflected only differences in lean. This suggested that a large part of the difference in the weight of the lean cuts was actually due to differences in the fat content of the cuts and that the rate of growth for lean was affected very little by the restriction of the feed intake to 85 per cent of a full feed during the finishing period.

The carcasses of the pigs fed on pasture and those of the pigs fed on concrete were very similar (with the exception of several possible interactions involving feeding locations). The pigs fed on pasture gained slightly more slowly and had higher feed requirements than the pigs fed on concrete, possibly because the pigs fed on concrete were confined much more than those fed on pasture.

The Yorkshires were considerably leaner than the Crossbreds. For most measures of leanness the difference between the two genetic groups was about twice as large as the difference between the full fed and limited fed pigs which were slaughtered at the same weight. The Yorkshires consumed 19 per cent less feed per day and gained only slightly less per day than the Crossbreds. Thus the feed requirements were much lower (54 lbs. per 100 lbs. gain) for the Yorkshires than for the Crossbreds.

The interactions of the genetic groups with treatments and/or feeding locations provided measures of genotype-environment interactions. The treatment x genetic group interaction was highly significant for carcass length. The interaction of the same variables was also significant for loin weight, weight of the lean cuts, and backfat probe. The treatment x genetic group x feeding location interaction was significant for live shrink and the weight of the remainder of the front portion of the carcass after the Boston butt and picnic were removed. Also the three-factor interaction approached significance for the weight of the fat trim (clear plate, fatback, and fat trimmings). Most of these interactions were larger than they should have been because the limited fed Crossbreds were restricted more than the Yorkshires and consequently the full fed Crossbreds at the older age were heavier than the full fed Yorkshires at the older age. However, the genotype-environment interactions accounted for a relatively small portion of the variation in most of the traits within the range of genotypes and environments used.

The interaction for treatments x feeding locations was significant for the weight of the lean cuts and approached significance for the weight of the Boston butt, the weight of the loin, and the area of lean in the face of the ham.

These interactions (except for the ham lean area) resulted because the pigs which were full fed to the older age on concrete were heavier than the pigs which were full fed to the older age on pasture. Also limiting the feed resulted in lower feed requirements when the pigs were finished on pasture, but did not lower the feed requirements when pigs were finished on concrete.

The relationships between several indicators of carcass merit and carcass characteristics were examined. The intragroup correlations for average probe at 140 lbs. with percent lean cuts and percent fat cuts were -.57 and .62, while the correlations for the probes taken at slaughter (approximately 210 lbs.) with these traits were -.70 and .70. The shoulder probes taken through the false lean were more accurate than the shoulder probes taken without penetrating the false lean.

The center of gravity of the chilled carcass was correlated .70 with the ratio of the rear to the front of the carcass. However, the center of gravity was only correlated .44 with the carcass index. Also, the multiple correlation of .66 for center of gravity and carcass backfat with carcass index was not much higher than the simple correlation of -.61 between carcass backfat and carcass index. Therefore, determining the center of gravity of the carcass did not provide much information about the value of the carcass beyond what was already given by measuring the carcass backfat only.

The average of six probes taken before slaughter was correlated -.67 with the carcass index.

The percent defatted ham was only slightly more highly correlated with percent lean cuts than was percent skinned ham. The loin fat/lean ratio was more highly correlated with percent lean cuts (.79) than was loin eye area alone (.58).

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ACKNOWLEDGMENTS

The author is very grateful to Dr. L. N. Hazel for his guidance and assistance throughout the course of this study. Appreciation is also expressed to Dr. E. A. Kline and his staff at the Meats Laboratory for their assistance in obtaining the carcass data and to Dr. J. L. Lush for valuable suggestions made during the preparation of this manuscript.